



The Effect of Problem-Solving-Based Physics Liveworksheets on Improving High School Students' Critical Thinking Skills

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Abstract: This research is motivated by teachers' tendency to use the lecture method, the suboptimal use of worksheets (LKS), and students' low critical thinking skills. The purpose of this study was to determine the effect of problem-solving-based physics liveworksheets on improving high school students' critical thinking skills and the improvement of critical thinking skills after implementing problem-solving-based physics liveworksheets in physics learning. The research method used was an experimental method with a pretest-posttest control group design. The instrument used was a critical thinking skills test in the form of essay questions based on critical thinking skills indicators according to Ennis. The results showed that problem-solving-based physics liveworksheets had a moderate effect on high school students' critical thinking skills. The increase in critical thinking skills after implementing problem-solving-based physics liveworksheets was 39.3 (maximum score of 100), which is included in the good category.

Keywords: critical thinking skills, liveworksheets, problem-solving, student's worksheet

Introduction

21st-century learning has entered a new era known as the Industrial Revolution 4.0. This era is marked by advances in information technology and science (Irvani & Anisah, 2024; Kalyani, 2024; Paling et al., 2024; Shadiev & Wang, 2022). Today's world is heavily influenced by many factors, including education. Education is a learning process carried out by teachers and students to develop potential, develop skills, and apply them in social, national, and state life (Irvani et al., 2024; Jahantab, 2021; Qolbi et al., 2024a; Shavkidinova et al., 2023). This situation suggests that holistic education must be provided as a comprehensive tool to emphasize that students not only acquire knowledge but also apply those skills in their daily lives. The American Association of Colleges for Teacher Education (AACTE) and the Partnership for 21st Century Skills explain that students must possess communication, collaboration, creativity, problem-solving, and critical thinking (Novia et al., 2024; Thornhill-Miller et al., 2023; Warliani et al., 2025). In solving complex problems, students' thinking patterns will be better trained with the 4C skills. This aligns with the principles of teacher learning and assessment, which are expected to help students become more innovative, creative, and critical thinkers in organizing and implementing learning (Meng, 2023; Saroyan, 2022). Therefore, teachers are expected not only to convey information but also to help students learn actively and meaningfully.

Assessment principles and learning principles cannot be separated. Students and teachers must master competencies, so they are expected to possess these abilities during the learning process

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(Agustianti et al., 2022; Ibda et al., 2023; Orakova et al., 2024; Purwanto et al., 2023). This learning principle emphasizes comprehensive learning that encompasses competency aspects, namely skills, knowledge, and attitudes. Attitudes and skills are prioritized over knowledge (Felesia & Irvani, 2025; Gabrian & Seitz, 2022; Pueyo-Garrigues et al., 2022). One form of soft skills expected in 21st-century learning is the 4Cs. Critical thinking skills are one of the fundamental skills students need to develop into independent and competitive individuals. Therefore, these skills are crucial to instill in students during learning activities.

In physics learning, critical thinking skills are important to develop, as they can help students improve their analytical skills in solving problems (Ady et al., 2024; Amarulloh & Irvani, 2025a). The choice of approach must be carefully considered to ensure the meaningfulness of learning in improving high school students' critical thinking skills (Kwangmuang et al., 2021; Raj et al., 2022; Williamson, 2023). Physics is a subject that requires critical thinking skills. Therefore, when studying physics, critical thinking skills are prioritized, such as observation, calculation skills, and manipulation (Jamil et al., 2024; Putra et al., 2023). If critical thinking skills are considered in the selection of strategies, making learning more meaningful and improving high school students' critical thinking skills, physics learning can run well.

Physics is a branch of science that discusses natural phenomena that occur in everyday life and how technology helps us solve problems (Heisenberg, 2025; Heryanto et al., 2023; Yu & He, 2022). This suggests that physics should be an engaging subject. However, according to the public's perspective, physics is a complex and difficult subject, threatening students, which leads to low learning outcomes (Shrestha et al., 2023; Zulkifli et al., 2024). Learning outcomes are relatively low, especially in problem-solving skills. Students typically only understand the terms given by the teacher and often memorize formulas without mastering the material from the lesson concepts (Hernandi et al., 2024; Kristianti et al., 2022; Muthmainnah, 2023). This results in students being unable to apply these concepts to solve problems.

Based on the results of a preliminary study conducted at a private high school in Garut Regency for the 2023/2024 academic year, information was obtained that in physics learning teachers tend to use lecture methods that make the teacher the center of learning, resulting in students being inactive and active when learning physics. However, most are inactive because they always consider physics a difficult and complicated subject and students are less interested in learning physics. Furthermore, the use of physics Student Worksheets in schools is also not optimal. Therefore, teachers often use school textbooks as references rather than Student Worksheets. As a result, teachers only use the blackboard to teach the material to students. Interviews also obtained information from teachers that in physics subjects, high school students' critical thinking skills are still lacking. This is because teachers have not practiced these skills in the learning process. This indicates that physics learning in schools still has many shortcomings.

One expected solution is for teachers to implement learning models and media that foster critical thinking skills and create student-centered learning. One way to help students improve their 4C skills, particularly critical thinking skills, is to utilize learning media such as student worksheets, which assist and facilitate teachers in delivering lesson material. Student worksheets are learning tools that help students understand lessons and develop their own knowledge (Chutami & Suhartini, 2021; Syahfitri & Sulaiman, 2023). This ensures effective learning and an active classroom.

This Student Worksheet is supported by Liveworksheets. Liveworksheets is an online platform. Liveworksheets can transform conventional worksheets into online worksheets. Students can complete them online and submit them to their teachers (Alfiansyah et al., 2022; Prabjandee, 2023; Widiantho et al., 2023). Liveworksheets offer advantages such as practicality, ease of access, and several attractive features. Therefore, combining problem-solving worksheet with Liveworksheets in physics learning can attract students. Furthermore, it helps both students and teachers during the learning process.

To create worksheets tailored to students' needs, the problem-solving learning approach is one approach that can be used to improve students' critical thinking skills (Dwijayanti et al., 2022; Ernawati & Sujatmika, 2021; Syahfitri & Sulaiman, 2023). The problem-solving model is a learning model that teachers can apply during the learning process (Diani et al., 2023; Munastiwi, 2021). Problem-solving is a method that teaches students to face existing problems, both individually and in groups, that can

be solved (Henukh et al., 2024; Nilimaa, 2023; Yapatang & Polyiem, 2022). This is because the problem-solving process is closely related to critical thinking skills. A problem will be resolved quickly if someone involves critical thinking skills that can be used to solve problems quickly.

Based on this background, research aimed at improving students' critical thinking skills in physics learning is still needed. Therefore, this study will examine "The Effect of Problem-Solving-Based Physics Liveworksheets on Improving High School Students' Critical Thinking Skills."

Method

The research method used is a quasi-experimental with a pretest-posttest control group design. A quasi-experiment is a study that assigns respondents non-randomly into control and experimental classes (Amarulloh & Irvani, 2025b; Creswell & Creswell, 2017). This method involves two groups, namely the experimental group that received treatment using problem-solving-based Physics Liveworksheets, while the control class was given treatment with a problem-solving learning model. The population in this study were students of class XI-MIPA at a private high school in Garut Regency in the 2024/2025 academic year. Fraenkel and Wallen (2012) explain that a population is a group larger than the group that is the source of data collection in a study. The sampling used in this study was a type of non-probability sampling with a saturated technique. The sample used in this study was 48 students, where XI MIPA 1 with a total of 24 students as the experimental class, and XI MIPA 2 as the control class with a total of 24 students.

The data sources used are primary data sources obtained from grade XI students at a private high school in Garut Regency, and secondary data sources obtained from test questions, observation sheets, worksheets, and documentation. Data collection techniques used include test instruments regarding critical thinking skills, observations of learning implementation, and documentation. The test instrument used consisted of five essay questions covering five dimensions of critical thinking skills, as shown in Table 1 below.

Table 1. Indicators of Pretest and Posttest Items for Critical Thinking Skills

Dimension of CTS	Indicator	Sub-Indicator	Item
Elementary clarification	Analyzing arguments	Identifying statements that are not questions	1
Basic support	Considering whether a source is reliable or not	Ability to provide reasons	2
Inference	Making inductions and considering inductive results	Presenting conclusions and hypotheses	3
Advanced clarification	Identifying assumptions	Constructing arguments	4
Strategies and tactics	Deciding on an action	Expressing problems	5

(R. Ennis, 2011; R. H. Ennis, 1985, 2015)

Before the instrument was used, the researcher tested the test instrument on students outside the research sample and also the researcher conducted data analysis of the test instrument before the study including validity tests, reliability, discrimination power, and measurement of the level of difficulty. In this research, the data analysis method used is a quantitative analysis method. Data analysis includes grouping data, compiling data, and testing hypotheses. In this study, the data analysis technique used is the IBM SPSS Version 27 application.

Result and Discussion

Analysis of Learning Implementation Results

In this study, the implementation of learning, as described, was measured using a learning observation sheet. Observation is an empirical scientific activity based on field facts and texts, through sensory experience that is free from fraud (Ikbal et al., 2022; Perović, 2021; Ulfa et al., 2024). Based on this statement, it can be concluded that observations must be conducted based on actual reality. These results were then processed, as shown in Figure 1.

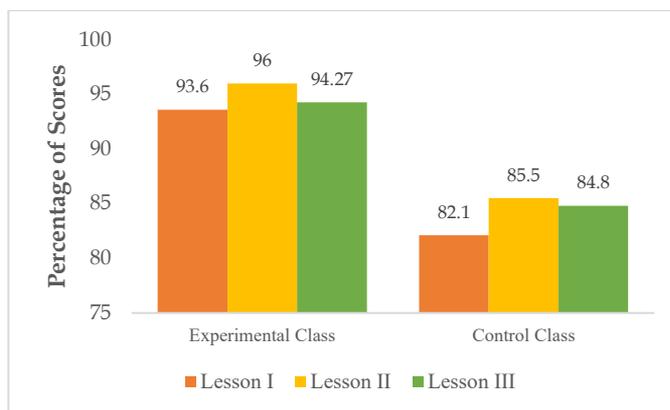


Figure 1. Implementation of Teaching and Learning Activities in Experimental Classes and Control Classes

Experimental Class Observation Results

In the first meeting, observations indicated that 93.6% of the meetings were successful. This phenomenon can be explained by the students' adaptation process to the use of problem-solving-based liveworksheets, which were new to them. Previous research revealed that liveworksheets are very engaging and easy to use.

In the second meeting, students were not fully accustomed to the procedures for using problem-solving-based physics liveworksheets, and some of them were distracted by their gadgets, thus affecting the observation results at the meeting. The observation results at the first meeting were categorized as "good", there was a progressive increase in the second meeting, namely 96% with the "good" category. However, from the second meeting to the third meeting there was a decline although in the third meeting there was a decline, but not too significant. The results of previous research show that a decline in the learning process is a common occurrence, but in the use of learning media it is important to maintain interpretation in learning, one of which is the liveworksheets learning media, so that the learning process is classified as very good (Avalos Valverde, 2022).

At the third meeting, the observation results reached 94.27%, categorized as "good." At this point, students had gained further experience using Liveworksheets. The skills and abilities gained from this experience enabled students to adapt to new learning media, increasing their level of attention and engagement in learning. Liveworksheets have been widely implemented in learning media development and have provided positive benefits (Widiantho et al., 2023).

Control Class Observation Results

Observations in the control group revealed that in the first session, learning achievement reached 82.17%, categorized as "good." There was a progressive increase in the second session, reaching 85.57%, categorized as good. However, in the third session, there was a slight decrease to 84.80%, categorized as "good." This decrease could be due to varying levels of student focus and engagement at each meeting. Student engagement is a psychological process involving interest, investment in learning activities, and attention (Kusumawati et al., 2024; Lane et al., 2022).

Analysis of LKS Results

The technique used was to calculate the total matched scores, then determine the percentage for each indicator, and then process the results. A summary of the percentage results for the experimental class is presented in the form of a bar chart, as shown in Figure 2.

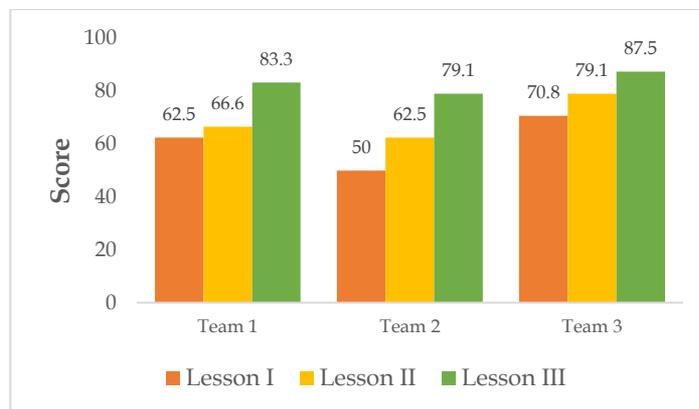


Figure 2. Results of Filling in the Experimental Class LKS

Based on Figure 2. Almost all answers from the experimental class student worksheets improved at each meeting, including the results of filling in groups 1, 2, and 3. When viewed based on the indicators, the results of filling in the LKS prove that students' critical thinking skills improved at the first, second, and third meetings. Problem-solving-based LKS have a more active tendency to significantly improve students' critical thinking skills (Nursabila et al., 2025; Qolbi et al., 2024b).

The results of filling in problem-solving-based physics liveworksheets for the experimental class, which were carried out in groups, showed very satisfactory results at each meeting. The results of filling in problem-solving-based physics liveworksheets for each group showed an increase. This shows that students' critical thinking skills in problem-solving improved after being given problem-solving-based physics liveworksheets. To get worksheets that suit students' needs, the worksheets are combined with a learning approach that suits students' needs (Nurhayati, 2022; Pratama et al., 2024). One learning approach that can be used to improve students' critical thinking skills is the problem-solving model.

The following is a summary of the percentage of control class filling results presented in the form of a bar chart shown in Figure 3.



Figure 3. Results of Completing the Control Class Student Worksheet

Based on Figure 3, it can be concluded that several groups experienced improvement at each meeting, including the results of groups 1, 2, and 3. Two groups, groups 1 and 2, had similar results at the second meeting. Based on this, the experimental class treated with problem-solving-based physics liveworksheets had higher answer scores than the control class. This indicates that students were more interested in using problem-solving-based physics liveworksheets than the control class, which only used the problem-solving stage. This is in line with previous research which stated that students are more involved when teachers use learning media (Maolani et al., 2025; Pulungan, 2021; Rahim et al., 2022).

Critical Thinking Skills Test

Descriptive Analysis of Critical Thinking Skills Test

Shows the differences in learning between the experimental class that used problem-solving-based liveworksheets and the control class that used the problem-solving model. Data collection for each class through pretests and posttests, as well as statistical results of critical thinking skills in the experimental and control classes, can be seen in Table 2.

Table 2. Descriptive Analysis Results of Critical Thinking Skills Test

Data	Mean	SD	Highest	Lowest
Pretest Experiment	42,5	6,1	54	34
Pretest Control	40,5	5,6	54	34
Posttest Experiment	81,8	8,5	100	67
Posttest Control	72,3	7,6	94	60
N-Gain Experiment	0,66	15,16	1,00	0,38
N-Gain Control	0,53	13,57	0,90	0,25

Based on the data in Table 2, it is used as a review to classify the results of critical thinking skills in both the experimental and control classes. Then, it is presented in specific categories. The descriptive analysis in Table 2 shows that the average pretest score in the experimental group was 42.5, categorized as sufficient, and increased by 39.3, resulting in a posttest score of 81.8, categorized as very good. Meanwhile, the pretest results for critical thinking skills in the control group were 40.5, categorized as poor, and increased by 31.8, resulting in a posttest score of 72.3, categorized as good.

Both classes, the treatment class and the comparison class, experienced improvements in critical thinking skills. However, the experimental class saw a more significant increase of 39.3 compared to the control class, which increased by 31.6. This was due to differences in the use of learning media between the experimental and control classes. Students' worksheet using the LiveWorksheets application can facilitate student understanding of the material during learning (Ghaisani & Setyasto, 2023; Maharani & Marhamah, 2024).

Liveworksheet is a web-based platform that provides materials in the form of worksheets that students can access and complete online. Liveworksheet transforms the paradigm of using traditional worksheets that must be printed and completed offline into worksheets that students can complete online without printing, offering an attractive display and diverse activities. These worksheets provide opportunities for students to learn independently (Mustika et al., 2024; Nenggala et al., 2024). Based on this, Liveworksheets help and facilitate the learning process for teachers and students.

Meanwhile, the average n-gain value of the experimental class was 0.66 in the moderate category, and the average n-gain value of the control class was 0.53 in the moderate category. Therefore, it can be concluded that the experimental class using problem-solving-based physics liveworksheets experienced an increase in the moderate category.

Results of Data Normality and Homogeneity Tests

Because the number of research objects was less than 50, the researcher used the Shapiro-Wilk test to test the normality of the data. To draw conclusions, we can look at the significance value: If the significance value is > 0.05 , then the data is distributed "normally," and if the significance value is < 0.05 , then the data is distributed "not normally." The following are the results of the normality test that has been conducted, presented in Table 3.

Table 3. Data Normality Test Results

Data	Statistics	Sig.	Conclusion
Pretest Experiment	.877	.007	Not normal
Pretest Control	.855	.003	Not normal
Posttest Experiment	.916	.047	Not normal
Posttest Control	.895	.017	Not normal
N-Gain Experiment	.974	.758	Normal
N-Gain Control	.965	.551	Normal

The homogeneity test aims to determine whether there is equality of variation between the control and experimental classes (homogeneous) or not (heterogeneous). The following results are presented in Table 4.

Table 4. Data Homogeneity Test Results

Data	Levene Stat.	Sig.	Conclusion
Pretest Experimental & Control Group	.988	.325	Homogen
Posttest Experimental & Control Group	1.127	.294	Homogen
N-Gain Experimental & Control Group	.820	.370	Homogen

Analysis of Critical Thinking Skills Pretest Data

The pretest results of the experimental class and control class can be seen in Figure 4.

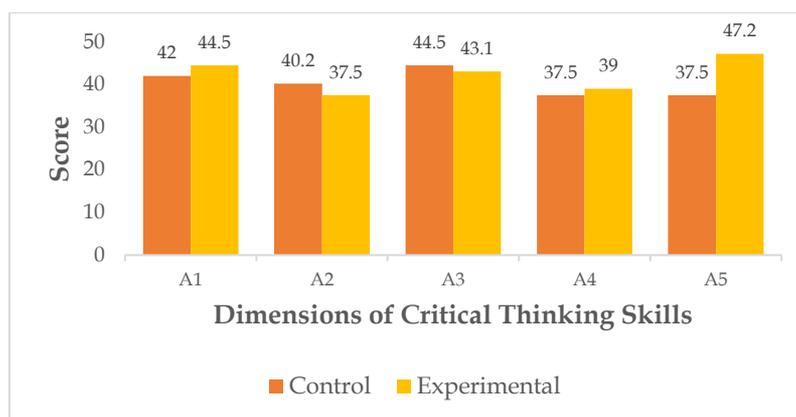


Figure 4. Pretest Results of Experimental Class and Control Class

Based on Figure 4, the results of the pretest scores of critical thinking skills of the experimental class and the control class of students with a maximum score of 100. The lowest pretest score of the experimental class was 34, and the highest pretest score was 54. Similar to the experimental class, the control class had the lowest score of 34, and the highest score of 54. The pretest score of the experiment had an average score of 42.5 in the sufficient category, while the average score of the control class was 40.5 in the sufficient category.

Based on the descriptive statistical data in Table 1, there is a difference in the pretest average for critical thinking skills. However, to see its significance, it is tested statistically. Because the distribution of both data is not normally distributed, the statistical test approach used is a non-parametric approach, namely using the Mann-Whitney difference test. The conclusion of the Mann-Whitney test is based on the Asymp.Sig. value. If the Asymp.Sig. value is <0.05 , H_0 is rejected. If the Asymp.Sig. value is >0.05 , H_0 is accepted. The following are the results of the Mann-Whitney test:

Table 5. Mann Whitney Test Results of Critical Thinking Skills

Statistical Test	
Mann Whitney U	235.500
Wilcoxon W	535.500
Z	-1.140
Asymp. Sig. (2-tailed)	.254

Based on Table 5, because the Asymp.Sig. value > 0.05 . It is concluded that H_0 is accepted, that the average pretest of critical thinking skills of the control class and the experimental class is not significantly different, which means that the initial abilities of the control class and the experimental class are the same. There is no significant difference in the average increase in Critical Thinking skills of the control class and the experimental class.

Analysis of Critical Thinking Skills Test Data (Posttest)

The posttest results of the control class and experimental class are presented in Figure 5.

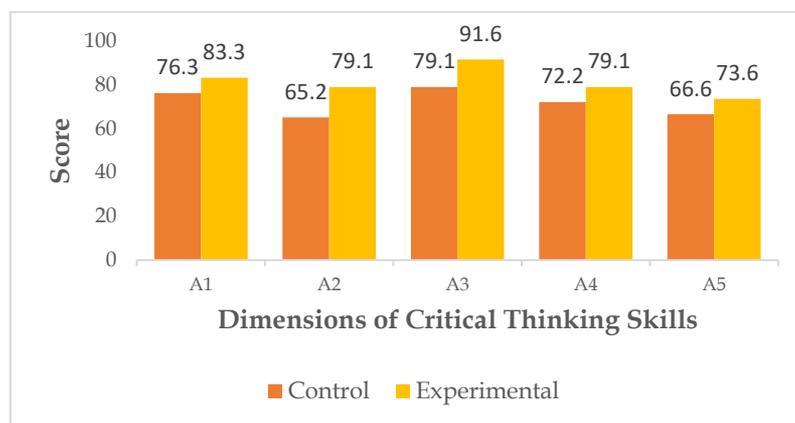


Figure 5. Posttest Results of Experimental Class and Control Class

Based on Figure 4.5, the posttest results for the critical thinking skills of the experimental and control classes show a maximum score of 100. The lowest posttest score for the experimental class was 67, and the highest posttest score was 100. Meanwhile, the control class had the lowest score of 60 and the highest score of 94. The experimental posttest had an average score of 81.8, categorized as very good, while the control class had an average score of 72.3, categorized as good.

Based on the results above, there was an increase in each dimension of critical thinking skills and its indicators from the pretest to the posttest in the experimental class. Therefore, it can be concluded that problem-solving-based physics liveworksheets can significantly improve high school students' critical thinking skills. Liveworksheets are a valuable tool to assist teachers in improving students' critical thinking skills (Ghaisani & Setyasto, 2023).

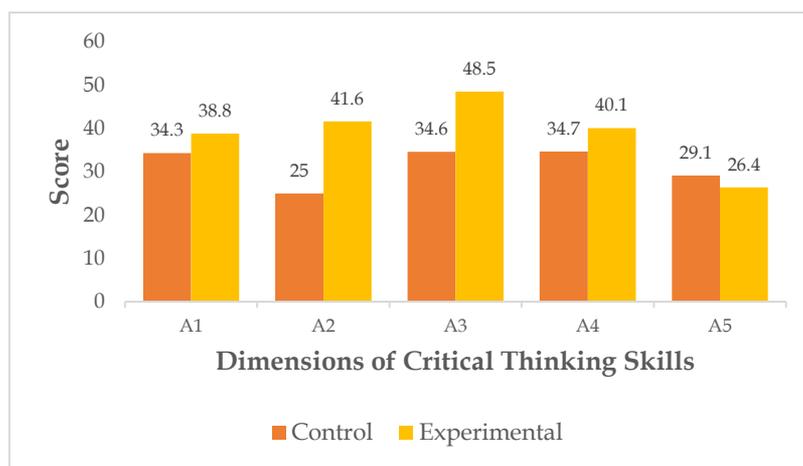


Figure 6. Improving Critical Thinking Skills in Experimental and Control Classes for Each Indicator

Figure 6 indicates that the increase in scores obtained in each indicator in the experimental class showed a higher average score compared to the control class. However, in the critical thinking skill dimension of developing strategies and tactics, the control class's score was higher. In the critical thinking skill dimension of providing simple explanations with the indicator analyzing arguments, there was a significant increase. The difference in treatment given to the two classes also influenced the results obtained. The treatment applied in the experimental class was more effective in improving critical thinking skills than the treatment in the control class.

Statistical Posttest Difference Test of Critical Thinking Skills

The conclusion of the Mann-Whitney test is based on the Asymp.Sig. value. If the Asymp.Sig. value is <0.05 , H_0 is rejected. If the Asymp.Sig. value is >0.05 , H_0 is accepted. The following are the results of the Mann-Whitney test:

Table 6. Mann Whitney Posttest Results of Critical Thinking Skills

Statistical Test	
Mann Whitney U	120.500
Wilcoxon W	420.500
Z	-3.571
Asymp. Sig. (2-tailed)	.000

Based on Table 6, since the Asymp.Sig. value is <0.05 , it is concluded that H_0 is rejected, that the average posttest of critical thinking skills of the experimental class and the control class. This indicates a significant difference between the experimental class and the control class, which means there is a significant difference in the average increase.

Improving Critical Thinking Skills

The normalized gain value, or N-Gain, determines the improvement in student abilities. The N-Gain calculation is used to determine whether there is a difference in student learning outcomes in the experimental and control classes (Normalized Gain).

$$N - Gain = \frac{\text{posttest value} - \text{pretest value}}{\text{ideal values} - \text{pretest values}} \quad (1)$$

Then the N-gain index criteria are interpreted in the following table 7.

Table 7. N-Gain Index Category

N-Gain Value	Category
$g > 0,7$	High
$0,3 \leq g < 0,7$	Medium
$g < 0,3$	Low

(Melzer in Syahfitri, 2008)

In this stage, researchers analyzed the effect of problem-solving-based physics liveworksheets on improving high school students' critical thinking skills. This normalized gain is a test to provide a general overview of the increase in understanding of students in the experimental and control classes between before and after the treatment. The pretest and posttest results collected from both tests were then calculated for normalized gain. From the results of the normalized gain calculation, the results were obtained in the form of a Gain Score, so that it can easily determine the category obtained by each student. The following are the results of the n-gain value of critical thinking skills in the experimental class presented in table 8.

Table 8. Improvement after being given Problem Solving-based Liveworksheets

Group	Pretest Average	Posttest Average	N-Gain	Category
Experiment	42,54	81,8	0,66	Medium
Control	40,58	72,33	0,53	Medium

From table 8 above, it is known that the experimental class, namely the class that received treatment using problem-solving-based physics Liveworksheets, had an average N-Gain of 0.66 and was included in the moderate category, that the experimental class experienced an increase. Meanwhile, in the control class, it was found that with the problem-solving learning model, the average N-Gain was 0.53 with a moderate category. So, it can be concluded that the improvement of the experimental class was higher by using problem-solving-based physics Liveworksheets.

The effect size in this study was determined to see the influence of problem-solving-based physics liveworksheets. The size of the treatment effect in this study used the following average effect Cohen's d formula.

To interpret the d value, the Cohen's effect size criteria are used regarding the smallness of the effect size presented in Table 9.

Tabel 9. Effect Size Criteria

Criteria	Effect Size (d)
High	$ES > 0,8$
Medium	$0,2 < ES < 0,8$
Low	$ES < 0,2$

(Larasati, 2019)

The Effect Size analysis concluded that the calculation obtained was 1.178, which is included in the high category. It can be concluded that the effect of using problem-solving-based physics liveworksheets is in the high category. This indicates that the use of problem-solving-based physics liveworksheets has a significant impact on improving critical thinking skills.

Conclusion

The findings of this study indicate that in all dimensions and indicators of critical thinking skills, there was a significant improvement from the pretest to the posttest in the experimental class. The average posttest score of the experimental class reached 81.8, categorized as very good, while the control class obtained an average score of 72.3, categorized as good. These results demonstrate that the implementation of problem-solving-based physics Liveworksheets effectively enhances students' critical thinking skills in physics learning.

The improvement in students' learning outcomes was also supported by the N-Gain analysis, where the experimental class achieved an average value of 0.66 and the control class 0.53, both categorized as moderate. However, the higher N-Gain score of the experimental class shows that learning assisted by problem-solving-based physics Liveworksheets provides better improvement compared to conventional problem-solving learning. This indicates that the interactive features and problem-oriented structure of Liveworksheets contribute positively to student engagement and comprehension.

The effect size calculation yielded a value of 1.178, which is categorized as high. This means that the use of problem-solving-based physics Liveworksheets has a strong and meaningful effect on improving high school students' critical thinking skills. Therefore, it can be concluded that integrating digital worksheets within a problem-solving framework serves as an effective learning innovation to strengthen analytical and reasoning skills in physics education.

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