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Guided Inquiry Model Supported by Tracker Application on Wave Material: The Influence of Critical Thinking Skills

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ABSTRACT

In the context of scientific and technological advancement, improving the quality of education is a crucial factor in producing quality human resources. In physics learning, students are not only required to understand basic concepts, but must also be able to apply and analyze them in various situations of daily life. This study aims to evaluate the impact of the guided inquiry learning model supported by the tracker application on students' critical thinking skills. Using a one-group Pretest and Posttest technique, the research design is a quasi-experiment experiment, or simply a quasi-experiment design. It falls within the quantitative research category. The SPSS 26 tracker program was used to analyse the data, perform a paired sample t-test, and assess for normality and homogeneity. The instrument used in the study was a written test in the form of an essay to conduct a pretest and postest. The pretest and posttest data were homogenous and regularly distributed, according to the statistical analysis's findings. Following the adoption of the guided inquiry learning paradigm supported by the tracker application, students' critical thinking abilities significantly improved, as evidenced by a significance value of 0.000 < 0.05 obtained from further analysis using the paired sample t-test.

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INTRODUCTION

In the era of scientific and technological advancement, enhancing the quality of education plays a vital role in shaping competent human resources. In physics learning, students are not only expected to grasp fundamental concepts but also to apply and analyze them in various real-life situations. One of the key competencies required for this is critical thinking. This skill enables students to identify problems, logically analyze information, evaluate findings, and draw conclusions based on valid evidence. Therefore, fostering critical thinking skills in physics education is essential for developing a deeper understanding and practical application of scientific knowledge.

Critical thinking skills not only enable students to grasp complex physics concepts but also equip them with the ability to systematically solve problems (Purwanto, 2016). Critical thinking is the use of skills and strategies to improve outcomes according to individual goals and values, evaluating our own and others' ideas without prejudice (Nastiti et al., 2021). In physics, various phenomena, such as the laws of motion, waves, and thermodynamics, require thorough analysis. Students who possess strong critical thinking abilities can more effectively bridge the gap between theory and practice, interpret experimental data, and assess multiple possible solutions to a given problem (Yuliani, 2023). Additionally, critical thinking fosters a rational and objective scientific mindset, which is essential in experiment-based and research-driven learning processes (Wahyuli & Indrawati, 2024).

One of the instructional approaches proven to enhance critical thinking skills is the guided inquiry learning model (Widiya & Radia, 2023). This method encourages students to actively investigate physics concepts with structured guidance from educators (Adilah & Budiharti, 2015). In guided inquiry learning, students engage in designing experiments, gathering data, and drawing conclusions based on their observations. This approach not only reinforces critical thinking but also enables students to gain a deeper understanding of the subject matter through inquiry and reflective learning. As a result, implementing the guided inquiry learning model in physics instruction serves as an effective strategy to create a more meaningful learning experience and improve the overall quality of education (Simbolon, 2015).

The guided inquiry model is an inquiry learning model in which the teacher provides quite extensive guidance/instructions for students (Reswanto et al., 2021).The guided inquiry learning model is one of the student-centered approaches, where they play an active role in the process of exploration and concept discovery with the guidance of teachers (Azizaturredha & Fatmawati,

2019). Teachers act as facilitators who provide direction, trigger questions, and assist students in finding scientific concepts based on the results of their own observations an d experiments (Husni & Rosad, 2025). Thus, this learning model allows learners to experience a more in-depth and meaningful learning process, as they not only receive information passively, but also build their own understanding through interaction with the material and the learning environment. The guided inquiry approach has been proven effective in improving students' critical thinking skills (Widiya & Radia, 2023). The guided inquiry model needs to be supported by the Tracker application because it makes the observation process more accurate, makes it easier to collect and analyze data, and strengthens the relationship between theory and real phenomena, thereby increasing the effectiveness of students' critical thinking. A chart of the relationship of the guided inquiry model with the help of the Tracker application to critical thinking skills can be seen in figure 1.

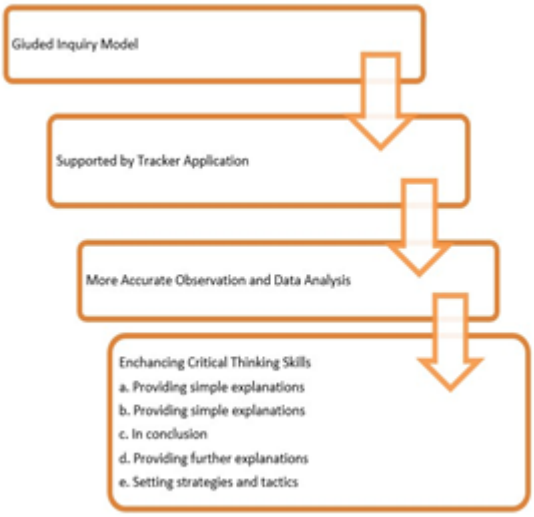

Figure 1. The relationship between the guided inquiry model and the tracker application on critical thinking skills

Extensive research has demonstrated the effectiveness of the guided inquiry learning model in developing students' critical thinking skills. For example, a study by Amellia et al. (2024) highlights that implementing this model significantly enhances students' ability to think critically, particularly in understanding concepts related to vibrations, waves, and sound. Students engaged in guided inquiry learning show improved skills in analyzing experimental data, identifying relationships between variables, and drawing scientifically grounded conclusions. These findings further emphasize that the guided inquiry learning model is a highly effective approach for cultivating critical thinking skills in the context of physics education.

Technological developments in the world of education have brought various innovations in learning methods, including in the field of physics. One of the innovations that is increasingly being applied is the use of tracker applications to help the learning process of complex concepts (Aisyah et al., 2024) In physics learning, it often requires clear visualization so that students can connect theory with real phenomena (Dendoli et al., 2024). Therefore, the integration of tracker applications in physics learning is becoming increasingly relevant to support the exploration of abstract concepts, such as motion, waves, and particle dynamics. One of the tracker applications that is widely used in physics learning is tracker, a video analysis tool that allows students to visualize, analyze, and interpret various physical phenomena in more depth (Mardiyah & Subali, 2024). Using trackers, students can record, track, and analyze the motion of an object in a video, so they can see firsthand how physics concepts are applied in real-world situations.

In physics learning, the guided inquiry model has been proven to improve students' critical thinking skills, in this case the researcher wants to integrate the guided inquiry model with the help of the Tracker application to find out if there is a significant influence on critical thinking skills after applying it especially in wave subjects. In inquiry-based physics learning, video-based analysis enables students to move beyond rote memorization of theories by actively engaging in data exploration, decision-making, and systematic interpretation of experimental outcomes (Azizaturredha & Fatmawati, 2019). This is consistent with the findings of Mulyani et al., (2021) which emphasize the substantial impact of combining the guided inquiry learning model with Tracker applications at SMA Negeri 1 Keluang. Students who implemented Tracker in their learning process exhibited remarkable enhancements in analytical reasoning, problem-solving skills, and their ability to link theoretical concepts to real-world phenomena. Therefore, integrating Tracker applications into guided inquiry learning presents an innovative strategy for improving the quality of physics education while strengthening students' critical thinking capabilities (Mulyani et al., 2021).

This study aims to bridge the research gap by investigating the effectiveness of integrating the Tracker application within the guided inquiry learning model to enhance students' critical thinking skills in comprehending wave concepts. Unlike PhET, Tracker enables students to analyze actual data obtained from experimental videos, allowing them to directly observe the relationship between physical theories and real-world phenomena (Fatimah et al., 2022). Within the guided inquiry learning framework, students engage in designing experiments, gathering data using Tracker, and analyzing their results to formulate conclusions based on empirical evidence. Therefore, this research not only expands the use of technology in physics education but also provides valuable insights into how integrating Tracker into guided inquiry learning can facilitate the development of students' critical thinking abilities, particularly in the study of wave theory.

Moreover, this study is anticipated to make a significant contribution to the advancement of innovative and effective learning strategies, particularly in enhancing students' critical thinking skills in physics education. By integrating the guided inquiry learning model with Tracker applications, this research introduces a more interactive and exploratory learning approach, allowing students to engage in hands-on experiences through real data analysis. This method encourages active student participation as they directly observe wave phenomena, analyze motion patterns, and assess experimental results, ultimately deepening their conceptual understanding. This approach aligns with the goals of 21st-century education, which emphasize critical thinking, problem-solving, and the integration of technology into the learning process. Additionally, the findings of this study can serve as a valuable resource for educators in developing more effective teaching strategies and as a foundation for further research on the application of technology in science education. By focusing on inquiry-based learning and real-data analysis, this research aims to improve the quality of physics education, ensuring that students not only comprehend theoretical concepts but also acquire the skills to apply them in real-world contexts.

Based on the results of observations, students still have difficulties in analyzing abstract and complex physics concepts, so they tend to memorize formulas without understanding the basic principles, students often only rely on procedures that have been learned beforehand, without trying to understand the underlying concepts, besides, students are not yet able to distinguish between relevant and irrelevant information in solving physics problems, So they are often trapped in unimportant information, students are still unable to identify the assumptions used in solving physics problems, so they are often unable to understand the limitations of the solutions given. Researchers are interested in exploring the impact of the guided inquiry learning model supported by the tracker application on critical thinking skills.

METHOD

This research was carried out at SMAN 5 Palangka Raya from January to February 2025. The main purpose of this study is to evaluate the impact of the guided inquiry learning model supported by the tracker application on students' critical thi nking skills. The study consisted of five meetings, of which the first meeting was conducted for Pretest, the second, third, and fourth meetings were focused on learning using a guided inquiry model with the help of a tracker application, and the fifth meeting was used for Posttest. Each meeting lasts for two hours of lessons, with a duration of one hour of lessons of 45 minutes. The analysis of quantitative data obtained related to students' critical thinking skills was carried out using SPSS 26.

The research in this study follows a quasi-experimental design, specifically employing a one-group pretest-posttest approach. The overall structure of the study is presented in Table 1.

Table 1. One-Group Pretest-Posttest Design

Pretest	Treatment	Posttest
O_1	X	O_2

X : Utilization of the guided inquiry model in conjunction with the Tracker app for treatment
O_1 : Before treatment (Pretest value)
O_2 : After treatment (Posttest value)

The population that is the focus of this study is all students of grade XI Saintek at SMAN 5 Palangka Raya for the 2024/2025 school year. This study applies the purposive random sampling technique in sample selection. Of the many classes, one class is determined as an experimental group, where the learning process will be carried out using a guided inquiry model supported by a tracker application. The class chosen as the location of the research is XI Saintek 2, which will apply a guided inquiry learning model with the help of a tracker application. The icon display of the tracker application can be seen in Figure 2.

Figure 2. Tracker app

This study focuses on two primary variables: the independent and dependent variables. The independent variable refers to the factor that affects changes in the dependent variable. In this research, the independent variable is the application of a practicum on water wave concepts utilizing the Tracker software. On the other hand, the dependent variable, which is influenced by this practicum, is the students' critical thinking skills.

The data gathered in this study focused on students' critical thinking skills, which were assessed through Pretest and Posttest scores. The instrument used in this study is a test in the form of an essay which has previously been tested for validity and reliability. Based on the questions that were tested as many as 10 questions, there were 7 questions that were declared valid with a reliability level of 0.552 with a medium category. According to Ennis, critical thinking indicators encompass the ability to offer further explanations, build fundamental skills, draw conclusions, and formulate strategies and techniques. Additionally, the collected data were analyzed using normality and homogeneity tests with the assistance of the SPSS 26 software. To evaluate the research hypothesis, a paired sample t-test was conducted to determine whether it should be accepted or rejected.

RESULT AND DISCUSSION

The students involved in this study are class XI Saintek 2 at SMAN 5 Palangka Raya. Before the learning process begins, a pretest is carried out to assess students' initial knowledge. The research design is then determined to formulate teaching strategies to be applied. After that, students take the Posttest. Before the research was carried out, the Pretest and Posttest questions were tested on students who had studied wave material, but were not included in the population or research sample, namely 36 students of grade XII Science 1 SMAN 5 Palangka Raya, to ensure the validity and reliability of the questions. After the validity and reliability test, the questions consisting of 8 questions were declared valid and reliable, so that they could be used in this study.

The first step in assessing the distribution of data is to conduct a normality test. This test was carried out using the Shapiro Wilk test with a significance threshold of 5% or 0.05 to verify the normality of the data.

Table 2. Results of the Normality test of Critical Thinking Skills

No	Aspects	Significance	Category
1	Prestest	0,158	Normally distributed
2	Posttest	0,320	Normally distributed

Table 2 indicates that the results of the normality test reveal a normal distribution of the data. The significance value for the Pretest was noted at 0.158, exceeding the significance threshold of 0.05, whereas the significance value for the Posttest was 0.320, which also surpassed the significance level of 0.05.

Additionally, a homogeneity test was conducted to assess variations within the sample data. The Pretest and Posttest results served as the foundation for this analysis. In this study, the homogeneity test was performed using SPSS 26, applying Levene's statistic with a significance threshold of 5% or 0.05. If the obtained significance value exceeds 0.05, the data is considered homogeneous, confirming the validity of the test results.

Table 3. Results of the Homogeneity Test of Critical Thinking Skills

Levene Statistik	df1	df2	Significance
2,698	1	66	0,105

This study gathered quantitative data through Pretest and Posttest results, which were utilized to analyze the research findings. The collected data is displayed in Table 4.

Table 4. Pretest and Posttest results

Parameter	Pretest	Posttest
N	34	34
Lowest rate	6	40
Highest scores	25	62
Grade point average	15,97	51,21
SD	4,783	5,558

Analysis of Pretest and Posttest data indicates an improvement in critical thinking skills. The scores obtained by students from the Pretest and Posttest were analyzed by utilizing five indicators to evaluate their critical thinking skills.

Table 5. Students' Critical Thinking Skills For Each Indicator

Critical thinking indicators	Average Pretest Score	Average Posttest Score
Providing simple explanations	1,5	5,47
Building basic skills	1,82	6,65
In conclusion	1,04	7,22
Providing further explanations	0,47	8,15
Setting strategies and tactics	4,29	6,44

Based on the data contained in Table 5, students showed the ability to provide further explanations with a score of 5.47, the ability to build basic skills with a score of 6.65, the ability to conclude with a score of 7.22, the ability to provide further explanations reached 8.15, and the ability to manage strategies and techniques of 6.44. The average Posttest score for each indicator indicates a change, indicating that students have developed critical thinking skills during the learning process.

Table 6. Results of the Paired Sample T-test critical thinking

Sig. (2-tailed)	Conclusion
0,000	H_1 (Accepted)

Based on the data presented in Table 6, the paired sample t-test resulted in a significance value below 0.05. This finding supports the acceptance of the alternative hypothesis (H_1) in line with the established testing criteria. The results indicate a significant improvement in students' critical thinking skills following the implementation of the guided inquiry learning model combined with the Tracker application, demonstrating a clear distinction between pretest and posttest scores.

The purpose of this study is to assess how students' critical thinking abilities are applied in the context of studying physics, particularly with regard to waves, using the guided inquiry learning approach backed by the tracker application. Through guided inquiry learning, students may investigate actual phenomena, dive into physics principles, and develop higher-order thinking abilities like critical thinking. This model allows students to identify problems, design solving strategies, and analyze the results of experiments more systematically.

The discussion in this study has been conducted following all the methodological steps outlined (Aisah et al., 2024). The guided inquiry learning approach places a strong emphasis on student engagement at every stage of the experiment, from initial planning to data analysis (Aswat & Aminu, 2023). In this model, the teacher plays a crucial role as a facilitator, guiding students to think independently and critically through problem-based exploration. Previous studies have demonstrated that integrating guided inquiry methods with digital tools, such as Tracker applications, enhances students' critical thinking skills by enabling them to observe, measure, and analyze physical phenomena with greater accuracy (Kurniawan et al., 2022).

Kuhlthau et al. (2010) suggest that applying guided inquiry learning methodologies can significantly improve students' critical thinking and problem-solving abilities. This instructional approach has been proven effective in fostering students' analytical and evaluative thinking skills. Each phase within the guided inquiry model engages students in intellectual and scientific processes essential for deeper understanding (Wenning, 2011). In the context of critical thinking, five key indicators are fundamental: basic clarification, basic support, inference, advanced clarification, and strategy and tactics (Ennis, 2018).

Providing a Simple Explanation, this ability is trained at the stage of identifying and formulating problems in guided inquiry learning. At this stage, students are invited to ask critical questions regarding the observed phenomena and understand the underlying basic concepts. Research by Putra et al. Students who are involved in the formulation of problems through an inquiry approach are more able to explain concepts logically and systematically compared to students who are only given information directly as shown (Putra, 2018). Building Basic Skills, these skills are practiced at the planning and execution stages of experiments. Students are required to gather empirical evidence, interpret preliminary data, and formulate hypotheses based on available facts. According to research conducted by Fakhri (2020), students who use the guided inquiry method have better abilities in connecting theoretical concepts with data obtained from experiments, thereby improving their critical thinking skills in understanding physics concepts (Fakhri, 2020)

In summary, during the data analysis stage, students are guided to develop inferences and draw conclusions based on the experimental results they have conducted. At this point, they utilize the Tracker application to identify data patterns and verify the accuracy of their findings. Research indicates that incorporating Tracker in physics education enhances students' analytical thinking abilities, as it enables them to compare experimental results with established theoretical concepts, as demonstrated (Andiantosa, 2023). Giving Further Explanation, this ability appears at the stage of interpretation of results and discussion.

Students were asked to compare the results of the experiment with relevant theories as well as identify possible errors in data collection. Students trained with guided inquiry methods are more able to construct evidence-based arguments and provide clarification on the phenomena they observe compared to students who learn using conventional methods (Cahaya, 2022).

Setting Strategy and Tactics, the last critical thinking ability in Ennis' model is to develop strategies and tactics in solving problems. These skills are trained in the reflection and evaluation stages of learning, where students are asked to identify weaknesses in their approach as well as propose more effective strategies to solve problems in the future. Students who are used to inquiry-based learning tend to have more adaptive and flexible thinking strategies in dealing with new problems (R. Fitri & Farida, 2024). In this study, a tracker application is used as a tool in video-based data analysis. Tracker is an open-source application developed to support physics learning, especially in understanding the concept of waves quantitatively. The app allows users to track the motion of particles in waves as well as analyze various parameters such as wavelength, frequency, wave speed, and amplitude. Thus, trackers are an effective tool in connecting wave theory with experiments conducted in the laboratory or virtually.

Tracker is a video-based program that is often used in physics experiments because of its ability to display wave phenomena in real life and visualize them in the form of accurate quantitative data (Yuliana, 2016). This tracker application is very effective in helping students understand the characteristics of waves by providing simultaneous representation between experimental recordings and graph data generated directly. Thus, trackers not only function as an analysis tool but also as an interactive and technology-based learning medium. The following is presented with a picture of the wave practicum using the tracker application in figure 3.

Figure 3. Wave practicum using the tracker application

Research shows that the use of trackers in physics learning can improve critical thinking skills towards the concept of waves has been carried out by (Subhan et al., 2020). This is due to its ability to provide visual representation and numerical analysis at the same time, so that students can connect theory with practice in a more concrete way. The tracker also supports a variety of additional features, such as wave vector analysis, the use of Cartesian and Polar coordinate systems, and wave modeling using mathematical regression methods. Furthermore, Tracker applications offer a significant advantage in supporting inquiry-based learning, enabling students to independently investigate observed wave phenomena. In the realm of modern physics education, integrating Tracker into virtual laboratory experiments helps students develop critical and analytical thinking skills. Research findings indicate that students who utilize Tracker in physics experiments are more actively engaged in understanding the interrelationship between wavelength, frequency, and wave velocity (Fadillah et al., 2022). Other research shows that physics learning involving trackers is able to improve students' problem-solving skills in understanding wave phenomena. This is because this tracker application allows students to test hypotheses directly through the experimental data obtained, so that they better understand the cause-and-effect relationship in the wave phenomenon they observe (Pratama & Susanto, 2022).

The normality test is conducted to assess whether the Pretest and Posttest data follow a normal distribution, ensuring the suitability of parametric statistical methods. This study utilized the Shapiro-Wilk test, which is particularly appropriate for small sample sizes ($n < 50$). The decision criteria for this test are as follows: 1) If the significance value (p-value) is greater than 0.05, the data is considered normally distributed; 2) If the p-value is 0.05 or lower, the data is categorized as not normally distributed. As shown in Table 2, the significance values for the Pretest and Posttest are 0.158 and 0.320, respectively, both exceeding the 0.05 threshold. This confirms that the data exhibit a normal distribution, allowing for further parametric statistical analysis, including homogeneity and hypothesis testing. Ensuring normality is essential to maintain the accuracy of statistical methods, as parametric tests yield more reliable results under this assumption (Diani et al., 2021). These findings are consistent with previous research (Pratama & Susanto, 2022). which indicates that the structured nature of inquiry-based learning often produces normally distributed learning outcomes, as it promotes systematic data collection and logical reasoning among students.

The homogeneity test was conducted to evaluate the variance similarity between the Pretest and Posttest data. The significance of data homogeneity in this research is crucial as it helps ascertain whether the data exhibits a consistent distribution across the sample groups. In this investigation, Levene's Test was employed for the homogeneity assessment, utilizing a significance threshold of 0.05. According to Table 3, a significance value of 0.105 was recorded, which exceeds the 0.05 threshold. This indicates that the Pretest and Posttest data are homogeneous, allowing for the application of parametric statistical analysis under the assumption that the variance remains consistent. These results align with the findings of Kurniawan et al. (2022), which demonstrate that the guided inquiry learning model yields homogeneous data regarding the enhancement of students' cognitive skills. The homogeneity of the data suggests that all participants in this study possessed a relatively uniform level of initial knowledge prior to the intervention, implying that the observed improvements post-treatment can be more accurately attributed to the intervention itself (Kurniawan et al., 2022).

The results of this study reveal that all critical thinking indicators experienced enhancement after applying the Guided Inquiry model with the support of the Tracker application. Critical thinking skills can be improved because guided inquiry encourages students to ask and answer high-level questions while Tracker provides clear and measurable evidence to support their reasoning. Without guided questions, students will passively use the Tracker without deep thinking; without a tracker, students will have difficulty obtaining accurate data to analyze. This finding suggests that students not only improved their comprehension of wave concepts but also strengthened their analytical, evaluative, and reflective thinking abilities when examining the studied phenomena. These outcomes align with research Fitri & Farida, (2024), which demonstrated that integrating technology into guided inquiry learning significantly improves students' critical thinking, particularly in connecting theoretical concepts with experimental data (A. N. Fitri & Farida, 2024).

To assess the statistical significance of the difference between Pretest and Posttest scores, a paired sample t-test was conducted with a significance threshold of 0.05. As illustrated in Table 6, the obtained significance value (Sig. 2-tailed) was 0.000, which is lower than the 5% threshold (0.05). This result confirms a substantial difference between Pretest and Posttest scores, validating the acceptance of the alternative hypothesis (H_1). The findings further underscore the significant influence of guided inquiry learning, enhanced by the Tracker application, on students' critical thinking skills. These results are consistent with the study by Cahaya (2022), which highlights that integrating digital technology into physics education fosters critical thinking and supports the development of higher-order cognitive abilities (Cahaya, 2022).

CONCLUSSION AND SUGGESTION

Guided inquiry learning involves five main indicators of critical thinking according to Ennis (2011), namely:1) Providing simple explanations, students are able to formulate problems critically and explain physics concepts more logically and systematically; 2) Building basic skills, students can interpret data, formulate hypotheses, and relate theories to experiments conducted; 3) In conclusion, the use of the tracker application helps students in drawing conclusions based on the results of the observed and analyzed experiments; 4) Providing further explanations, students are able to compare the results of experiments with relevant theories and identify errors in data collection; 5) Setting strategies and tactics, students are more adaptive in facing new problems and able to develop effective problem-solving strategies.

The findings from the statistical analysis indicated that the Pretest and Posttest data were normally and homogeneously distributed. The significance value obtained from the paired sample t-test analysis was 0.000 (< 0.05), which confirmed a notable enhancement in students' critical thinking abilities following the implementation of the guided inquiry learning model supported by the tracker application. The integration of tracker applications in physics education has demonstrated its effectiveness in enhancing critical thinking regarding wave concepts. The tracker functions as an analytical tool, enabling students to monitor particle movement in waves and measure wave parameters such as wavelength, frequency, and velocity. Through video-based data visualization and analysis capabilities, trackers assist students in bridging theoretical knowledge with practical application, thereby enhancing their analytical skills and promoting independent inquiry. The results of this study indicate that the application of the guided inquiry learning model, aided by the tracker application, significantly benefits students' critical thinking skills in physics, particularly concerning wave material. This educational approach encourages students to engage more actively in exploring physics concepts, identifying challenges, devising problem-solving strategies, and systematically analyzing experimental outcomes.

During the learning process, some students do not pay attention to what is conveyed by the researcher so that the results they get are not satisfactory, the time in several stages of research must be done quickly so that the learning process is not optimal and affects the quality of research results. To improve the quality of the teaching and learning process, I suggest that teachers can increase interactive activities and group discussions, so that students can be more active and involved in the learning process. In addition, teachers can also consider providing constructive feedback and motivating students to improve their academic performance. Thus, it is hoped that the quality of the teaching and learning process can improve and students can achieve their academic goals better.

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