JPPIPA 10(7) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

The Influence of Technology-Based Teaching Materials on Natural Sciences Learning: Material on the Properties of Light on Students' Critical Thinking Abilities

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Received: March 11, 2024
Revised: June 26, 2024
Accepted: July 25, 2024
Published: July 31, 2024

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DOI: 10.29303/jppipa.v10i7.8283

Abstract: The aim of this research is to find out how technology-based teaching materials influence students' critical thinking abilities when studying the properties of light in science. This research is using experimental method. The experimental method was chosen because it allows researchers to control all the variables involved and determine the cause-and-effect relationship between the use of technology-based teaching materials and increasing students' critical thinking abilities. The research results show the effectiveness of using technology-based teaching materials. The statistical table shows that the average post-test score for the experimental class was 81.25, while the control class obtained an average score of 66.88. This indicates that students who learn with technology-based teaching materials have better critical thinking skills compared to students who use conventional learning methods. Thus, there is a significant influence of the use of technology-based teaching materials on students' critical thinking abilities. Implementation of this strategy not only improves learning outcomes but also motivates students through learning methods that are more interesting and relevant to current technological developments.

Keywords: Critical thinking; Properties of light; Science; Teaching materials

Introduction

In recent decades, rapid advances in technology have brought major changes in various aspects of life, including education (Haleem et al., 2022). Technology in education offers many opportunities to improve the quality of learning. One form of implementing technology in education is the use of technology-based teaching materials (Ratnasari et al., 2019). Technology-based teaching materials are a collection of learning materials that are arranged systematically and can be accessed via technological devices such as computers, tablets or smartphones. This technology not only provides easy access to learning resources, but also offers students direct access to learning materials. (Trinaldi et al., 2022). Technology also influences the very important science and social sciences (IPAS) subjects in the classroom. The properties of light are one of the topics taught at IPAS. This topic covers important concepts that require students' in-depth understanding and critical thinking skills.

Therefore, using technology-based teaching materials can be an effective strategy for improving students' critical thinking abilities (Purwaningsih et al., 2021). Critical thinking ability is a very important skill in the modern era, where information is easy to find but must be analyzed carefully (Rusdin et al., 2024). Critical thinking skills involve the ability to understand, analyze, and evaluate information systematically. In learning, this ability allows students to be more critical

How to Cite:
Ulinuha, W., Nurwati, A., Chaeratunnisa, E., Zahra Agustina, S., & Leksono, S. M. (2024). The Influence of Technology-Based Teaching Materials on Natural Sciences Learning: Material on the Properties of Light on Students' Critical Thinking Abilities. *Jurnal Penelitian Pendidikan IPA*, *10*(7), 3880–3886. https://doi.org/10.29303/jppipa.v10i7.8283

and analytical about what they learn, so they can find better solutions to the problems they face (Darling-Hammond et al., 2020; Keiler, 2018). The ability to think is one of the life skills that must be learned through the educational process. Therefore, building critical thinking skills is very important for students at every level of education.

One effort to improve students' critical thinking skills is by developing technology-based teaching materials (Meirbekov et al., 2022; Perdanasari et al., 2021). Learning that utilizes technology can create an interesting, interactive learning atmosphere and facilitate students to be actively involved in the learning process (Almusaed et al., 2023). Apart from that, technology-based teaching materials can present material with more interesting visualizations, so that they can help students understand abstract concepts in science learning, such as the properties of light (Guindy et al., 2024; Nada et al., 2022). Many researchers have acknowledged that technology-based teaching materials are very important for science learning (Pozo et al., 2021; Walan, 2020). Studies show that the use of technology in learning can increase students' engagement, their understanding of concepts, and their critical thinking skills (Pandita et al., 2023). For example, students can see and interact with scientific phenomena that are difficult or cannot be observed directly in class through computer simulations (Krüger et al., 2022). In addition, learning videos and interactive applications can provide clearer and more interesting explanations compared to conventional methods (Abdulrahaman et al., 2020; Rosendahl et al., 2024; Tarchi et al., 2021). The aim of this research is to find out how technology-based teaching materials influence students' critical thinking abilities when studying the properties of light in science. The hope is that by using technology-based teaching materials, students can more easily understand complex concepts and develop the critical thinking skills necessary to succeed in the future.

Method

This research uses experimental methods to measure the influence of technology-based teaching materials on students' critical thinking abilities in learning science on the properties of light. Experimental research examines the effect of certain treatments on other variables under controlled conditions. In experiments, researchers change the stimulus or treatment and then see how it impacts the variable under study (Daniel et al., 2017).

The experimental method was chosen because it allows researchers to control all the variables involved and determine the cause-and-effect relationship between the use of technology-based teaching materials and increasing students' critical thinking abilities. Two groups of students were involved in this research, namely the experimental group and the control group. The experimental group will receive technology-based learning, while the control group will receive conventional learning. To find out whether the experimental group and control group show a significant increase in critical thinking skills, statistical techniques will be used to analyze pretest and posttest data. This analysis will be carried out using the t-test to compare the average pretest and posttest scores between the two groups.

Results and Discussion

Teacher strategies in implementing technology-based teaching materials in science and science learning material on the properties of light using a Problem Based Learning learning approach (Aidoo, 2023; Rahmawati et al., 2020; Roehrig et al., 2021). Problem Based Learning is a learning atmosphere that is directed at solving problems in everyday life (Hidayati et al., 2020). Meanwhile, according to Yew et al. (2016), and Wijayanto et al. (2023) states that the Problem Based Learning (PBL) learning model helps students develop problem-solving skills, increase understanding and knowledge, and be active in gaining knowledge. There are 5 work steps (syntax) of the Problem Based Learning (PBL) model in learning, which are as follows (Purba et al., 2020): Student orientation to the problem, organizing students to learn, guiding individual and group investigations, develop and present the results of the work, analyze and evaluate the problem solving process.

The learning content chosen by the teacher is experimental worksheets, reading texts, and learning videos (Ziaulhaq, 2022). Meanwhile, for evaluation, use interactive questions from Quizziz and for reflection, use Mentimeter. Apart from the experimental worksheets, all content is integrated into a microsite using s.id so that students can easily access it and the learning process using a technology platform can be realized (Yamtinah et al., 2023; Zen et al., 2022). Before presenting the technology platform, the teacher first prepares the content he wants to present. In this good practice, the content needed in the technology platform is (Lo et al., 2017; Ng et al., 2023). Reading material about the properties of light. Created with Canva with PDF format then saved on Google Drive, video learning the properties of light from YouTube, five LKPD that can be used collaboratively according to differentiated groups and products, evaluation questions in the form of Quizizz, reflection on the meter.

In the computer laboratory, students sit close to their group members. Students are directed to read the literature provided by the teacher regarding the properties of light. This activity accommodates students with a visual learning style and includes process and content differentiation. Students write important information in the reading text (Fitri et al., 2022). After reading the text, students watch the learning video which is also embedded on the mini site. This video listening activity aims to accommodate students with an audio learning style and includes process and content differentiation. The next syntax is to develop and present the results of the work. In this activity, students and their groups create works related to the properties of light. Determination of worksheets is adjusted to students' interests and talents which have previously been mapped according to the results of the initial assessment.

There are three types of products produced, namely; mind maps, experiment reports, and simple videos related to the properties of light (Spence, 2020). Students collaborate to work on student worksheets according to their groups using Canva Education which has been linked by the teacher on the mini site, making it easier for students to collaborate to create work that suits their interests. After all the works have been successfully created, the next step is to present the work in the form of a presentation explaining the results of the discussion. Each group takes turns presenting the results of their discussion and the other groups provide responses.

The learning step using the PBL model ends with the activity of analyzing and evaluating the problems solving process, the teacher and students evaluate the strengths and weaknesses of each group's work and provide clarification if there are wrong concepts so that misconceptions do not occur. The activity continues with carrying out an evaluation using the quizizz application, students independently complete and answer questions as data on how much students understand the material provided. The teacher embeds the quiz link on the mini site then students enter the quiz code and start working individually. This activity trains each student's sense of competition and motivation.

After the evaluation, the teacher provides follow-up in the form of searching for information related to the human sense of sight which will be studied at the next meeting. Meanwhile, reflection activities were carried out by asking students' understanding regarding the material on the properties of light and their feelings by writing them on a timer embedded in the microsite and the lesson ended with prayer (Patterson et al., 2023) . All content is inserted on the microsite, namely with the appropriate appearance and title. The learning process stage begins when the teacher explains the material first. After the teacher has finished explaining the material, students observe the video that the teacher has shown and invite students to ask questions if there is something they don't understand from the video.

When students can explain the process sequence of each heat transfer correctly, the student will get a prize and a score, this is given at the end of the learning process meeting. Meanwhile, in control classes, learning is centered on the teacher or teacher center, where the teacher acts as a material presenter from the beginning of the lesson to the middle, after which students are asked to work on questions individually. After giving different treatment to the experimental class and the control class, the two classes were then given a final test (post-test) to assess students' critical thinking abilities in science subjects. This post-test consists of 10 essay questions. The results show that the average score for the experimental class is 81.25, while the average score for the control class is 66.87. Examination of the post-test results shows that the data from both classes are normally distributed and have homogeneous variance. Next, a hypothesis test was carried out using the t test to determine the differences in science students' critical thinking abilities between the two classes.

Students' critical thinking tests in science subjects show differences in each critical thinking indicator between the experimental class and the control class (Ramadhan et al., 2024). In other words, students who learn using technology-based teaching materials show better improvements in critical thinking abilities compared to students who learn conventionally (Tan et al., 2023). This proves that the use of technology-based teaching materials can improve students' critical thinking abilities, as seen from the post-test results.

Table 1. Average Experimental Post-test and Control Post-test Scores

Group Statistics					
	Class	N	Mean	Std. Deviation	Std. Error Mean
Results of critical thinking abilities	Post-test experiment	16	81.25	8.06	2.01
	Post-test control	16	66.88	10.78	2.69

Before testing the hypothesis using the t test on students' critical thinking results, the prerequisite tests are first carried out including:

Normality Test

Before carrying out statistical tests, one of the data analyzes that must be fulfilled is that the distribution of the data for the two samples must be normally distributed. To find out whether the distribution is normally distributed or not, the Lilifors normality test is used with the condition that Lcount < Ltable at the significance level α = 0.05. The results of the pre-test and post-test data normality test calculations can be seen in Table 2.

Table 2. Data Normality Test Results

		Kolmogorov-smirnov			Shapiro-wilk		
	Class	Statistics	df	Sig.	Statistics	df	Sig.
Results of critical thinking skills	Pre-test experiment	0.186	16	0.143	0.892	16	0.060
	Post-test experiment	0.236	16	0.017	0.808	16	0.003
	Pre-test Control	0.167	16	0.200	0.931	16	0.253
	Post-test control	0.167	16	0.200	0.931	16	0.253

*This is a lower bound of the true significance
Liliefors significance correction

From table 2, it can be seen that the pre-test and post-test data from the two sample groups, namely the experimental group which was taught using technology-based teaching materials and the control group which used conventional learning were normally distributed at the significance level α = 0.05 where Lcount<Ltable.

Homogeneity Test

The homogeneity test is used to determine whether the sample comes from a population with the same variance, using the science students' critical thinking ability test scores. Data is considered homogeneous if Fcount < Ftable, which is determined by comparing the largest and smallest variances, as shown in the Table 3.

Table 3. Summary of Homogeneity Tests

Test of homogeneity of variances		Leven Statistics	df 1	df2	df3
Results of critical thinking skills	Based on mean	1.730	1	30	0.198
	Based on median	0.692	1	30	0.412
	Based on median and with adjusted df	0.692	1	26.13	0.413
	Based on trimmed mean	1.590	1	30	0.217

The significance value based on the mean is 0.198 > 0.05 indicating that the variance of the post-test data for the experimental and control classes is the same or homogeneous.

Hypothesis Testing

After ensuring that both samples are normally distributed and have homogeneous variances, the next step is to test the hypothesis using the t test. This test aims to determine whether the hypothesis proposed in the research can be accepted or must be rejected. By using the t test, researchers can evaluate the difference in post-test averages between the experimental class and the control class statistically. The t test applied to the post-test data was carried out as a one-tailed test, which means the test was focused on one particular direction of the mean difference. In this context, researchers want to know whether the post-test average of the experimental class, which uses technology-based teaching materials, is significantly higher than the post-test average of the control class which uses conventional learning methods. Thus, a comparison of these means helps to assess the effectiveness of different teaching methods.

Table 4. Independent Sample Test

		Levene's test of equality of variances								
		f	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confedence interval of difference	
									Lower	Upper
Results of critical thinking skills	Equal variances assumed	1.73	198	4.27	30	0.000	14.37	3.36	7.50	21.24
	Equal variances not assumed			4.27	27.77	0.000	14.37	3.36	7.47	21.27

The proposed research hypothesis is that the use of technology-based teaching materials can improve students' critical thinking abilities significantly better than conventional learning methods. The null hypothesis (H_0) states that there is no significant difference between the post-test averages of the two classes, while the alternative hypothesis (H_1) states that there is a significant difference. The results of the t test will determine whether there is sufficient evidence to reject the null hypothesis and accept the alternative hypothesis, which shows the success of technology-based teaching materials. H1: There is an influence of the use of technology-based teaching materials on critical thinking skills, H_0: There is no influence of the use of technology-based teaching materials on students' critical thinking skills in science subjects.

Based on the table above, a significance value (2 tailed) of 0.000 < 0.05 is obtained, so it can be concluded that there is a difference in the average results of students' critical thinking abilities between learning using technology-based teaching materials and conventional learning. For more details about the post-test average for the experimental class and control class, you can see the statistical Table 5.

Table 5. Average Experimental Post-Test and Control Post-Test Scores

Group Statistics					
	Class	N	Mean	Std. Deviation	Std. Error Mean
Results of critical thinking abilities	Post-test experiment	16	81.25	8.06	2.01
	Post-test control	16	66.88	10.78	2.69

Based on the statistical table above, the average post-test score for the experimental class is 81.25, while the average post-test score for the control class is 66.88. Thus, it can be concluded that the average post-test score for the experimental class is higher than the average post-test score for the control class, so the alternative hypothesis (H_1) is accepted.

Conclusion

The teacher's strategy in implementing technology-based teaching materials in science and science learning with material on the properties of light using the Problem Based Learning (PBL) approach involves various types of interactive learning content and supports active student involvement. The selected content includes experimental worksheets, reading texts, as well as learning videos designed to facilitate in-depth understanding of concepts. For evaluation, interactive questions from Quizziz are used which allow students to test their understanding in a fun and challenging format. The reflection process is carried out using Mentimeter, a platform that allows students to provide feedback anonymously and interactively. All of this learning content is combined into a microsite using s.id, so that students can access the material easily and the learning process becomes more structured and integrated through the use of technology. The research results show the effectiveness of using technology-based teaching materials. The statistical table shows that the average post-test score for the experimental class was 81.25, while the control class obtained an average score of 66.88. This indicates that students who learn with technology-based teaching materials have better critical thinking skills compared to students who use conventional learning methods. Thus, the alternative hypothesis (H_1) is accepted, which states that there is a significant influence of the use of technology-based teaching materials on students' critical thinking abilities. Implementation of this strategy not only improves learning outcomes but also motivates students through learning methods that are more interesting and relevant to current technological developments.

Acknowledgments

Thank you to the Sultan Ageng Tirtayasa University campus, especially the Basic Education Study Program, which provided the research team with the opportunity and academic environment to carry out this research. The author would like to thank Mr. Suroso Mukti Leksono as the supervisor for the motivation, guidance, direction and guidance provided during the process of completing this article.

Author Contributions

Conceptualization; W. U.; methodology.; A. N.; validation; E. C.; formal analysis; S. Z. A.; investigation.; S. M. L.; resources; W. U.; data curation: A. N.; writing—original draft preparation. E. C.; writing—review and editing: S. Z. A.; visualization: S. M. L. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflict of interest.

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