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Profile of the PhET Assisted Problem-Based Learning Model for Improving Critical Thinking Skills of High School Students

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Abstract

This research discusses the implementation of a Problem-Based earning learning model assisted by PhET Simulation to improve students' critical thinking skills on the material of traveling waves and stationary waves. The purpose of this study is to obtain a profile of students' critical thinking skills in physics learning at the Senior High School level and to evaluate the effectiveness of the PBL model enhanced by using PhET Simulation in improving these skills. This research method is a preliminary study and descriptive qualitative. The research instruments used were a critical thinking skills test, a teacher interview, and a learner response questionnaire. The findings of students' critical thinking skills are categorized into low, medium, and high. There are 62 students in the low category and 8 students in the medium category and the level of critical thinking skills of female students is higher than male students. Based on the results obtained, it can be concluded that the critical thinking skills of students are in a low category, and practice and the use of appropriate learning models are needed.

Keywords: Problem-Based Learning, Critical Thinking, PhET Simulation

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INTRODUCTION

In the 21st century, with the development of technology and increasingly sophisticated information, it is easier for us to obtain information. The information obtained no longer has limits, access to information can be reached in all parts of the world. Technological advances also have a major impact on all areas of life, one of which is the field of education (Fadliyani, 2016). Education is the foundation of life and plays an important role in improving the quality of human resources (Yulianti & Gunawan, 2019). Education must also pay attention to the objectives of education, especially in the 21st century, namely to develop critical thinking skills. According to Ennis, critical thinking skills have the aim of providing strong reasons to be able to answer problems correctly and make rational decisions (Bilad et al., 2022; Ekayanti et al., 2022; Herliandry et al., 2018; Suhirman & Ghazali, 2022). Therefore, there needs to be an effort to improve student learning outcomes by developing critical thinking skills in learning.

Critical thinking skills have a very important role for students in developing critical analytical abilities. One example of a subject that requires critical analytical understanding skills in everyday life is physics (Ramadani & Nana, 2020). However, many students find physics difficult because it involves many formulas (Saharsa et al., 2018). The way of thinking of each individual is influenced by the environment where they live and the surrounding community. Critical thinking includes a way of thinking in responding to problems logically based on facts that exist in the surrounding community. Critical thinking skills are skills that

involve rational decision-making (Asy'ari & Rosa, 2022; Herliandry et al., 2018). This shows that critical thinking skills are important to be taught to students.

The application of problem-based learning models or PBL can stimulate learners to develop critical thinking skills in solving problems. Through PBL, learners actively seek solutions to given problems. However, learning must also be supported by using technology-based learning media. One of the learning media that uses electronic devices is the Colorado PhET simulation (Saregar, 2016). PhET is one of the media that can be used in solving physics problems through simulated experiments (Agustina et al., 2020).

Research related to the PBL model has been reviewed by many previous studies. However, each researcher has different characteristics. The use of the PBL model with the help of PhET Simulation media on the material of traveling waves and stationary waves has not been widely done by previous researchers. Research conducted by (Novita et al., 2023) uses temperature and heat material and only knows the effect on cognitive learning outcomes, but does not improve the skills that must be possessed in the 21st century, namely critical thinking skills. Meanwhile, the research uses critical thinking skills as an indicator measured on traveling waves and stationary wave material. Research conducted by (Amalia et al., 2022) stated that there was an increase in critical thinking skills in effort and energy material with the application of a problem-based learning model assisted by PhET simulation. In the research to be carried out using wave material, this is because so that students know that one of the wave phenomena, for example, water waves, is a phenomenon related to physics. In addition, the previous research was conducted by comparing the PBL model with focused on experimental experience and assisted by PhET with conventional learning, while in this study it was conducted by comparing the PBL model assisted by PhET with the PBL model to find out how PhET plays a role in improving critical thinking skills (Verawati et al., 2022).

This study aims to identify the profile of students' critical thinking skills in physics learning at the Senior High School level and to evaluate the effectiveness of the PBL model enhanced by using PhET Simulation in improving critical thinking skills. In the PBL model, students will be actively involved in learning activities to improve their understanding and critical thinking skills. The use of PhET Simulation will facilitate learning by providing a real simulation of the material being taught and plays an important role in helping students understand concepts more effectively. Through this research, it is expected that a deeper understanding of the critical thinking skills of students in high school physics learning and the effectiveness of PBL models enhanced with PhET Simulation in improving critical thinking skills will be obtained.

METHOD

This research uses preliminary study research with data analysis techniques in the form of qualitative descriptive analysis. Qualitative descriptive data analysis was carried out by looking at the results of students' answers to determine the profile of critical thinking skills. Preliminary studies are used to find information needed by researchers to find out the actual situation at school and add information related to the problem in more detail. This research does not use hypothesis testing but uses a descriptive research design. The results of this study will be taken into consideration for improving learning models and learning media that can improve critical thinking skills in high school.

The subjects in this study were 11^{th} grade high school students in Surabaya. The total number of students in this study was 70 students. The research instruments used were critical thinking skills tests, interviews with teachers, and student response questionnaires. The tests given were questions developed from five aspects of critical thinking skills indicators which became the benchmark for the study (Ennis, 2015). The indicators of critical thinking skills used are as follows.

Table 1 Indicators of Critical Thinking Skills

No.	Indicators of Critical Thinking Skills	Indicator Description
1.	Giving Simple Explanations	Formulating questions and answering questions
		Presenting an argument
2.	Building Basic Skills	Comparing observation results with references
		Observing and considering the observation report
3.	Making Inferences	Inducing and considering the results
4.	Providing Advanced Explanations	Problem solving strategy
5.	Organizing Strategy and tactics	Problem-solving strategy Determining an action

(Ennis, 2015)

This study uses five indicators, the indicator provides a simple explanation related to formulating questions based on a phenomenon. Indicators of building basic skills related to comparing observations with references. In the indicator of making inferences about concluding a phenomenon. Indicators provide advanced explanations and presented questions about strategies for determining the decisions taken. Meanwhile, for indicators of organizing strategies and tactics related to determining an action based on the problems given. This study used a critical thinking skills test with traveling wave and stationary wave material consisting of 5 questions with each indicator consisting of one question. Interviews with teachers were conducted to obtain in-depth information related to critical thinking skills as well as learning models and media used in learning. In addition, a response questionnaire was given using Google Forms to get students' responses related to the learning process. The response questionnaire consists of 10 questions in the form of responses to the learning process at school. This research was conducted by following the research stages described in Figure 1.

Figure 1. Research Methods

This preliminary research has limitations, as it was only conducted on a specific sample and may not be generalizable to a wider population. Therefore, further research with a more rigorous research design can be conducted to strengthen the findings of this study.

RESULTS AND DISCUSSION

Critical thinking skills test

The critical thinking skills test in this study was conducted using a written test instrument consisting of descriptive questions with 5 questions. Each question represents an indicator of critical thinking skills. Indicators of critical thinking skills are 1) Providing a simple explanation, 2) Building basic skills, 3) Making Inferences, 4) Providing further explanation, and 5) Organizing strategies and tactics (Ennis, 2015). Students are asked to answer questions about the existing problems. Based on the research that has been done, the results of thinking skills are shown in Figure 2.

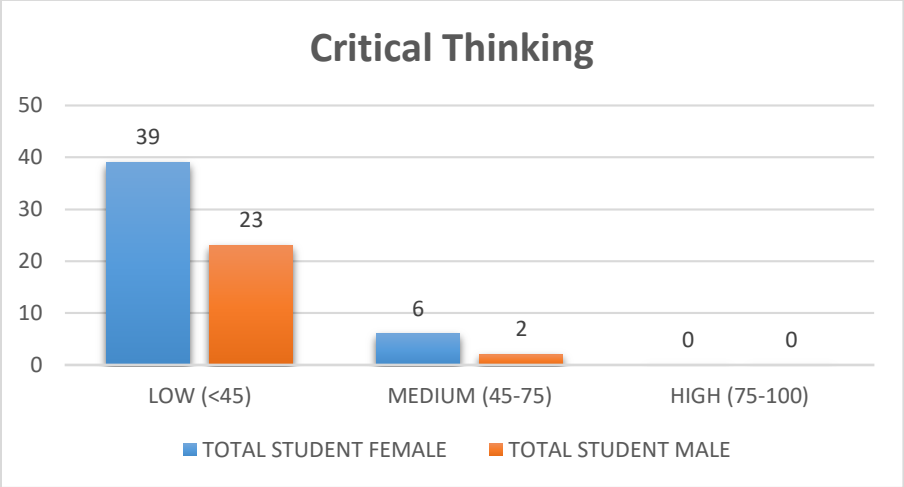

Figure 2. Critical Thinking Skills Test Results

Figure 2 shows the results of the critical thinking skills test of students. Based on these results, it is known that the level of critical thinking skills of students is still low. The graph shows that there are 62 students in the low category, namely 39 female students and 23 male students. While those included in the medium category were 8 learners, namely 6 women and 2 men. Therefore, it can be concluded that the level of critical thinking skills of female students is higher than that of male students.

Previous research conducted by (Miswari et al., 2020) showed that the critical thinking skills of female students were higher than men. This is because female students can identify and analyze existing information in detail and carefully and always double-check the answers (Harso & Gago, 2018). In addition, female students are also better able to identify the elements needed in concluding by considering relevant information (Miswari et al., 2020). However, the learning methods used such as teacher-centered learning can also be a factor that causes low critical thinking skills of students (Amalia et al., 2022). Therefore, there is a need for innovations in learning as an effort to improve students' critical thinking skills regardless of gender and involve students in actively participate.

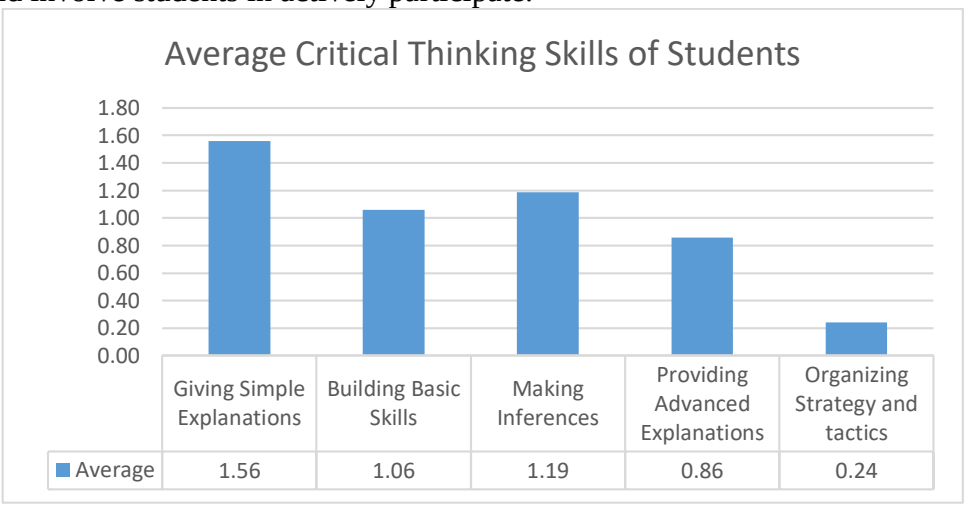

Figure 3. Average Critical Thinking Skills of Students

Figure 3 shows the average results of critical thinking skills for each indicator obtained by students. Based on this data, the critical thinking skills indicator provides a simple explanation with the highest score with an average of 1.56 and the indicator of organizing strategies and tactics gets the lowest score with an average of 0.24. This shows that students *can* provide simple explanations, while the ability to build basic skills, make inferences, and provide advanced explanations still needs to be improved. It also shows that students still have

difficulties and are not optimal in organizing strategies and tactics. This is in line with previous research which shows that students are more proficient in providing simple explanations than other indicators (Negoro et al., 2018). Students' thinking skills are not optimal can be caused because students have not been trained in the indicators of critical thinking skills, and the lack of learning that trains students' critical thinking skills(Wijayanti & Siswanto, 2020). This can affect students in mental activities such as solving problems, making decisions, analyzing assumptions, and conducting scientific research (Farisi et al., 2017). Therefore, it is necessary to make efforts to improve students' critical thinking skills through proper training and learning. The following is an example of a learner's answer with critical thinking skills indicators:

1. Provide a Simple Explanation

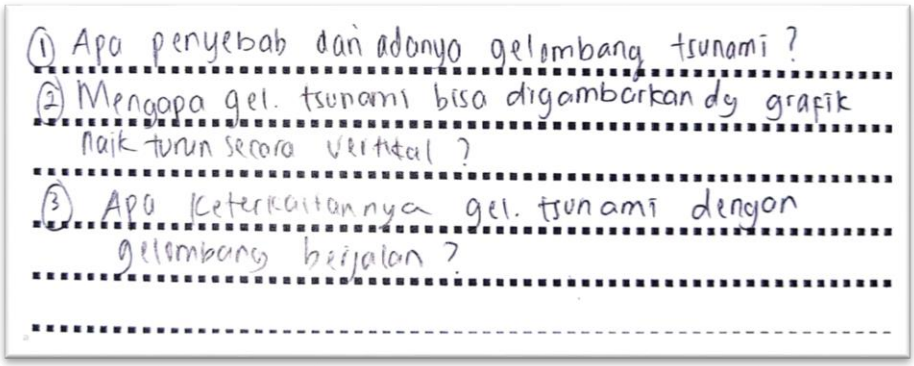

Figure 4 Learners' answers on the indicator of giving simple explanations

Figure 4 is the first critical thinking skills indicator, namely providing a simple explanation with the type of problem to provide a simple argument or formulate a problem. In this study, the problem in the first indicator, students were asked to formulate a problem based on the phenomenon given. Based on the analysis of student's answers in Figure, it can be seen that students are still confused about understanding the phenomenon to formulate problems. This is because students are used to responding to a phenomenon or question and actively participating in asking questions (Kusuma Dewi & Rahayu Utami, 2016). This indicator has the highest value compared to other indicators. In line with research (Wijayanti & Siswanto, 2020) namely the indicator of providing simple explanations obtained the highest percentage.

2. Building Basic Skills

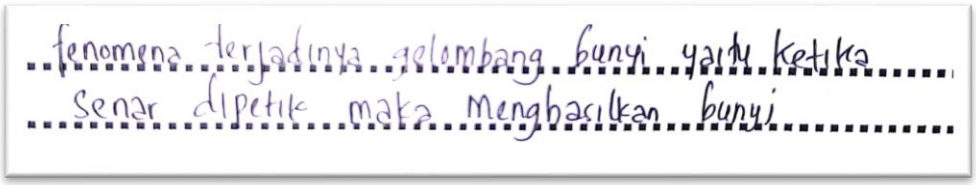

Figure 5. Learners' answers on the indicator of building basic skills

Figure 5 shows the results of students' answers to the basic skills-building indicator questions. On the question of building basic skills with the sub-indicator of comparing observations with references, students are asked to compare their observations with references based on the phenomenon of stationary waves. However, before the learning is implemented, students only answer by giving reasons for the phenomenon without mentioning the phenomenon that occurs. Learners are less able to understand and provide reasons based on something that can be observed and measured (Agustina et al., 2020). This is because students are not accustomed to looking for references related to the problem so they cannot compare the results of observations with references (Harso & Gago, 2018).

3. Making Inference

Figure 6. Learners' answers on the indicator of making an inference

Figure 6 shows the results of students' answers to the indicator question of making inferences. In the indicator question of making inferences, students are asked to make conclusions based on the phenomenon of traveling waves. Critical thinking skills can affect students' understanding in drawing conclusions and making the right decisions (Miswari et al., 2020). However, before the learning is implemented, students only answer by giving statements that are not by the phenomenon. This is because students are not accustomed to making conclusions based on the phenomena given according to their thoughts (Kusuma Dewi & Rahayu Utami, 2016).

4. Provide a further explanation

Figure 7. Learners' answers on the indicator of providing further explanation

Figure 7 shows the results of students' answers to the indicator question of providing further explanation. In the indicator question to provide further explanation, students are asked to determine the type of phenomenon that occurs accompanied by relevant supporting theories. This indicator has critical criteria because students are required to read the problem text and discuss and find solutions to existing problems (Kusuma Dewi & Rahayu Utami, 2016). However, before the implementation of learning, students only answered by mentioning the phenomena that occurred but were still inaccurate and not accompanied by reasons. Learners have not been able to identify the assumptions of the problem based on the phenomena given (Agustina et al., 2020). This is because students are not accustomed to providing reasons or theories that support their arguments. In line with research (Miswari et al., 2020) which states that students' critical thinking skills are still low, especially on indicators of providing further explanation.

5. Organizing Strategies And Tactics

Figure 8. Learners' answers on indicators of organizing strategies and tactics

Figure 8 shows the results of students' answers to the indicator questions on organizing strategies and tactics. This indicator is in the form of skills to determine an action in obtaining the right decision (Wijayanti & Siswanto, 2020). In the indicator question of organizing strategies and tactics, learners are asked to determine the actions that must be taken to avoid the danger of coral reefs. The purpose of using strategies is that students are encouraged to use their knowledge and experience to solve problems, without always relying on others (Kusuma Dewi & Rahayu Utami, 2016). However, before the learning was carried out, students only answered the depth limit for swimming without being accompanied by stages. This is because learners are not accustomed to determining the actions to be taken accompanied by stages to obtain the right solution without relying

on others. Learners who have good communication skills can understand and solve various problems faced (Miswari et al., 2020).

Based on the results of the analysis, it can be seen that the level of critical thinking skills of students is still low. Factors that can affect this are the lack of practicing critical thinking skills in students. Thus, students need to be trained with critical thinking skills and use the right learning model.

Student Response Results on Physics Learning:

After completing the essay test to measure critical thinking skills, the next step was to ask students to respond to physics learning at school. The response consists of 10 statements that can be selected on a scale from strongly disagree, disagree, agree, to strongly agree, which is represented by numbers 1 to 4 using Google form. The results of the questionnaire responses are then represented in Table 2.

Table 2. Students' Responses to physics learning and problem-solving skills at School

No	Statement	Student Response Results (%)			
		Strongly Disagree	Disagree	Agree	Strongly Agree
1	I find learning physics boring	8.8	52.9	35.3	2.9
2	I find it difficult to understand physics material, especially Walking and Stationary Waves	1.5	29.4	64.7	4.4
3	Walking and Stationary Waves material is important to learn because it is related to everyday life	7.4	19.1	70.6	2.9
4	Teachers more often use conventional book-assisted lecture learning methods rather than Problem-Based Learning (PBL) methods	4,4	29,4	61,8	4.4
5	I am often trained with critical thinking skills questions	7.4	30.9	61.8	0
6	Critical thinking skills are important to be taught at school	1.5	19.1	64.7	14.7
7	I learn physics not only from books and teachers but also using other learning resources such as Virtual Laboratory	14.7	38.2	42.6	4.4
8	Physics teachers at school have used Virtual Laboratory learning media, namely PhET	36.8	30.9	27.9	4.4
9	I prefer learning physics by using a virtual laboratory, namely PhET	8.8	23.5	64.7	2.9
10	I am interested in obtaining physics learning assisted by Virtual Laboratory, namely PhET	7.4	19.1	67.6	5.9

Based on Table 2 shows that the majority of students (64.7%) agree that physics material is difficult to understand, especially the material of traveling waves and stationary waves, but most (52.9%) consider physics learning not boring. In physics material, some steps must be taken to gain knowledge or find explanations for natural phenomena (Sudiarta, 2019). The majority of students (70.6%) agreed that the material of traveling waves and stationary waves is important to learn because it is related to everyday life. Then, the problem-based learning (PBL) method is less often used by teachers than the lecture method with books.

Meanwhile, students need new teacher innovations in teaching with more varied methods so that students can learn in a fun and exciting atmosphere (Gusniar & Juliani, 2019). Furthermore, related to students' critical thinking skills, the majority of students (61.8%) felt they were often trained with critical thinking skills. Most learners (64.7%) agreed that critical thinking skills are important to be taught at school. This is in line with research (Wijayanti & Siswanto, 2020) that there needs to be further efforts in improving students' critical thinking skills. The majority of students (64.7%) like learning physics using a virtual laboratory, namely PhET, and most students (67.6%) are interested in learning physics using a virtual laboratory, namely PhET. This is in line with research (Novita et al., 2023) that students are interested in learning physics using the PBL model assisted by PhET simulation.

From these data, it can be concluded that in physics learning some students find it difficult to understand certain material. Physics learning requires students to learn about nature that is commonly found in the real world (Novita et al., 2023). However, the majority of students realize that physics material, especially related to traveling waves and stationary waves, is important to learn because it is related to everyday life. In addition, most learners have also used different physics learning resources and feel trained with critical thinking skills. This shows that there needs to be a variety of methods and learning resources that are more interesting and interactive in physics learning so that students can be more interested and motivated and understand the material better (Qomariyah, 2017).

Results of Interview with Physics Teacher at School

To strengthen the research data, researchers conducted interviews with teachers to obtain more detailed information related to physics learning at school. Interviews were conducted with teachers to ask for opinions related to learning models and physics learning outcomes at school. Based on the results of the interview, the learning method that is often used is the lecture method and practicum in the laboratory, so students are rarely given the PBL learning model. The learning media used is PowerPoint (PPT) and practicum is only carried out in conventional laboratories and still has not applied learning media such as PhET Simulation which can provide practicum simulations with limited facilities or experimental equipment that supports practicum in conventional laboratories. So that there has been no special treatment carried out by the teacher to improve students' critical thinking skills. This causes students to not have high interest and become passive during the learning process (Agustina et al., 2020).

Learning models and methods used in learning greatly affect students' critical thinking skills. The lecture method with a conventional learning model causes a lack of opportunity for students to develop critical thinking skills (Suliyati et al., 2018). In this model, learning is teacher-centered, so students play a less active role in the learning process (Novita et al., 2023). Learning that does not relate the material to real life is also lacking to develop students' critical thinking skills. Learning media also affects the motivation and interest of students in learning. Learning media that utilize technology and provide simulations can improve students' concept understanding. In addition, an example of the wave phenomenon in everyday life is the battle rope sport, which is a sport that utilizes ropes and produces a wave. Thus, media that can provide real simulations to better understand the concept of waves can improve students' critical thinking skills.

Efforts that can be made to improve students' critical thinking skills are by using the right learning model (Farisi et al., 2017). The problem-based learning model is a learning model that focuses more on students (Ardianti et al., 2021). Learners are given real phenomena so that they can develop ways of thinking, problem-solving and critical thinking skills. Therefore, learners will be able to develop better problem-solving skills that are relevant to the real world.

Relevant research

Several studies have been conducted to understand and analyze the impact of the application of PBL models and PhET Simulation media, namely integrating the application of

PBL models with PhET Simulation aids, especially in physics learning. Based literature studies with relevant research related to the application of PBL with PhET Simulation are as follows: (1) The application of Problem-Based Learning can help develop students' critical thinking skills (Fakhriyah, 2014). The results of the study found that the thinking skills of students were still low so that the use of PBL learning models could improve students' critical thinking skills. 2) The application of the PBL learning model assisted by PhET can improve student learning outcomes (Gusniar & Juliani, 2019). This is in line with the results of this study that students are interested in learning using the PBL model assisted by PhET so that it can improve student learning outcomes. 3) Learning with the Problem-Based Learning Model assisted by PhET Virtual Lab can activate student participation so that it can also increase concept understanding in students (Ramadani & Nana, 2020). In this study, the results of students' responses were obtained which stated that physics was boring and difficult to understand so that the use of the right model could increase students' participation and understanding of concepts. Thus, it is expected that the implementation of the PBL model assisted by PhET Simulation will be used as an effective learning model and interesting learning innovation for students so that it will increase motivation in teaching and learning activities.

CONCLUSION

Based on the results of the research conducted, it can be concluded that students' critical thinking skills are still low. The indicator that showed the highest level of skill was "giving simple explanations," while the indicator with the lowest score was "organizing strategies and tactics." Mapping by gender shows that women have a higher level of critical thinking skills than men. This research also shows that critical thinking skills need to be trained in learners by educators. Findings from surveys and tests with critical thinking skills indicators that these skills can be improved through proper learning. In this study, it was also found that schools still apply conventional learning models with the lecture method in physics learning. However, learners showed interest in learning using PhET Simulation. Therefore, it is important to recognize the importance of innovation in learning models that aim to improve learners' critical thinking skills. Thus, the findings of this study indicate the need for the development of learning models that are innovative and in line with technological developments, especially in the context of physics learning. By applying appropriate methods and utilizing technology, it is expected that learners' critical thinking skills can be effectively improved.

RECOMMENDATION

It is expected that in future research there will be innovations in the learning process with the aim of increasing students' interest, motivation, and critical thinking skills. One innovation that can be considered is the application of the PBL Learning Model assisted by PhET Simulation.

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