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Effectiveness of Guided Inquiry Model in Enhancing Students' Critical Thinking on Light Waves

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Abstract

This study examines how guided inquiry learning can be applied to the material of light waves in physics subjects. This study investigates the potential for increasing students' critical thinking skills. The research method used was a quasi-experimental design, creating the same conditions for the experimental and control groups in other aspects except for particular interventions in the experimental class. This research involved 60 samples of class XI high school students. The sample was divided into two groups (experimental and control) of 30 students each. The research data were obtained through pre-test and post-test from critical thinking instruments containing ten essay-type questions (validated, with validity 0.78 and reliability 0.96). Data were analyzed by parametric t-test on n-gain scores for each group. The results showed that the experimental group scored 0.526 and the control group 0.148. These results indicate differences due to intervention, where applying the guided inquiry model can significantly encourage the development of student's critical thinking skills. The research implications encourage teachers to apply this learning approach model in improving critical thinking skills so that students can be actively involved in facing complex challenges in everyday life. This study also emphasizes the need for curriculum development to improve critical thinking skills in various subjects.

Keywords: Critical thinking; Guided inquiry; Light wave

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INTRODUCTION

The competencies necessary in the contemporary digital and global landscape are encapsulated in 21st-century skills. Improving one's ability to engage in critical thinking is a crucial component of personal skill advancement. Acquiring these competencies empowers individuals to adjust to modifications, resolve intricate issues, and confront obstacles in a perpetually developing professional milieu. Critical thinking is a cognitive process involving reflective and logical thinking, employed in decision-making, and encompasses beliefs and actions (Ennis, 1985). Critical thinking ability is essential in the learning process, particularly concerning how students engage in critical thinking and apply it to the study of science (Astall & Cowan, 2016; Kusumawati & Lesmono, 2020). The 2018 PISA evaluation conducted by the (OECD, 2019) revealed that Indonesia ranked seventh-lowest among 72 countries in science. In line with

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previous research, “the level of students' critical thinking skills is still low” (Isnawati & Noer, 2020). The PISA report highlights the need to enhance the critical thinking skills of students in Indonesia.

The deficiency in critical reasoning skills among Indonesian students is a concern in physics education. The possession of proficient critical thinking abilities is essential in the field of physics, as it involves comprehending complex concepts and utilizing logical reasoning in the process of acquiring knowledge. According to prior research, students' critical thinking abilities were found to be at a level of 35.91%, suggesting a low classification (Arini et al., 2018). A further investigation revealed that students' critical thinking skills about evaluation still need to catch up to the expected standard. According to the results of the 2019 High School National Examination (UN) in Physics, students in Indonesia demonstrated a low level of critical thinking skills in the context of physics education. The overall score obtained was 44.42 out of a possible 100 points. Specifically, the topic of light waves showed the lowest scores, ranging from 33 to 49 (Kementrian Pendidikan dan Kebudayaan, 2019). The discipline of physics necessitates a profound comprehension of intricate principles and the utilization of rationality in acquiring knowledge. Hence, acquiring optimal critical thinking skills is imperative in comprehending physics. These skills are crucial in equipping students to tackle problem-solving tasks reliably and swiftly (Phonna et al., 2020). However, a considerable number of students require assistance in cultivating these skills. The primary issue at hand pertains to the requirement of assistance for students in analyzing information and attaining a comprehensive understanding of concepts. Students often resort to rote memorization of formulas and replicating teacher-provided examples without comprehending the fundamental principles underlying physical phenomena in physics. Research has shown that the traditional approach to teaching physics, which fails to establish a connection between the subject matter and real-world experiences, challenges students' progress in physics education. Establishing interactions among teachers, students, learning resources, and groups is imperative for promoting effective learning. It is a frequent occurrence for students to require assistance in addressing various obstacles, including inadequate comprehension of conceptual knowledge, misconceptions, difficulties in comprehending abstract concepts, insufficient mathematical proficiency, and temporal limitations. Thus, it is imperative to adopt a methodology that integrates concrete representations and mathematical depictions to facilitate students in connecting the theoretical principles of physics with their pragmatic implementation in actual scenarios (Aykutlu et al., 2015; Beck & Perkins, 2016; Erinosho, 2013; Karuru et al., 2021; Priyadi et al., 2018).

The deficiency in critical thinking skills among students may impact their capacity to scrutinize physics problems methodically, recognize variables that influence empirical outcomes, and construct coherent justifications. The role of educators and the curriculum is crucial in enhancing students' critical thinking abilities in the context of physics education. Developing critical thinking skills can be achieved through an instructional methodology that enables learners to attain profound and extensive conceptual comprehension, employ practical scenarios, and participate in analytical and evaluative activities. Based on empirical evidence gathered from interviews conducted with physics educators and 70 high school students in South Tangerang City in February 2023,

it was determined that the majority of the learning process, approximately 80%, continues to utilize a traditional teacher-centered methodology. The failure to prioritize the cultivation of critical thinking abilities, including analysis, logical reasoning, and problem-solving, can constrain students' capacity to independently acquire knowledge and promote reliance on rote memorization and passive comprehension. Traditional pedagogical approaches must encourage students to inquire, think critically, or delve deeper into the subject. Consequently, students critical thinking abilities are impeded, which poses difficulties in applying physics principles to real-world situations, ultimately resulting in a decline in motivation and enthusiasm toward the subject.

One disadvantage of traditional physics education is the need for hands-on experimentation and direct engagement with the subject matter. Students must be provided with sufficient opportunities to actively participate in experiments and direct observations, which can restrict their capacity to cultivate crucial cognitive abilities such as observation, data collection, and analysis. The knowledge and skills students acquire stem from their needs rather than merely memorizing facts and formulas (Mulhayatiah et al., 2019; Putri & Syafriani, 2020). The significant influence of the inadequacies of traditional physics education on the development of critical thinking skills among students is noteworthy. The impairment of critical thinking skills in the face of intricate problems and decision-making is a detrimental consequence.

The issue of insufficient critical thinking skills among students is recommended to be solved by adopting interactive, practical, and contextual learning models. The intricate nature of light waves and their associated phenomena make them a fitting subject for exploration through a guided inquiry methodology within an academic context. Using a guided inquiry methodology, pupils can enhance their comprehension of light waves through dynamic exploration and inquiry. The guided inquiry model is an approach that empowers students to develop critical thinking skills, data analysis, and understanding of physics concepts through active exploration and discovery. The guided inquiry learning model also emphasizes scientific process skills and scientific inquiry, thereby assisting students in developing a profound understanding of physics phenomena (Azizmalayeri et al., 2012; Chernicoff & Echeverría, 2012; Kusumawati & Lesmono, 2020; Ratna & Simanjuntak, 2021). Within light waves, pupils can acquire knowledge regarding many principles, including but not limited to wavelength, frequency, intensity, refraction, interference, diffraction, and reflection. By employing a guided inquiry methodology, learners can cultivate their analytical reasoning capabilities, hone their aptitude for observation and data gathering, and augment their applied proficiencies. Furthermore, using the guided inquiry approach enables students to establish links between the principles of light waves and tangible occurrences in the world around them. As an illustration, experiments can be carried out to comprehend the phenomenon of light passing through a prism and generating a range of colors or light reflection and polarization when interacting with diverse surfaces. Under an educator's or facilitator's supervision, students can delve into knowledge and comprehend the fundamental principles underlying these phenomena. The guided inquiry approach facilitates the development of collaborative work skills, idea-sharing abilities, and effective communication among students. Students can participate in group discussions, cooperate on

experiments, and offer constructive criticism to their peers. These activities facilitate the acquisition of crucial social skills and promote a more comprehensive comprehension of light waves. In general, the subject matter of light waves is well-suited for examination through the implementation of a directed investigation methodology. This pedagogical approach enables students to comprehend light wave concepts profoundly, establish links between them and actual occurrences in the world, and foster their abilities to engage in critical thinking and collaborative work. According to recent research investigations, implementing guided inquiry in the classroom has significantly enhanced students' thinking abilities (Martatis, 2023).

The present investigation aims to assess the efficacy of guided inquiry learning strategies in enhancing the critical thinking abilities of secondary school students when studying the subject of light waves within the realm of physics. According to the meta-analysis, implementing guided inquiry learning models substantially affected the academic achievements in physics, science process proficiencies, and critical thinking aptitudes of secondary school students (Ramadhani et al., 2021). The focus of the problem lies in the students' limited critical thinking skills when comprehending and applying concepts related to light waves. Previous research has highlighted the necessity for students to possess strong critical thinking abilities in the context of light wave topics. Students often encounter difficulties in identifying wave patterns, comprehending the principles of interference and diffraction, and applying the concepts of reflection and refraction. They also struggle with grasping phenomena such as color dispersion, light refraction, and the properties of electromagnetic waves. To address this issue, the present study adopts an approach suggested by Tiruneh, which identifies five critical thinking indicators relevant to physics education. These indicators encompass “reasoning, hypothesis testing, argument analysis, considering possibilities and uncertainties, problem-solving, and decision-making”. This research aims to enhance students' critical thinking skills in learning light wave material.

The emphasis on the abstract characteristics of light wave material holds significant importance in this study. Lightwave material possesses properties that cannot be directly observed by human senses, necessitating strong critical thinking skills for comprehension. Students must be proficient in logical reasoning, analyzing complex arguments, and navigating uncertainty within light waves.

By incorporating the critical thinking indicators proposed by Tiruneh et al. (2017) into physics education, specifically in the context of light wave material, this research will significantly enhance students' critical thinking abilities. Consequently, the findings of this study can offer valuable recommendations for educators and curriculum developers, enabling them to improve teaching strategies to enhance students' understanding of light wave material and develop their critical thinking skills.

This research differentiates itself from previous studies in several key aspects. Firstly, it focuses explicitly on the domain of light wave material, acknowledging the unique challenges associated with comprehending abstract concepts related to light waves. Secondly, it adopts the approach Tiruneh et al. (2017) proposed for identifying critical thinking indicators in physics education. By incorporating their framework, this study expands the understanding of critical thinking skills within the context of light wave material. Thirdly, it provides practical

recommendations for educators and curriculum developers to improve teaching strategies. By identifying the challenges students face in understanding light wave material and proposing integrating critical thinking indicators, this research contributes to developing effective instructional methods tailored to enhance students' understanding and critical thinking skills in this domain.

METHOD

The research is designed and conducted using a quantitative approach and an experimental method to test the efficacy of guided inquiry learning to enhance students' critical thinking abilities (Sugiyono, 2013). This topic adopts a quasi-experimental design known as the Nonequivalent Control Group Design, "the experimental group received a specific treatment or intervention, while the control group did not receive that treatment and served as a comparison" (Shadish et al., 2002). Pretest and posttests were assessed at the beginning and completion of the investigation, respectively. The research design is described in Table 1.

Table 1 Investigation begins

Group	***Pretest***	**Treat-ment**	***Posttest***
Experiment	O_1	X	O_2
Control	O_3	X_1	O_4

(Sugiyono, 2013)

The research was launched in March 2023 at a public high school in South Tangerang City, consisting of 6 sessions. The study population consisted of all 11th grade in the public high school in South Tangerang City for the academic year 2022/2023, totaling 195 students divided into five classes. Sampling was done based on teacher considerations and the average results of the pretest for Class XI Science 1 and Class XI Science 2. Purposive sampling was the approach being used, and it was based on specific criteria (Malik & Chusni, 2018). Therefore, Class XI Science 1 was referred to as the control group, and Class The experimental group was labeled as XI Science 2, with 30 students in each class, totaling 60 students as the overall sample. This study involved a control group that used the conventional learning model and an experimental group that applied the guided inquiry learning model as a different treatment. The treatment was administered in four sessions, focusing on the topic of light waves in physics.

The test instrument has been validated by three material experts, three construct experts, and three linguists and is prepared regarding critical thinking indicators.

The instrument was developed based on indicators of critical thinking and has been validated by three subject matter experts, three construct experts, and three language experts with highly consistent CVI results. The construct validation of the instrument was conducted using IBM SPSS Statistics version 26. Out of the ten tested items, it was found that all items were valid based on the validation test results as follows in Table 2.

Table 2 The results of the validity evaluations

Case Processing Summary			
		N	**%**
Cases	**Valid**	30	100,0
	Exclude[a]	0	,0
	Total	30	100,0

Based on these results, it can be concluded that this test instrument is valid and suitable for use in research. Reliability refers to the consistency of test results when administered to the same subjects (Arikunto, 1999). To determine the overall reliability of the test, the Cronbach's Alpha formula was used as follows:

$$r_i = \frac{k}{(k-1)}\left\{1 - \frac{\sum {s_i}^2}{\sum {s_t}^2}\right\} \qquad \text{……..(1)}$$

In this study, reliability testing was conducted using SPSS, and the results are as follows in Table 3.

Table 3 Reliability test results

Statistics	Reliability
r_i	0.96
Conclusion	High

From these results, it is evident that the test instrument used has a very high reliability category. Next is the discriminative power of the test items. Discriminative power refers to a question's ability to differentiate between students with high and low abilities. In this study, IBM SPSS version 26 software was utilized to calculate the discriminative power. After obtaining the discriminative power output, the results were then interpreted using specific classifications. Out of a total of 10 items, nine items had a "very good" discriminative power category, while 1 item was categorized as "good". This indicates that the test instrument effectively distinguishes students with high and low abilities.

The n-gain test was conducted to measure the changes in students' critical thinking skills before and after the implementation of the treatment in both groups. The analysis followed the criteria for n-gain proposed by Richard R. Hake.

Table 3 N-gain criteria

N-gain	N-gain Criteria
n-gain ≥ 0.7	High
0.3 ≤ n-gain < 0.7	Medium
n-gain < 0.3	Low

(Hake, 1999)

Then, the normality test and homogeneity test were conducted based on the obtained n-gain values. The normality and homogeneity tests are statistical prerequisites before hypothesis testing is performed. Afterward, hypothesis testing was carried out to analyze the difference in the effectiveness of the guided inquiry learning model and the conventional learning model in enhancing students' critical thinking skills, referring to the obtained pretest and posttest results.

RESULT AND DISCUSSION

The changes in students' critical thinking skills before and after the treatment can be observed by analyzing pretest and posttest scores. Information on the pretest results of critical thinking can be found in Figure 1, which includes data from both groups.

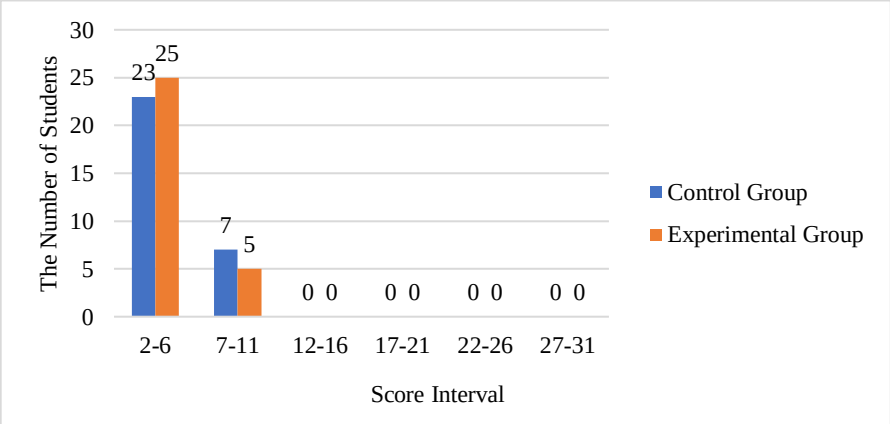

Figure 1 Diagram of the outcome of the students' critical thinking pretest

Figure 1 shows a visualization of the distribution of student scores within score intervals. From the results, it can be observed that the scores of students in both groups fall within the low category. Overall, there is no significant difference in scores between the two groups. The initial abilities of both groups are comparable. Information regarding the

percentage of student pretest results on critical thinking indicators according to Tiruneh can be found in Table 4.

Table 4 Pretest result for each critical thinking indicator

Critical Thinking Indicator	Control Group (%)	Experimental Group (%)
Reasoning	40.69%	39.58%
Hypothesis Testing	7.83%	5.33%
Argument Analysis	10.56%	7.22%
Analysis of Possibilities and Uncertainties	4.58%	7.36%
Problem-solving and Decision-making	1.32%	0%

Based on the percentage for each indicator, the abilities of both groups are similar in each indicator. Both groups demonstrate relatively good reasoning compared to other critical thinking indicators but perform very poorly in the problem-solving and decision-making indicators. The visualization of the posttest data after the intervention can be found in Figure 2.

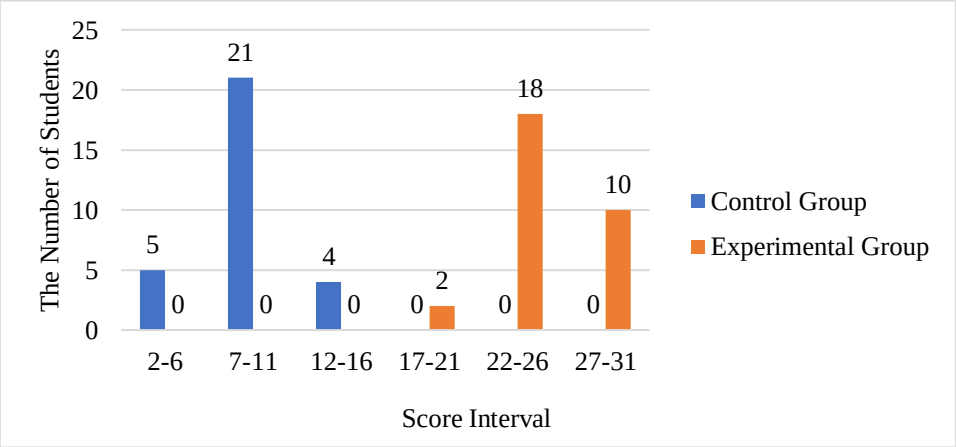

Figure 2 Diagram of the outcome of the students' critical thinking posttest

Figure 2 shows a significant difference in the posttest results between the two groups. The posttest scores of the control group are distributed between 2 and 16, while the experimental group obtains scores in the range of 17-31. Table 5 presents information on the percentage of posttest results regarding critical thinking indicators for the control and experimental groups, according to Tiruneh.

Table 5 Posttest results for each critical thinking indicator

Critical Thinking Indicator	Control Group (%)	Experimental Group (%)
Reasoning	41.39%	62.78%
Hypothesis Testing	17.83%	76.83%
Argument Analysis	27.78%	61.39%
Analysis of Possibilities and Uncertainties	22.50%	61.94%
Problem Solving and Decision Making	12.36%	56.32%

Significant differences between the groups in each aspect of critical thinking are evident in Table 5. The maximum increase is observed in the experimental group. The improvement in students' critical thinking skills can be analyzed using the value of the gain score between the pretest and posttest results in Table 6.

Table 6 Average N-gain results for control group and experimental group

Group	N-Gain	Classification
Control	0.13	Low
Experimental	0.64	Moderate

Table 6 informs about the difference in N-Gain values between the two groups. The control group is classified as low, while the experimental group falls into the moderate category for N-Gain. This indicates a lower improvement in critical thinking skills in the control group compared to the experimental group. After obtaining the N-Gain values for both groups, a normality test was conducted, with the results shown in Table 7.

Table 7 Normality test results

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Control Group	0.130	30	0.200*	0.948	30	0.148
Experimental Group	0.110	30	0.200*	0.970	30	0.526

Based on the statistical analysis, the N-Gain values for both groups meet the normality assumption according to the Shapiro-Wilk test in Table 7. The significance value for N-Gain in the control group is 0.148, while for the experimental group, it is 0.526. Therefore, it is believed that the data are normally spread. A homogeneity test will be carried out after that using analysis of variance (ANOVA) to evaluate the differences in variability between the groups. Information regarding the homogeneity test for N-Gain values can be found in Table 8.

Table 8 Details of N-gain homogeneity analyses

		Levene Statistic	df1	df2	Sig.
N-gain	Based on mean	0.416	1	58	0.521
	Based on Median	0.323	1	58	0.572
	Based on Median and with adjusted df	0.323	1	54.718	0.572
	Based on trimmed mean	0.371	1	58	0.545

The homogeneity test results indicate that the data variability between the two groups is homogeneous. Since the data is normally distributed and homogenous, a t-test can be conducted to analyze the hypothesis. The results of the hypothesis testing using the t-test are presented in Table 9.

Table 9 T-test hypothesis testing results

	t-test for Equality of Means			
	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence ... Lower
Equal variances assumed	0.000	-.48000	0.01984	-.51972
Equal variances not assumed	0.000	-.48000	0.01984	-.51972

The hypothesis analysis using the t-test resulted in a Sig. (2-tailed) value of 0.001.

The appraisal of students' critical thinking abilities included an exam consisting of ten structured essay questions based on the Tiruneh critical thinking indicators. The use of Tiruneh's critical thinking indicators as a reference in this study is based on the theory's relevance and applicability to exact sciences, particularly in physics. The low initial ability of students is evident from the average pretest scores of the control group, which is 4.53, and the experimental group, which is 4.13. The pretest scores for both groups range from 2 to 11 (see Figure 1). The highest score achieved by both groups is only 11 out of a maximum score of 39. If analyzed based on the critical thinking indicators (see Table 3), it is apparent that both groups have a sufficient percentage of reasoning ability but still low scores for other indicators. Factors contributing to students' low critical thinking skills in physics lessons include a lack of deep conceptual understanding, limited time for learning that leads students to focus only on memorizing formulas and definitions, and a lack of exploration and direct experimentation in physics learning. The lack of implementation of teaching models that encourage students to analyze, connect, and apply physics concepts in real-life situations can also contribute to students' low critical thinking skills in solving complex physics problems. This is consistent with previous studies that state an optimal learning process involves guiding students to develop skills that evaluate the extent to which reasoning and evidence support a statement (Sadidi & Pospiech, 2019).

The main obstacles in developing students' critical thinking are the need for more implementation of appropriate learning models in scientific inquiry or experiment and the lack of exposure to teaching methods that allow them to observe, engage, and discover expert strategies. In addition, a curriculum that focuses on mastering concepts and factual knowledge can hinder critical thinking skills. Constraints such as lack of training, limited resources, biased prejudices, and time constraints are also barriers to providing critical thinking instruction to students. Therefore, to overcome these barriers, it is necessary to pay more attention to the implementation of appropriate learning models, the introduction of teaching methods that actively engage students, and the creation of a learning environment that encourages critical thinking (Buabeng, 2018; Cascarosa et al., 2021; Ku et al., 2012; Rambe et al., 2020; Snyder & Snyder, 2008). Compared to the control group utilizing a traditional model, the experimental group using a guided inquiry methodology significantly boosted their critical thinking abilities. The average posttest score of the control group was 9.13, while the average posttest score of the experimental group was 25.43. These results indicate that students involved in guided inquiry learning experienced a significant improvement compared to students who underwent conventional learning methods (Maknun, 2020).

The guided inquiry model can enhance students' critical thinking skills in physics lessons because their active and independent participation is required in this learning approach. Previous research findings have shown that the guided inquiry model positively impacts students' critical thinking skills, with consistent improvements being observed, particularly in the area of static fluids (Nisa et al., 2018). This is supported by other findings that show “striking differences in students' critical thinking skills regarding the concept of work and labor at SMA N 3 Kota Bengkulu” (Medriati et al., 2021). Students can execute studies, grow hypotheses, create

research methods, and ask questions. These steps foster students' critical thinking in designing solutions for complex problems. Then, students are encouraged to develop their understanding of physics concepts through exploration and discussion. In this process, students consider the physics concepts they have learned and apply critical thinking to understand them comprehensively. The learning process stimulates students to develop their critical thinking skills through problem identification and developing a deep understanding of physics concepts.

Based on the research findings, it is evident that the practice of guided inquiry learning activities that promote students' thinking skills in the experimental group led to a significant improvement in students' critical thinking skills compared to the control group. As indicated in Table 4, there are significant differences in students' critical thinking skills in each indicator. Reasoning ability falls under the moderate category, but the experimental group (62.78%) has a higher reasoning ability than the control group (41.39%). This is because the experimental group was trained to connect physics concepts with real-life practices through independent experimentation activities during the learning process. However, both groups tend to answer questions with low difficulty levels. Significant differences are observed in the hypothesis testing ability, where the experimental group (76.83%) far surpasses the control group (17.83%). This is because the experimental group is accustomed to designing and conducting their research, which makes students more actively involved in discovery and data collection, whereas in conventional learning, students are not guided to conduct research in the classroom. For the argument analysis indicator, the percentage obtained by the experimental group is 61.39%, while the control group is 27.78%. For the ability to analyze possibilities and uncertainties, the experimental group obtained a percentage of 61.94% compared to the control group's 22.50%. The high percentage of ability in the experimental group in both indicators is due to the freedom given to the experimental group to provide ideas based on their prior knowledge in completing practical worksheets. This is particularly evident during practical learning, where students are allowed to identify problems and verify hypotheses.

The last indicator is problem-solving and decision-making. The difficulty level of questions in this indicator tends to be difficult, as students are required to solve problems using equations. As a result, the percentage obtained by the experimental group is 56.32%, and the control group is 12.36%. Although this indicator has a lower percentage than other indicators, the experimental group still demonstrates higher ability. This is because the experimental group is trained to solve real-life physics problems through experimentation and discover their knowledge based on individual analysis. Meanwhile, in the control group, students only used equations found in the physics textbook without understanding and delving into the origins of those equations.

Based on the presentation of the proportion of critical analysis features, it has been demonstrated that the experimental group possesses greater capacities than the control group. A combination of specific learning approaches and models is needed to encourage rational thinking skills in seeking problem solutions and reduce the learning process' reliance on activities as a source of information. Findings from (Darmaji et al., 2021) concluded that students often lack activity and initiative in applying critical thinking skills to overcome challenges due to difficulties in problem-solving.

The n-gain analysis resulted in the control group obtaining an n-gain score of 0.13, while the experimental group achieved 0.64. That means a significant disparity among the two groups was identified. The higher n-gain value in the experimental group indicates “the effectiveness of guided inquiry in improving students' critical thinking skills” (Sari Simatupang et al., 2021). The n-gain value of the control group suggests a low development of student's critical thinking skills, leading to the conclusion that the control group did not experience significant changes in critical thinking skills after the learning process. This is supported by previous research indicating that students taught using conventional models do not improve critical thinking abilities compared to students using other learning models (Ulfah & Hamid, 2017). The difference in n-gain values between the control and experimental groups demonstrates the positive impact of guided inquiry on enhancing students' critical thinking skills.

Before hypothesis testing, a preliminary test was conducted on the n-gain values of both groups. The normality test results indicated that the data from both groups were normally distributed, and the homogeneity test indicated that the data variances were homogeneous. Subsequently, a hypothesis test was conducted using the t-test. As shown in Table 8, the significance value (2-tailed) was 0.001, which is smaller than 0.05. The hypothesis test decides to accept H_1, indicating a difference in effectiveness between the guided inquiry model and the conventional model in enhancing students' critical thinking abilities. In other words, the hypothesis test results show that the guided inquiry model has a more significant influence on improving students' critical thinking abilities than the conventional model. This is because, in implementing the guided inquiry model, students are trained to develop critical thinking through experiments, observations, data analysis, problem-solving, cooperation, communication, discussions, idea-sharing, and stimulating each other's critical thinking. The significant difference occurs in the critical thinking indicator "hypothesis testing". Students who received the guided inquiry model treatment excelled in this indicator because they were trained to formulate hypotheses in the "formulating hypotheses" stage and test the hypotheses they have made in the "designing and conducting experiments" stage of learning. Students using the guided inquiry learning model also excelled in the "analysis of possibilities and uncertainties" indicator, as they were accustomed to the learning stage of "interpreting data analysis results and discussions," which stimulated the development of students' analytical abilities during the learning process. These findings are consistent with students' positive response to implementing the guided inquiry model in the context of light wave learning, which reached 90.67%. The results of this investigation offer strong support for implementing the guided inquiry pedagogical approach in the context of light wave learning. This model has demonstrated efficacy in enhancing students' understanding of the subject matter and developing their critical thinking skills. Hence, educators should integrate the guided inquiry methodology as a pedagogical instrument to promote knowledge acquisition in light-wave learning.

This research holds significant implications for educational practices in the field of education. The guided inquiry learning model has demonstrated its effectiveness in enhancing students' critical thinking skills in light waves. Educators can apply this model by providing appropriate guidance to students throughout the inquiry process,

encouraging them to think creatively, analyze data, and pose profound questions. Moreover, through collaborative work, teachers can establish a learning environment that facilitates student discussions and interactions, enriching their understanding. We can expand the technology to support learning by utilizing digital resources, simulations, or interactive tools. By considering the implications of this research, teachers can develop teaching strategies that prioritize the development of students' critical thinking skills, foster collaboration, and broaden their comprehension of light waves.

The Guided Inquiry learning model has a substantial long-term effect on students' critical thinking abilities. This approach encourages students to cultivate strong analytical skills, enabling them to analyze information, identify cause-and-effect relationships, and solve problems. Additionally, the model promotes honing critical and deep questioning skills among students. By asking relevant questions, students are continuously exercising their critical thinking abilities. Furthermore, the Guided Inquiry model nurtures students' self-directed learning, empowering them to search for, manage, and critically utilize information. In the long run, students trained with this model will also possess superior capabilities in solving complex problems through creative and critical approaches. Therefore, the Guided Inquiry learning model has been empirically proven effective in enhancing students' critical thinking skills.

The study's outcomes can be significantly influenced by external factors such as the classroom environment, teacher proficiency and execution, student attributes, and school culture and backing. The comprehensive classroom milieu, encompassing elements such as classroom administration and accessible resources, can significantly influence students' involvement and academic achievements. Moreover, the guided inquiry framework's efficacy is contingent upon educators' comprehension and proficiency in executing the approach proficiently, and divergences in teacher aptitude and pedagogical methodologies may impact the outcomes. In addition, variances in student characteristics, such as pre-existing knowledge, level of motivation, and preferred learning modalities, may influence their receptivity to the guided inquiry framework. In addition, the wider educational environment, backing from the administration, and congruence with academic objectives can either enable or impede the execution and efficacy of the guided inquiry approach. In addition to the aforementioned external factors, temporal restrictions may impose constraints on the research investigation. Factors such as the intervention duration, research timeline, and sampling duration influence the study outcomes. Researchers must recognize and account for these various factors and limitations, thereby ensuring thorough deliberation in research design, statistical analysis, and interpretation of results.

Several factors influencing the research findings on students' critical thinking abilities in the guided inquiry learning model must be comprehensively examined. One crucial factor to consider is limited instructional time. When the learning time is constrained, students' understanding and development of critical thinking skills can also be limited. Therefore, it is necessary to extend the implementation time of the guided inquiry model to achieve a more comprehensive understanding. In addition to instructional time, external factors such as students' socio-economic backgrounds also need to be considered. Socio-economic background can influence students' access to relevant

learning resources and experiences. Previous experiences are also crucial as students who have relevant prior knowledge in the context of light waves may have an advantage in developing critical thinking skills related to the topic.

Furthermore, the teaching methods employed by teachers need to be evaluated. The efficacy of the guided inquiry pedagogical approach relies on teachers' ability to design and deliver materials to facilitate the development of student's critical thinking skills. Therefore, a detailed analysis of students' characteristics and other factors that can affect their critical thinking abilities in the context of light waves learning is necessary.

Research involving monitoring and evaluating these factors is needed to comprehensively understand the guided inquiry learning model's impact. By considering adequate instructional time, students' socio-economic backgrounds, prior experiences, and teaching methods employed by teachers, a deeper understanding of the influence of the guided inquiry learning model on the development of student's critical thinking skills in the topic of light waves can be achieved.

CONCLUSION

The research results indicate a significant improvement in students' critical thinking skills when they receive guided inquiry learning. The group that did not use the guided inquiry model had low critical thinking skills. The group that received the treatment achieved maximum results on the posttest, especially in the hypothesis testing indicator. Therefore, the guided inquiry learning model can be an alternative for enhancing students' critical thinking skills. This study shows that guided inquiry learning models significantly enhance students' critical thinking abilities, supporting their practical use in developing these skills. It emphasizes integrating this approach into the curriculum, providing teacher training and support, and creating interactive and profound learning experiences. Additional research is necessary to gain a deeper understanding of the efficacy of guided inquiry models across diverse learning contexts. Moreover, future investigations on fostering students' critical thinking abilities should concentrate on establishing a conducive learning environment that nurtures critical thinking, harnessing technology to augment critical thinking skills, and comprehending the impact of cultural factors on students' critical learning.

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