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Improving Critical Thinking using a Guided Inquiry Approach assisted by PhET Simulations in Wave Material

Dewi Marina[1,2], **Kissi Marwanti dan I Made Astra**[1]
[1]Physics Education Master's Program, Jakarta State University

[2]E-mail: dewimarina08@gmail.com

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Abstract. This research shows that using guided inquiry with PhET simulations significantly improves students' critical thinking skills. In this study, Classroom Action Research *(Penelitian Tndakan Kelas*) method was used with the participation of 39 students of Class XI IPA 3 SMAN 6 Tangerang Regency. Data collection spanned three learning cycles comprising planning, action implementation, observation, and reflection. outcomes consistently showed progress across cycles, with the average score on critical thinking tests rising from 65 pre-intervention to 80 by the third cycle. Moreover, the percentage of students achieving a "Very Good" rating increased significantly from 10% to 20% in cycle III. Observations highlighted heightened student engagement and underscored the pivotal roles of teacher and peer feedback in advancing critical thinking skills. Consequently, the guided inquiry method complemented by PhET simulations effectively cultivated a vibrant and efficacious learning atmosphere that fostered students' critical thinking capabilities.

Keywords: guided inquiry, phet simulation, critical thinking

1. Introduction

Critical thinking skills hold significant importance within the realm of science education, particularly in the research of physics[1], because they help students analyze information, evaluate arguments, and solve problems effectively. However, many students have difficulty developing critical thinking, especially when the material studied has a high level of abstraction and complexity as is the case with the concept of waves [2] [3].

Although much research has explored the importance of critical thinking skills in physics education, there are still gaps in our understanding of how specific learning models, such as the guided inquiry model, can be effectively implemented to address these challenges, especially for abstract concepts such as waves. Furthermore, the use of simulations such as PhET in this context has not been studied extensively to assess their impact on students' critical thinking skills.

One effective approach to address these challenges is the guided inquiry model, where students are placed as the main learning subject and encouraged to actively ask questions, explore, and discover answers independently [4]. In this model, the teacher acts as a facilitator, providing guidance and structure to the learning process, helping students stay focused and oriented [4].

The use of simulation materials such as PhET (Physics Education Technology) can also increase the effectiveness of the guided inquiry learning model [5,6] [7]. PhET simulations discover answers independently physics concepts. Moreover, these simulations enable the visualization of challenging ideas through firsthand experience, enhancing both retention and comprehension. By utilizing PhET simulations, intricate concepts related to waves can be presented vividly, enabling students to directly observe interactions, propagation, and behaviors in different situations.

This study makes a novel contribution by comprehensively examining how a combination of guided inquiry modeling and PhET simulation can be effectively used to improve students' critical thinking

skills related to wave concepts, an innovative approach that has not been widely explored in previous studies, especially in the context of physics education at the secondary school level.

In addition to aiding comprehension, PhET simulations foster the development of students' critical thinking abilities by promoting exploration and discovery. Past studies indicate that combining guided inquiry with PhET simulations leads to notable improvements in student engagement and critical thinking capabilities. Thus, implementing the guided inquiry learning approach with support from PhET simulations is anticipated to offer an effective strategy for enhancing the quality of physics education in classroom [8].

The main objective of this study is to analyze the effectiveness of combining a guided inquiry model with PhET simulation in improving students' critical thinking skills regarding waves. The study also aims to identify factors that influence the successful implementation of this model in the context of physics education.

2. Method

This research utilizes the *Penelitian Tindakan Kelas* (PTK) or Action Research method with the objective of addressing classroom challenges faced by teachers and enhancing the quality of education. Conducted at SMAN 6 Tangerang Regency, the research involved 39 participants from Class XI IPA 3 during the academic year 2023/2024, totaling 39 people, consisting of 22 women and 17 men. Data collection was carried out from the fifth week of May 2024 to the first week of June 2024. The research consisted of three cycles, each cycle consisting of planning, implementation, observing, and reflecting, as in Figure 1.

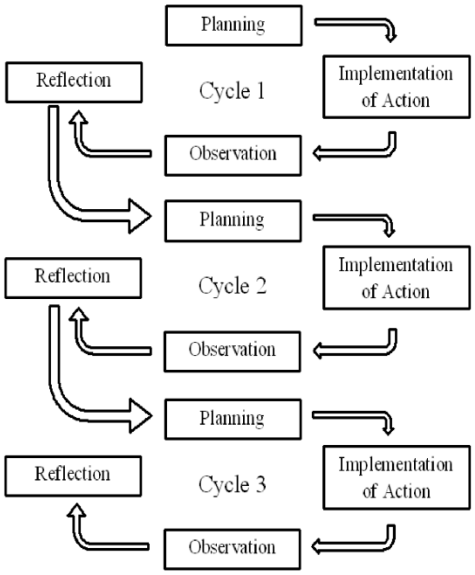

Figure 1. Action research cycle.

During the planning stage, a detailed action plan is formulated that encompasses the preparation of resources, tools, and educational strategies utilizing guided inquiry enhanced by PhET simulations. The implementation phase entails executing this plan in the classroom, where students participate in activities aimed at enhancing their critical thinking skills. In the observation phase, the learning process is closely monitored, and data on student engagement, learning outcomes, and the development of critical thinking abilities are gathered. The reflection phase involves assessing the outcomes of the actions taken, analyzing the observational data, and devising plans for subsequent cycles based on the outcomes.

The learning activities in this study are divided into three cycles. In cycle 1, students are introduced to the basic concept of waves using a simple PhET simulation showing different types of waves. They independently explore the simulation answering guiding questions and then review their results in a class discussion, providing an initial assessment of their critical thinking skills. In cycle 2, the focus

shifts to the application of wave concepts in more complex situations, such as studying wave interference and diffraction using PhET simulations.Students work in groups to solve problems set by the teacher and present their analysis, focusing on their ability to analyse and evaluate complex information. Finally, in Cycle 3, students will work on real-world scenarios where they have to apply wave concepts in everyday situations such as communication technology. They will use PhET to design virtual experiments that demonstrate real-world applications of the concepts they have learned. As a culmination, there will be a final critical thinking test to measure their overall progress.

In this research, the instruments utilized encompass observation sheets for documenting student activities throughout the learning sessions, critical thinking assessments administered before and after each cycle to gauge students' critical thinking abilities, and interviews conducted to delve deeper into students' perspectives and experiences with the learning process. The collected data were subjected to both qualitative and quantitative analyses. Qualitative analysis involved categorizing and interpreting data from observations and interviews, while quantitative analysis entailed comparing pre- and post-cycle critical thinking test results to assess improvements in students' critical thinking skills.

To ensure data validity and reliability, this research used data triangulation by comparing the results of observations, tests, and interviews. Cross-checking with colleagues was also conducted to ensure the accuracy of observations and data interpretation. With this approach, it is expected that the research can make a significant contribution in improving the quality of physics learning, especially by improving students' critical thinking skills through guided inquiry learning assisted by PhET simulation.

Assessment of the level of ability of students' critical thinking level is categorized based on table 2.

Table 2. Level of critical thinking.

Scale	Indicator
80% - 100 %	Very Good
70% - 79%	Good
60% - 69%	Moderate
50% - 59%	Poor
0% - 49%	Very Poor

3. Results and Discussion

This research showed a significant increase in students' critical thinking skills after the application of guided inquiry using PhET simulation in learning wave material. The data collected from 39 students of Class XI IPA 3 SMAN 6 Tangerang Regency showed a steady improvement trend from one cycle to the next as shown in Table 3.

Table 3. Results of improvement in students' critical thinking skills.

Cycle	Average Test Score	% Students (Very Good)	% Students (Good)	% Students (Moderate)	% Students (Poor)	%Student (Very Poor)
Before Intervention	65	10%	20%	40%	25%	5%
Cycle 1	70	10%	25%	45%	15%	5%
Cycle 2	75	15%	30%	45%	10%	0%
Cycle 3	80	20%	40%	30%	10%	0%

Observations during the research also noted an increase in students' active participation in learning, reflecting higher levels of engagement in discussions and problem-solving [9].

The outcomes unequivocally demonstrated substantial enhancements in students' critical thinking abilities across each learning cycle. The data indicates a consistent rise in the average score of the critical thinking tests throughout each cycle, underscoring the efficacy of guided inquiry with PhET simulations in advancing students' conceptual understanding and critical thinking skills in the domain of wave phenomena. For comparison, research by [10] and [11] also reported similar findings, where the use of interactive simulations and guided inquiry models significantly improved student learning outcomes in science, especially on abstract concepts.

Beginning with an initial average score of 65 before intervention, the test scores notably increased to 80 by cycle III. These results affirm the success of this instructional approach in enhancing the quality of physics education at SMAN 6 Tangerang Regency.

In addition, the percentage of students who scored "Very Good" grade also tended to increase positively from one cycle to the next. Starting from 10% in the pre-intervention cycle, the proportion of students in this highest group increased to 20% in cycle III. This change shows that the learning method used has the potential to promote student success through the achievement of critical thinking. This is consistent with the findings of [12–14] who showed that learning strategies that focus on active student engagement can significantly improve learning outcomes.

Other categories such as "Good", "Moderate", "Poor", and "Very Poor" also experienced encouraging changes. The proportion of students at the "Good" and "Moderate" levels tended to increase from semester to semester, while the proportion of students at the "Poor" and "Very Poor" levels tended to decrease over time.

The increased active involvement of students is also strong evidence of the success of this guided inquiry approach. Observations show an increase in student involvement in the learning process, which is reflected in the quantity and quality of reflective questions and critical discussions carried out by students. This confirms that the guided inquiry method has the ability to stimulate students' active participation in learning so as to increase the development of their critical thinking skills.

Observations showed that students' engagement in the learning process increased, reflected in the quantity and quality of student-led reflective questioning and critical discussions [15][16], supporting the ability of guided inquiry method to promote students' active participation in their learning, thereby facilitating the development of critical thinking skills.

Finally, the importance of teacher and peer feedback on student progress is also a key factor in improving critical thinking skills. The reflection and feedback process built into each cycle allows students to identify their weaknesses and work on improving them gradually. Therefore, the overall research results and student data analysis consistently showed that the guided inquiry method with PhET simulation successfully improved students' critical thinking skills, thus creating a dynamic and effective learning environment. Similar studies by [17,18], [19] and [20] also highlight the importance of continuous feedback cycles in learning to promote the development of students' critical thinking skills.

4. Conclusion

Based on research the guided inquiry method supported by PhET simulations led to a substantial enhancement in students' critical thinking abilities. The research demonstrated a consistent upward trajectory across successive learning cycles, with the average score on critical thinking tests rising from 65 before the intervention to 80 by the third cycle. Moreover, there was a notable increase in the percentage of students achieving an "Very Good" rating, indicating improved critical thinking performance. Observations during the research revealed an increase in students' active involvement, as well as the importance of teacher and peer feedback in improving students' critical thinking skills gradually. The guided inquiry approach assisted by PhET simulations was effective in creating a dynamic learning environment and effective in improving students' critical thinking abilities.

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