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The Influence of the Project Based Learning Model Assisted by PhET Simulation on Students' Critical Thinking and Problems Solving Abilities in Sound Wave Material

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Abstract: This research aims to test the effect of the Project Based Learning model assisted by PhET simulations on students' critical thinking and problems solving abilities in sound wave material. The type of research used was a Quasi experiment with a pretest-posttest control group design. The population in this study were all students in class XI Science at SMAN 3 Mataram. The sampling technique used purposive sampling technique, so that XI IPA 1 was obtained as an experimental class which was given treatment using a Project Based Learning model assisted by PhET simulation and XI IPA 2 as a control class using a conventional model. The test instrument used is a description of 12 question items consisting of 7 question items to measure critical thinking abilities and 5 question items to measure problem solving abilities. The hypothesis test used in this research is one-way MANOVA. The results of the hypothesis test show that the significance value of 0.001 is less than 0.05, so H_0 is rejected and H_a is accepted. Based on these results, it was concluded that there was an influence of the Project Based Learning model assisted by PhET simulations on students' critical thinking and problems solving abilities in sound wave material.

Keywords: Critical thinking; PhET simulation; Problem solving abilities; Project based learning model

Introduction

The 21st century is called the digital era which is marked by the rapid development of technology and information which requires many capabilities and skills. The development of technology and information affects all aspects of life, one of which is education. 21st century education demands various skills that students must master (Hikmah et al., 2023; Stehle & Peters-Burton, 2019). The skills in question include collaboration and communication, critical thinking (Doyan et al., 2022), creative thinking (Zulkarnaen et al., 2022; Tang et al., 2020), problem solving (Usman et al., 2021) and self-efficacy. Science education plays an important role in preparing quality young people to face the challenges of the 21st century (Syukri et al., 2021). Science education is a combination of several elements including physics, biology and chemistry. Physics is a branch of natural science that studies natural phenomena related to matter and energy. Liu (2018) stated that physics is a part of science which studies matter, energy and the relationship between the two.

Physics learning emphasizes providing direct experience by involving students directly in the learning process. In this case, students must build their own knowledge (Fatimah et al., 2019). Based on the results of observations through interviews with one of the physics teachers at SMAN 3 Mataram, it shows that physics learning implemented in schools uses little discussion and question and answer methods, therefore learning is

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still teacher-centered (centered on the teacher). This kind of learning process is less effective because it does not give students more access to discover their own knowledge. In teacher-centered learning, it tends to be passive, just listening to the teacher's explanation, so that students' knowledge only comes from the teacher.

Apart from that, limited practicum tools in schools often hinder students' investigative activities, this has an impact on students' critical thinking and problems solving abilities which are still lacking. Therefore, a learning model is needed that can facilitate students in improving their critical thinking and problems solving skills. The effort made to deal with the above problems is to apply a learning model that can provide full opportunities for students to discover their own knowledge. Of the many types of learning models, one of the recommended ones is the Project Based Learning model. According to Zulyusri et al. (2023) the Project based learning model is a learning model that involves students directly in conducting research to work on or complete a project in learning activities. The advantage of the Project based learning model is that it can train students' abilities in identifying and formulating problems, identifying research variables, developing and proving hypotheses and compiling experimental results (Wahyudiati & Qurniati, 2022).

The Project Based Learning model can help students hone critical thinking skills (Khairani Astri et al., 2022) and problem solving (Safithri et al., 2021). Apart from that, the use of projects in this learning model can be combined with virtual media, so that students do not get bored with learning, the virtual media that is suitable to be combined is Physics Education Technology Simulations or better known as PhET simulations (Hadi et al., 2023). PhET simulation media is a learning media that contains several physics learning simulation materials. The advantage of this PhET simulation media is that it can make it easier for students to understand physics concepts using visual animations and conceptual models used by physical scientists (Susilawati et al., 2021; Liswar et al., 2023). It is hoped that the application of the Project Based Learning model assisted by PhET simulations will improve students' critical thinking and problems solving skills, especially in sound wave material. Critical thinking skills include high-level thinking skills which are one of the life skills that every student must have.

Critical thinking skills are a directed and clear process used to obtain new information through mental activities such as solving problems, making decisions, analyzing assumptions and conducting scientific research (Doyan et al., 2023; Purnamasari, 2023; Safitri, 2023). Critical thinking skills are very necessary in solving problems, making decisions and can support the development of broader knowledge (Rahman et al., 2021). Problem solving ability is one of the higher orders thinking skills that leads students to acquire knowledge and skills (Rahmana et al., 2021). Problem solving ability is a basic ability that students must have to find a solution to a problem (Suwandi et al., 2021), especially problems related to physics. It is important for students to have critical thinking and problems solving skills so that they are accustomed to facing problems and choosing the right strategy in solving these problems. Therefore, this research aims to test the effect of the Project Based Learning model assisted by PhET simulations on students' critical thinking and problems solving abilities in sound wave material.

Method

The type of research used in this research is quasi-experimental with a design, namely pretest-posttest control group design.

Table 1. Research Design with Pretest-Posttest Control Group Design

Class	Pretest	Treatment	Posttest
Experiment	O_1	X_1	O_3
Control	O_2	X_2	O_4

This research was carried out at SMAN 3 Mataram. The population in this study were all students in class XI Science. Sampling used purposive sampling technique with class XI Science 1, totaling 31 students, as the experimental class and class XI Science 2, totaling 31 students, as the control class. The experimental class was given treatment using a Project Based Learning model assisted by PhET simulation while the control class used a conventional model. The variables in this research consist of the independent variable, namely the Project Based learning model assisted by PhET simulations, the dependent variable, namely the ability to think critically and solve problems. The data collection technique uses a description test which consists of 7 items about critical thinking skills and 5 items about problem solving.

The critical thinking ability indicators used are as follows: providing basic explanations, building basic skills, making interference, providing further explanations, and strategies and tactics. Meanwhile, the problems solving ability indicators used are as follows: understanding the problem, planning a solution, implementing the solution, and evaluating the results. Before being used in the two sample classes, the research instrument used to measure critical thinking and problems solving abilities was tested using validity, reliability, level of difficulty and differentiability of questions. Prerequisite tests use the normality test and homogeneity test. Hypothesis testing was carried out using the MANOVA test (testing the overall effect) with

a significance level of 5%. Data analysis using SPSS 25 software.

Results and Discussion

Based on the results of the pretest that was carried out, it was found that the critical thinking and problems solving abilities of students in the experimental class and control class were still low. The low average pretest score is because students have not received material about sound waves, so students only rely on the basic knowledge they have acquired during the learning process at school and the experiences they have had with the surrounding environment. After being given treatment during the learning process, students are then given a posttest with the same weight as the pretest. Data on the results of critical thinking and problems solving abilities for the experimental class and control class can be seen in Table 2 below.

Table 2. Data on the Results of Critical Thinking and Problems Solving Abilities from Pretest-Posttest for Experimental Class and Control Class

Variable	Test	Class	The number of students	The highest score	Lowest Value	Average
Critical Thinking Ability	Pretest	Experiment	31	61	11	35.02
		Control	31	57	7	33.41
	Posttest	Experiment	31	100	71	83.18
		Control	31	93	71	78.87
Problem solving skill	Pretest	Experiment	31	58	10	29.11
		Control	31	60	10	21.21
	Posttest	Experiment	31	100	70	84.37
		Control	31	98	65	77.74

The table 2 shows that the experimental class and control class had the same abilities before being given treatment. After being given treatment, it showed that there was an increase in critical thinking and problems solving skills in both the experimental and control classes, however, the increase in the average score in the experimental class was higher than in the control class. Hypothesis testing in this study used a one-way MANOVA test assisted by SPSS 25 software. Before carrying out the MANOVA test, it is necessary to carry out a prerequisite test first, namely the Box'M test which must be fulfilled. The test results showed that the Box's M value was 2.625 with a significance of 0.470. The significance value obtained in the Box' M test is greater than 0.05 so the data can be tested using the MANOVA test. The Box'M test results are shown in Table 3.

After the prerequisites for hypothesis testing are met, the one-way MANOVA test can be continued. This test aims to compare the critical thinking and problems solving abilities of students who are treated using the Project Based Learning model with students who use the conventional model. The decision was taken using Pillae Trace, Lambda Wilk, Hotteling Trace and Roy's Largest Root. The MANOVA test results show that the F value for Pillae Trace, Lambda Wilk, Hotteling Trace and Roy's Largest Root obtained the same value, namely 8.081 with a significance value of 0.001, which is less than 0.05, so it can be concluded that there is a difference in critical thinking and problems solving abilities between students who use the Project Based Learning model assisted by PhET simulations and students who use conventional models.

Table 3. Box's Test

Box's Test of Equality of covariance Matrices[a]	
Box's M	2.625
F	.843
df1	3
df2	648000.000
Sig.	.470

Table 4. Multivariate Tests[a]

	Effect	Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.995	5710.338[b]	2.000	59.000	.000
	Wilks' Lambda	.005	5710.338[b]	2.000	59.000	.000
	Hotelling's Trace	193.571	5710.338[b]	2.000	59.000	.000
	Roy's Largest Root	193.571	5710.338[b]	2.000	59.000	.000
Class	Pillai's Trace	.215	8.081[b]	2.000	59.000	.001
	Wilks' Lambda	.785	8.081[b]	2.000	59.000	.001
	Hotelling's Trace	.274	8.081[b]	2.000	59.000	.001
	Roy's Largest Root	.274	8.081[b]	2.000	59.000	.001

a. Design: Intercept + Class
b. Exact statistic

The results of the influence test on each variable separately show that there is a difference in critical thinking abilities between students who use the Project Based Learning model and the conventional model, producing an F value of 9.41 with a significance of 0.003. This shows that there are differences in critical thinking abilities caused by differences in the learning models used. On the other hand, there is a difference in problem solving abilities between students who use the Project Based Learning model and the conventional model resulting in an F value of 11.21 with a significance of 0.001 less than 0.05, this means that the differences in learning used also result in differences in problem solving abilities. The results of this test are shown in table 5.

Table 5. Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Critical thinking	428.53[a]	1	428.53	9.41	.003
	Solution to problem	752.51[b]	1	752.51	11.21	.001
Intercept	Critical thinking	397920.79	1	397920.79	8746.54	.000
	Solution to problem	385363.61	1	385363.61	5740.45	.000
Class	Critical thinking	428.53	1	428.53	9.41	.003
	Solution to problem	752.51	1	752.51	11.21	.001
Error	Critical thinking	2729.67	60	45.49		
	Solution to problem	4027.87	60	67.13		
Total	Critical thinking	401079.00	62			
	Solution to problem	390144.00	62			
Corrected Total	Critical thinking	3158.21	61			
	Solution to problem	4780.38	61			

a. R Squared = .136 (Adjusted R Squared = .121)
b. R Squared = .157 (Adjusted R Squared = .143)

Based on the results of the MANOVA test, it was found that the significance value was less than 0.05, so H_0 was rejected and H_a was accepted, which means that there was an influence of the Project Based Learning model assisted by PhET simulation on students' critical thinking and problems solving abilities in sound wave material. This research is supported by (Ananda et al., 2021) stating that there is a positive influence of physics learning using the Project Based Learning model compared to conventional models on students' critical thinking abilities. The application of the Project Based Learning model has been proven to improve students' critical thinking skills because students are required to be more active in exploring information to solve problems so that the knowledge students receive during the learning process is more meaningful (Dewi et al., 2023; (Lestari et al., 2023).

Other research conducted by Adnyani et al. (2023) and Husyain Rifai, (2023) shows that the experimental group, namely the group that applied the project based learning model, had a higher average score than the control group because in the experimental class students were more active in discovering their own knowledge through experimental activities, so that the application of project-based learning affects students' critical thinking abilities (Desiana et al., 2022). Apart from improving critical thinking skills, students' problems solving abilities also increase due to the implementation of the Project Based Learning model (Novalina Indriyani et al., 2022). This is supported by research by Susanta et al. (2020), Chamisijatin et al. (2023) and Faozi et al. (2020), concluding that there is an influence of implementing a project-based learning model on students' problems solving abilities. This is indicated by an increase in the average score of problems solving abilities in the post-test for the experimental class which was treated using the Project Based Learning model, which is higher than the control class which applied the conventional model (Solong et al., 2022). Hindriyanto et al. (2019), stated that the Project Based Learning model has significant benefits for students' problems solving skills.

The benefits that are awakened through project learning activities are critical thinking, creative and spatial skills that are useful for students to carry out problem solving activities. Student activities in collecting data and working on projects can improve students' problems solving abilities (Harefa & Purba, 2020; Le et al., 2018). The Project Based Learning model applied to the learning environment and raising contextual problems can provide meaningful experiences and increase problem solving abilities because raising contextual problems has been proven to be able to train students (Waruwu et al., 2023; Putri et al., 2023). The application of PhET simulation media in learning has been proven to increase student activity in the classroom. According to Widiarta et al. (2023) and Markula et al. (2022) concluded that the combination of the Project Based Learning model with the PhET simulation is very suitable, this is because in the Project

Based Learning model the teacher is the facilitator while the students are involved in conducting research, this causes the students to have more experience and practice cooperation. group in completing a product.

Conclusion

Based on the results of the research and discussion, it can be concluded that there is an influence of the Project Based Learning model assisted by PhET simulations on students' critical thinking and problems solving abilities in sound wave material. The effect in question is an increase in the average score in the experimental class both in terms of critical thinking and problems solving abilities. The Project Based Learning model assisted by PhET simulations can be used as an alternative by teachers in choosing learning models and media for teaching in class. However, its implementation requires careful planning, preparation and time estimation so that learning can proceed according to the goals to be achieved.

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