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

Baiq Julia Setyaningrum[1], Joni Rokhmat[1,2,3], Syahrial A[1], Jannatin 'Ardhuha[1]
[1]Physics Education. Faculty of Teacher Training and Education, University of Mataram, Lombok, West Nusa Tenggara, Indonesia.
[2]Master of Science Education Program, University of Mataram, Lombok, West Nusa Tenggara, Indonesia.
[3]Doctor of Science Education Program, University of Mataram, Lombok, West Nusa Tenggara, Indonesia.
Corresponding author e-mail: joni.fkip@unram.ac.id

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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. The results of the calculation of the N-gain score are 0.75 in the experimental class with a high category and 0.52 in the control class with a medium category. 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, and 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, this is what makes students think that physics is difficult and boring. This is in line with the opinion of 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.

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). This is in line with research conducted by (Ariyana *et al*., 2018) which states that critical thinking is the process of using all knowledge and skills to solve problems that arise, make decisions, analyze all assumptions that arise and draw the desired information or conclusions based on research or investigation 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.

According to Rokhmat (2023), a learning model is a conceptual framework that describes a systematic process of organizing learning experiences to achieve predetermined learning objectives. Innovative learning models are very important because they help learners acquire the skills needed in an increasingly complex and rapidly changing world. With regard to the learning model needed, Setyorini *et al*. (2011) stated that 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.

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

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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.

Hidayat (2011) states that the problem-based learning model is a learning model that emphasizes learning experiences so that students have the ability to learn independently by creating their own knowledge through solving real problems. This model utilizes examples of problems from everyday life to arouse learners' interest before they start studying a particular topic. According to Anam (2022), the two main components of the learning process that must be considered include learning models and learning media. With the help of learning media, educators can more easily deliver 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 used was all XI science classes in the 2024/2025 school year. The samples used were class XI.2 and XI.4. The sampling technique used purposive sampling technique. Class XI.2 as the experimental class and XI.4 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, hypothesis and N-Gain tests. 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. The N-Gain test is a test used to measure the effectiveness of learning before and after treatment and this test helps researchers evaluate the extent to which the treatment provided provides understanding to students (Sukarelawan, 2024).

Result and Discussion

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

- **Instrument Test Results**

The research instrument used in the form of a description test of 6 question items and corrected according to the six indicators of critical thinking skills with a total of 30 students. The following are the results of the analysis which includes the validity test, reliability, differentiation of questions and the level of difficulty of the questions.

A. 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.

B. 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.

C. 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 below.

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	-	-

D. 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**

A. 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	Category	Highest Score	Category	Average	Category
Experiment	32	25	Very Low	58,33	Low	41,40	Low
Control	34	29,17	Very Low	58,33	Low	42,76	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 42.76 for the control class. Graphically the pretest score

data of students is shown in Figure 1 below:

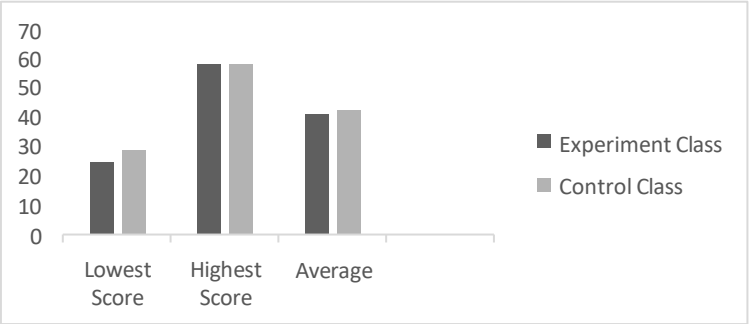


Figure 1 *Pretest* Results of Critical Thinking Ability of Students

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 42.76. 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.

B. 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	Category	Highest Score	Category	Average	Category
Experiment	32	54,17	Very Low	100	Very Critical	85,54	Critical
Control	34	33,33	Very Low	91,67	Very Critical	72,67	Medium

Based on Table 6, the number of students in the experimental class is 32 people with the highest and lowest scores obtained are 100 and 54.17, while the number of students in the control class is 34 people with the highest score and lowest score obtained are 91.67 and 33.33. The average score for the experimental class was 85.54 and 72.67 for the control class. Graphically the posttest score data of students is shown in Figure 2 below:

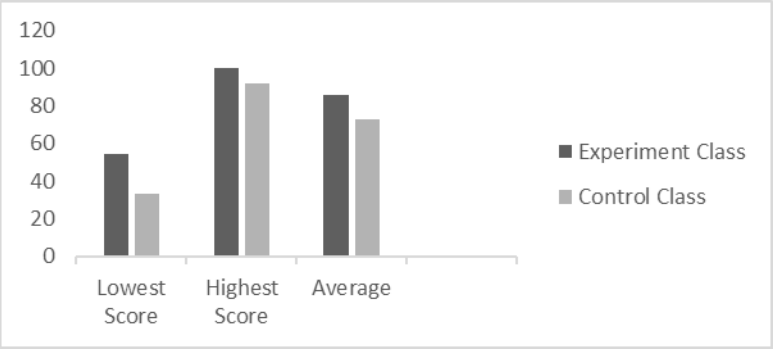


Figure 2 *Posttest* Results of Critical Thinking Ability of Students

These results show that the critical thinking skills of experimental and control class students have increased. The difference in students' critical thinking skills is due to the provision of different treatments between the experimental and control classes. Although both have an average value that increases, the class that applied the problem-based learning model is much better than the direct learning model. This is evidenced by the difference in the average posttest scores in the two classes.

- **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.

A. 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	Students (N)	(s^2)	F_{count}	F_{table}	Description
Experiment	*Pretest*	32		1,29	1,80	
Control		34				Homogenized
Experiment	*Posttest*	32		1,24	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 1.29 < 1.81 and 1.24 < 1.81 for the posttest. Based on the decision-making criteria, the research data is homogeneous.

B. 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*	5,77		
Control		5,44	11,07	Normally
Experiment	*Posttest*	7,30		Distributed
Control		7,88		

Based on Table 8 above, it shows that the research data is normally distributed 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	4786,78	4,65	1,66
Control	34	29,90	5085,78		

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.

The increase in the average score obtained by the experimental class higher than the control class is also due to the use of a problem-based learning model. The use of problem-based learning models makes students more active and independent so that they better understand the concepts presented because they look for the concepts themselves. This is in line with research conducted by Idris (2020) students taught using problem-based learning models 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 that are given can confront students with real problems and require them to actively participate in solving problems.

N-Gain Test

The N-Gain test was conducted by comparing the initial test results (pretest) and the final test results (posttest) in the experimental class and control class. The results of the N-Gain analysis test can be seen in Table 10 below.

Table 10 N-Gain Test of Critical Thinking Ability of Experimental and Control Classes

Class	N	Average N-Gain	Category
Experiment	32	0,75	High
Control	34	0,52	Medium

Table 10 shows that the experimental class has an N-Gain with a high category of 0.75 while the control class has an N-Gain with a medium category of 0.52. This proves that the application of problem-based learning models with PhET simulation is effective in improving critical thinking skills compared to using conventional learning models. Graphically, the N-gain score of problem solving ability of experimental class and control class is shown in Figure 3 below:

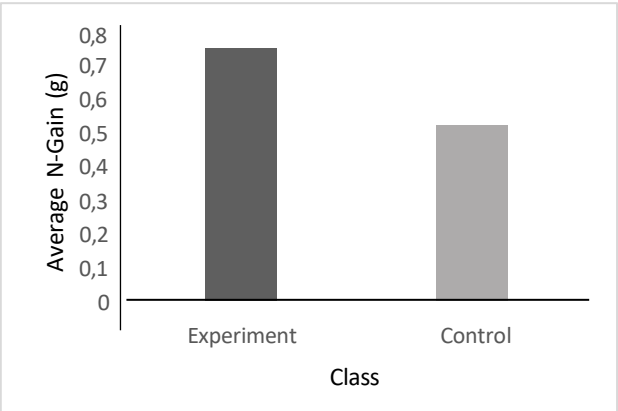


Figure 3 N-Gain Score of Critical Thinking Ability of Experimental and Control Classes

N-gain calculations were also carried out to determine the average increase in critical thinking skills per indicator of students in both classes. The results of the calculation of the average N-gain in both classes are shown in table 11 below:

Table 11 N-Gain of Critical Thinking Ability per Indicator

Class	N-Gain per Indicator of Critical Thinking Ability (ICTA)						Avergae N-gain	Criteria
	ICTA -1	ICTA -2	ICTA -3	ICTA -4	ICTA -5	ICTA -6		
Experiment	0,76	0,76	0,76	0,75	0,76	0,74	0,75	High
Control	0,48	0,52	0,55	0,60	0,47	0,51	0,52	Medium

Table 11 shows the N-gain score of problem solving ability per indicator in both classes. The experimental class has a greater increase in IKBK than the control class, this is indicated by the N-gain of ICTA-1, ICTA -2, ICTA -3, ICTA -4, ICTA -5, and ICTA -6 of the experimental class higher than the control class. Graphically, the N-gain score of problem solving ability per indicator is shown in Figure 4 below:

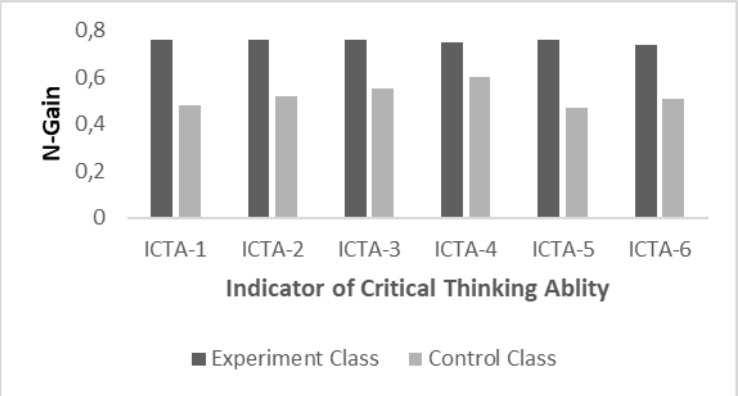


Figure 4 N-Gain Score of Critical Thinking Ability per Indicator

The increase in critical thinking skills of both classes was carried out the N-Gain test. The N-gain of critical thinking skills of the experimental class was in the high category, while the N-gain of critical thinking skills of the control class was in the medium category. Researchers also used the N-gain test to determine the extent of the increase in critical thinking skills per indicator in experimental and control classes. In ICTA-1, ICTA-2, ICTA-3, ICTA-4, ICTA-5, and ICTA-6 the experimental class has a higher N-gain score increase than the control class.

ICTA of the experimental class has a higher N-gain score increase than the control class because experimental class students are able to understand the meaning of something in the problem given correctly, are able to write the relationship between the concepts and ideas used to solve the problem correctly and correctly, are able to solve the problem correctly, are able to draw the right conclusions based on the context of the problem, are able to write the results and explain the reasons appropriately and are able to provide a proper review in accordance with the concept. In the learning process using a problem-based learning model with PhET simulation , at the beginning of learning students are given complex problems about the material studied then discussed and solved in groups through practicum using PhET media so that students are able to find their own answers to problems through group work and class discussions based on the diversity of answers they have.

The increase in the N-gain score of the experimental class which is higher than the control class in this study is in accordance with research conducted by Idris (2020) students who are taught using a problem-based learning model with students who are taught using a direct learning model have different levels of achievement in critical thinking skills due to the application of the problem-based learning model provided can confront students with real problems and require them to actively participate in solving problems. In line with research conducted by Zahara, S. R., Yusrizal, Y., & Rahwanto, A. (2015) stated that the use of PhET simulations affects the critical thinking skills of students, because the use of PhET simulations can involve students in learning activities that require higher cognitive skills. Munandar, H., Sutrio, S., & Taufik, M. (2018) in his research concluded that there was an increase in students' critical thinking skills by using PhET media because the use of PhET media students not only hear but also see what is learned directly.

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. Learning by using problem-based learning model with PhET simulation is better in improving students' critical thinking skills compared to conventional learning.

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