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PAPER

Influence of E-Scaffolding in Problem-Based Learning on Students' HOTS in Standing Wave

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ABSTRACT

In the 21st century, students' higher-order thinking skills (HOTS) are crucial, as they focus on students' capacity to identify problems and think analytically to solve them. Therefore, students were required to have higher-order thinking skills. The purpose of this research was to assess the impact of e-scaffolding in problem-based learning (PBL) on students' HOTS in the context of standing waves. This study utilized a quasi-experimental approach employing a non-equivalent control group design. The experimental group, which was taught with e-scaffolding in PBL, consisted of 31 students, while the control group, taught only with the PBL model, had 29 students. A total of eight multiple-choice questions that had been proven valid with a reliability of 0.752 were used to assess students' HOTS. The data were then analyzed using ANCOVA, with pretest scores as covariates. The results showed statistically significant differences among students with increased higher-order thinking skills in favor of using e-scaffolding in PBL: 0.000 ($\alpha < 0.005$). The eta squared statistic (0.785) indicates a large effect size. By employing PBL with electronic scaffolding, students actively participate in collaborative activities focused on successful problem-solving, resulting in a high success rate. Consequently, it is recommended to consider e-scaffolding as a primary method for developing higher-order thinking skills.

KEYWORDS

e-scaffolding, higher-order thinking skills (HOTS), problem-based learning (PBL), standing wave

1 INTRODUCTION

Education in today's modern era focuses on cultivating essential skills relevant to the 21st century. It requires critical thinking, communication skills, collaboration skills, and problem-solving skills [1]. These skills are developed by promoting and enhancing higher-order thinking skills (HOTS) in students. HOTS refers to thinking processes that stem from recognizing facts and details of information and knowledge as the foundation of comprehension, enabling the application of complex

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thinking processes [2]. HOTS is a skill that allows someone to acquire new information by leveraging existing knowledge, then effectively organize and expand upon this information to explore alternative solutions in decision-making, foster innovation, and generate novel ideas to address challenges [3]. These skills are not new concepts in education but have been increasingly emphasized recently. Anderson and Krathwohl [4] state that HOTS includes analysis (C4), evaluation (C5), and creativity (C6).

Efforts to enhance students' HOTS in physics learning have yet to yield optimal results. Indonesian students have not yet been able to secure top positions. The results of the programmer for international student assessment (PISA) and the trends in international mathematics and science study (TIMSS) revealed that most Indonesian students are still at the lower order thinking skills (LOTS) level [5]. Research findings indicate that students' proficiency in solving HOTS-based physics problems still needs improvement. This suggests room for improvement in students' HOTS [6]. Other findings revealed that students' skills in solving HOTS-based problems are still deficient, especially in C6 questions, with an average student score of 13.88, while C4 and C5 questions are in the sufficient category, with the average student score in solving C4 being 40.0 and C5 being 32.90 [7]. Research conducted by [8] revealed that 42% of students' thinking skills in solving temperature and heat problems were categorized as high or low, while the remaining 16% were categorized as sufficient. Physics is one of the subjects that emphasizes HOTS. Standing waves are one of the physics topics that students often struggle to understand. Most students are prone to focusing on solving problems without realizing the underlying concepts. Instead of developing a conceptual understanding of waves in physics to solve problems, students tend to focus on memorizing formulas [9]. As many as 34.19% of students find standing wave topics difficult [10]. Therefore, students must possess HOTS to be actively engaged in constructing and discovering knowledge to solve problems.

Based on the description above, a solution is needed to enhance students' HOTS on the topic of standing waves. HOTS can be developed through active learning models that engage students in the learning process. One of the active learning models is problem-based learning (PBL). This model focuses on real-life situations, complex problems, independent learning, and collaborative learning in small groups [11], [12]. The PBL model helps students enhance their critical thinking skills by guiding them to search for data to find solutions to problems, leading to logical and genuine resolutions for a specific challenge [13]. One of the crucial aspects is that teachers cannot simply transmit content to their students. On the contrary, students should proactively broaden their understanding through the development of knowledge derived from their own experiences and ideas [14]. PBL involves students actively exploring knowledge, seeking new information, integrating new knowledge with what they already know, organizing known information, explaining it to peers, and involving technology in the learning process [15]. Students engage in a learning process that demands critical thinking, collaboration with team members, information gathering, and exploration of different possibilities to solve problems. Several studies that have been conducted show that PBL can improve students' conceptual understanding [9], critical thinking skills [16], creative thinking skills [17], and science process skills [18]. PBL significantly impacts students' learning outcomes compared to conventional learning models [19].

Problem-based learning is highly successful when combined with computer-based scaffolding [20]. Given the rapid advancement of technology, scaffolding, specifically e-scaffolding, has been developed online. When technological tools are available and efficiently integrated into learning activities, the result is often active student participation and the provision of opportunities to develop students' HOTS [21]. E-scaffolding assists students in achieving learning objectives and performance by providing support to solve complex problems beyond their current skills [22]. Scaffolding assists students in articulating problems, structuring the problem, connecting concepts, and finding reasons to answer the problem [23]. The study by [24] found that e-scaffolding positively impacts students' academic ability by enhancing their conceptual understanding of the subject matter and the selection of strategies implemented when solving problems. E-scaffolding has also been proven to prevent misconceptions [25] and improve science process skills [26], problem-solving skills [27], and student learning outcomes [28]. Implementing e-scaffolding allows students to engage and acquire skills in independently solving complex problems [29].

Numerous studies confirm the effectiveness of scaffolding in learning. However, there is a need for more information on the effectiveness of electronic scaffolding in enhancing HOTS resulting from the combination of PBL with procedural electronic scaffolding. Therefore, researchers are interested in implementing e-scaffolding in PBL that can be accessed anytime and anywhere to assist students in solving physics problems. This study aims to: 1) determine the impact of e-scaffolding in PBL on students' HOTS regarding the Standing Wave topic, and 2) assess the variation in HOTS levels between students instructed with PBL assisted by e-scaffolding and those taught with PBL alone on the Standing Wave topic.

2 LITERATURE REVIEW

Higher-order thinking skills are a set of cognitive skills. HOTS is defined as a broader use of the mind to discover new challenges, including critical, logical, reflective, metacognitive, and creative thinking [30]. HOTS challenges learners to interact effectively and apply knowledge to achieve problem objectives by, associating, manipulating, and modifying existing insights and skills. This contributes to enhanced argumentation and decision-making [3]. Creating questions that require higher-order thinking skills only occasionally involves crafting challenging questions [31]. Difficulty alone does not guarantee the presence of HOTS. For instance, asking about an unfamiliar concept can sometimes turn it into a HOTS question. A literature study by [32] pointed out that students can make comparisons, provide validation, or conduct investigations based on their initial knowledge by addressing question or accomplishing open-ended task. This ability helps to develop their higher-order thinking skills. A fundamental comprehension of the concept of waves is crucial for studying other subjects, such as standing waves. Many students still need help solving problems related to wavelength, wave propagation speed, and wave properties [9], [10]. These challenges indicate that there is still room for further research to enhance students' HOTS on standing waves to achieve even greater optimization. For years, PBL has been highlighted as a practical approach that suits the dynamic needs of 21st-century education.

Problem-based learning is typically organized in small study groups where students collaborate on real problems to enhance motivation and stimulate discussion [33]. Barrows [34] defines PBL as a learning model in which problems serve as the essential teaching material and function as the initial step in the learning process. Using real contexts to explore is essential, as it means that learning activities are based on contextual issues. PBL requires active student engagement as they investigate and seek solutions to the presented problems [35]. PBL is not intended to help educators transmit information or materials to students. However, this model guides students' thinking, problem-solving, and intellectual skills [36]. In PBL, learners can acquire knowledge and engage in discussions with others [37]. They then enhance and restructure their cognition based on their initial and new knowledge and experiences. During the information collection phase, if inconsistencies arise, students can engage in discussions to address these obstacles and explore solutions to reach an agreement or find common ground. Students can enhance HOTS through negotiation processes and be involved in the development of shared knowledge [34]. In the educational setting, instructors function as facilitators, guiding students to engage in learning through problem-solving activities. This includes tasks such as recognizing or scrutinizing problems and pertinent information, formulating hypotheses, engaging in self-directed learning to acquire new knowledge, applying acquired knowledge, exploring potential solutions, and assessing the effectiveness of those solutions [38], [39]. A study by [40] exploring the effect of PBL reported that the approach reinforced students' HOTS. Therefore, it is believed that students' HOTS will improve.

E-scaffolding is a form of web-based online scaffolding. E-scaffolding, as web-based assistance, can help students achieve learning and performance goals by solving complex problems that are beyond their current skills [22], [41]. When compared to traditional scaffolding, the utilization of e-scaffolding is more flexible and effective. This notion is because e-scaffolding can help students improve their performance independently, making it easier to detect the difficulties they experience [42]. Procedural scaffolding involves a sequence of steps that students must navigate and adhere to [43]. It involves a series of actions that will be taken to find a solution through investigation. A study by [44] developed a web-based model incorporating a comprehensive range of scaffolding types, such as conceptual, procedural, strategic, and metacognitive. The e-scaffolding system encouraged students to construct knowledge, enhance competence, and facilitate collaborative learning. [45] implemented blended-physics learning with the assistance of procedural e-scaffolding. The results showed that physics learning with procedural e-scaffolding improved students' scientific explanations, specifically claims, evidence, and reasoning. In reference [46], a scientific explanation-based e-scaffolding website was developed by integrating PhET simulations as a virtual practicum. The results showed that it significantly improved students' ability to produce scientific explanations.

Utilizing e-scaffolding procedures in the design of physics learning through PBL presents opportunities and challenges that can inspire educators and researchers to create more successful and streamlined educational innovations. Empirical research extensively supports the advantages of PBL as an instructional approach aligned with the requirements of the 21st century. These advantages include the development of HOTS. While numerous studies affirm the efficacy of PBL in enhancing HOTS, there is limited application of physics learning design incorporating electronic scaffolding procedures within the PBL framework in educational research. The combination of the foundational elements mentioned suggests the potential effectiveness of PBL with procedural e-scaffolding in addressing the challenges of HOTS in physics education, particularly in the context of standing waves. However, the combination of these basic foundations can only be proven through appropriate physics education research. Hence, this study seeks to address the existing knowledge gap identified in prior research and contribute to the expanding field of study by investigating how the incorporation of e-scaffolding procedures in PBL supports and enhances the HOTS of students.

The key research question of this study was:

1. Is there a difference in higher-order thinking skills related to standing wave material between students who receive procedural e-scaffolding in PBL and students who only engage in problem-based learning?

Consequently, the hypothesis is presented as follows:

H0: There is no difference in the HOTS of students who learn using the PBL with procedural e-scaffolding compared to those who only learn using the PBL model.
H1: There is a difference in the higher-order thinking skills of students who learn using the PBL model with procedural e-scaffolding and students who only learn using the PBL model.

3 METHODOLOGY

3.1 Research methods

This study employed a quantitative research approach, utilizing the quasi-experimental method. The selected design was a non-equivalent control group design [47]. This study was conducted in two classes where students received two treatments: the PBL model with e-scaffolding procedures in the experimental class and the PBL model in the control class. Both groups underwent an initial pretest, followed by distinct learning interventions, and were later assessed through a posttest. This study specifically focuses on examining the impact of e-scaffolding procedures in PBL on enhancing HOTS related to the topic of standing waves.

3.2 Sampling

The population of this study comprised all secondary school students in Malang, Indonesia. This study included two classes as its samples: the experimental group and the control group, with a total of 60 students—31 in the experimental group and 29 in the control group. The selection of samples involved the utilization of a cluster random sampling technique, ensuring the randomization of classes. Cluster sampling occurs when the population has been divided into pre-existing natural groups, such as schools, classrooms, districts, and roads [48].

3.3 Data collection

In this study, there are two types of instruments: learning instruments and measurement instruments. The learning tools utilized include a Lesson Plan that has undergone validity testing by mentoring teachers, resulting in 92% accuracy, a Student Worksheet with e-scaffolding procedures that expert validators have tested and scored at 86%; and mentoring teachers have related it at 94%. Meanwhile, the measurement instruments consist of pretest and posttest sheets that measure the cognitive domain based on HOTS, starting from Analysis (C4), Evaluation (C5), and Creation (C6). The questions administered to both the experimental and control groups are identical. The tests consist of eight multiple-choice questions that have been empirically validated and are considered valid, with a reliability score of 0.752.

3.4 Data analysis

Quantitative data were collected by administering a test on higher-order thinking skills using multiple-choice questions in both the pre- and post-tests. The analysis of data to determine the impact of e-scaffolding procedures in PBL on students' HOTS across the two classes was conducted using ANCOVA, with the prior knowledge score serving as a covariate. Furthermore, the impact of field operations was determined using Cohen's effect size [49]. Table 1 contains the d-effect size categories for the improvement of higher-order thinking skills data.

Table 1. The category of Cohen's d effect size

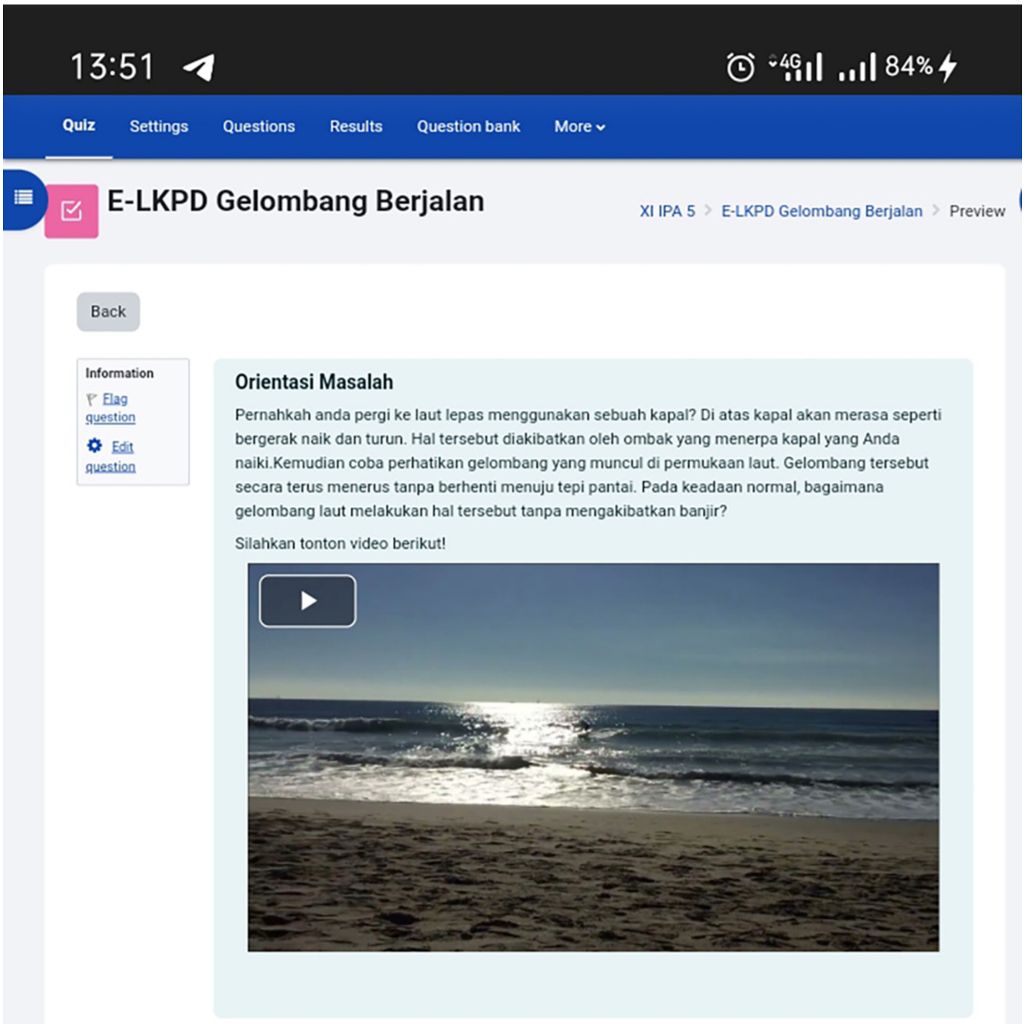
d-effect	Category
>1	Strong
0.21–1.0	Moderate
0–0.20	Weak

3.5 Procedure and implementation

The study sought to explore the impact of e-scaffolding procedures in PBL on students' HOTS related to standing waves. Consequently, the study participants were divided into the experimental group (n = 29), which received worksheets with e-scaffolding procedures, and the control group (n = 31), which received worksheets without e-scaffolding procedures.

The experiment began with a pretest for both classes to evaluate any differences between the two groups before starting the experiment. After working on pretest questions, the teacher provides information to the experimental class about the website that students will use to access worksheets with procedural e-scaffolding. One week before the learning implementation began, students in the experimental class were asked to access Moodle using the account created for each student. Hence, they understand how to use it. The main menu on this website is structured like a worksheet. The worksheet includes various elements to assist students in conducting virtual experiments, such as the objectives of the experiment, procedures for implementation, and the outcomes obtained from the experiment.

In the PBL model, education follows five PBL syntaxes. The learning process begins with the student's orientation to the problem stage. At this stage, students are given a problem to learn about standing waves. Problems were provided in worksheets that are accessible online (see Figure 1).



E-LKPD Gelombang Berjalan

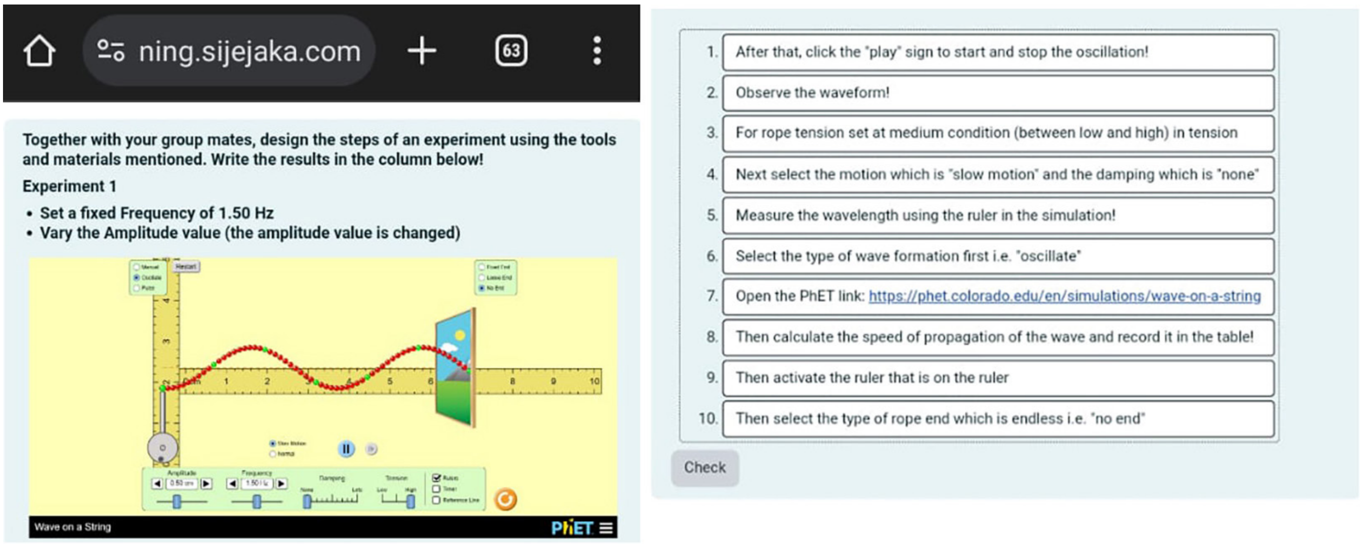
Orientasi Masalah

Pernahkah anda pergi ke laut lepas menggunakan sebuah kapal? Di atas kapal akan merasa seperti bergerak naik dan turun. Hal tersebut diakibatkan oleh ombak yang menerpa kapal yang Anda naiki.Kemudian coba perhatikan gelombang yang muncul di permukaan laut. Gelombang tersebut secara terus menerus tanpa berhenti menuju tepi pantai. Pada keadaan normal, bagaimana gelombang laut melakukan hal tersebut tanpa mengakibatkan banjir?

Silahkan tonton video berikut!

Fig. 1. Student orientation to the problem

The problem-solving process is carried out in groups with four to five members per group. This second stage is the phase of organizing students to learn. The teacher led the students in a group division and asked them to gather with their group members. After that, students use the standing wave LKS to conduct a rope wave experiment. Students pay attention to the teacher's instructions on the key points to consider when conducting experiments. Then, students begin to perform the rope wave experiment. The third stage involves assisting individual or group investigations. After all the students gathered in groups, each group planned the experiments. During this stage, each group receives a student worksheet with procedural scaffolding in the form of prompt questions to guide the ordering of investigation activities and provide hints on data analysis. Students can design an experimental procedure using the PhET simulation "Wave on a String" by following the steps provided (see Figure 2). Several groups encountered difficulties, trouble, so they sought teacher assistance to create waves on the rope. After completing the rope waves, groups then finalize the worksheets that were distributed.



Together with your group mates, design the steps of an experiment using the tools and materials mentioned. Write the results in the column below!

Experiment 1

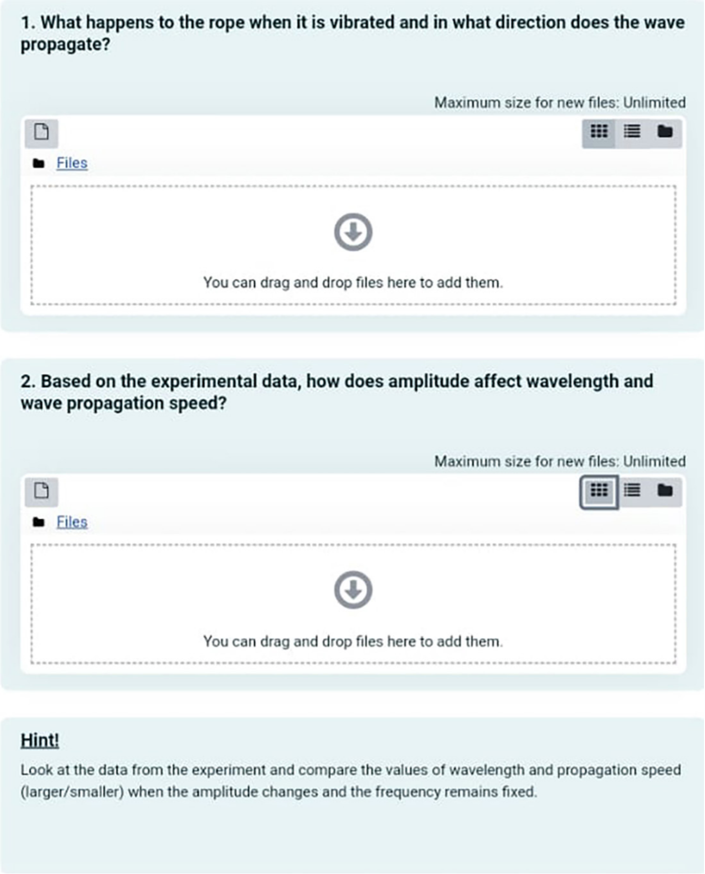
- **Set a fixed Frequency of 1.50 Hz**
- **Vary the Amplitude value (the amplitude value is changed)**

1. After that, click the "play" sign to start and stop the oscillation!
2. Observe the waveform!
3. For rope tension set at medium condition (between low and high) in tension
4. Next select the motion which is "slow motion" and the damping which is "none"
5. Measure the wavelength using the ruler in the simulation!
6. Select the type of wave formation first i.e. "oscillate"
7. Open the PhET link: https://phet.colorado.edu/en/simulations/wave-on-a-string
8. Then calculate the speed of propagation of the wave and record it in the table!
9. Then activate the ruler that is on the ruler
10. Then select the type of rope end which is endless i.e. "no end"

Check

Fig. 2. Prompt questions on investigation steps

After completing the experimentation process, students can propose solutions to the problems presented. The students' responses to the practical outcomes allow the teacher to assess their performance. Subsequently, students are guided to scrutinize the data derived from the experiment. In the data analysis, there is scaffolding in the form of hints to help students with their answers (see Figure 3).



1. What happens to the rope when it is vibrated and in what direction does the wave propagate?

Maximum size for new files: Unlimited

Files

You can drag and drop files here to add them.

2. Based on the experimental data, how does amplitude affect wavelength and wave propagation speed?

Maximum size for new files: Unlimited

Files

You can drag and drop files here to add them.

Hint!

Look at the data from the experiment and compare the values of wavelength and propagation speed (larger/smaller) when the amplitude changes and the frequency remains fixed.

Fig. 3. Hint on data analysis

The fourth stage involves developing and showcasing the work. Each group conducts problem-solving activities. At this stage, students engage in group discussions to complete the worksheet with procedural scaffolding. The teacher then assisted each group in checking the correctness of their answers and guided groups that were still struggling. After students discuss with their group members to complete the data analysis, randomly selected groups will present the results of their discussions. The representatives of each group present the outcomes of their discussions to the entire class, and the other groups can react and provide recommendations in response to the discussion results that have been submitted. This activity marks the fifth step in analyzing and evaluating the problem-solving process.

4 RESULTS

Before commencing the intervention in each class, both the experimental and control groups underwent identical pretests using an eight-item multiple-choice instrument to assess students' initial understanding of the standing wave topic in terms of higher-order thinking skills. A normality assumption test has been conducted, and the results reveal that the pretest and posttest data distributions in all groups follow a normal distribution. A homogeneity test has also been performed, indicating that the variance between the experimental and control groups regarding the students' initial HOTS data and the final HOTS data is homogeneous. As for the linearity test results of students' HOTS scores against their initial HOTS scores, the significance value is 0.921 ($p > 0.05$). This result indicates a linear relationship between the initial and final HOTS, suggesting that the initial HOTS data can be used as a covariate variable. In this case, the data analysis process continued with an ANCOVA test to determine whether the treatment improved students' higher-order thinking skills.

4.1 Prior knowledge results of experimental group and control group

The outcomes of the prior knowledge assessment provide insights into the students' existing knowledge before engaging in PBL with e-scaffolding procedures in the experimental group and the PBL model without e-scaffolding procedures in the control group. Detailed statistical results for students in both the experimental and control groups can be found in Table 2.

Table 2. Data description of prior knowledge (Pretest)

Class	N	Mean	Std Dev	Min Score	Max Score
Experimental	31	19.35	13.40	0	50
Control	29	27.59	15.03	0	50

Based on Table 2, the control group shows a higher mean score for prior knowledge compared to the experimental group. Within the 0–80 range, the average value for the experimental class is 19.35, while for the control class, it is 27.59. Details regarding students' prior knowledge (pretest) in both the experimental and control groups for each aspect can be observed in Figure 4.

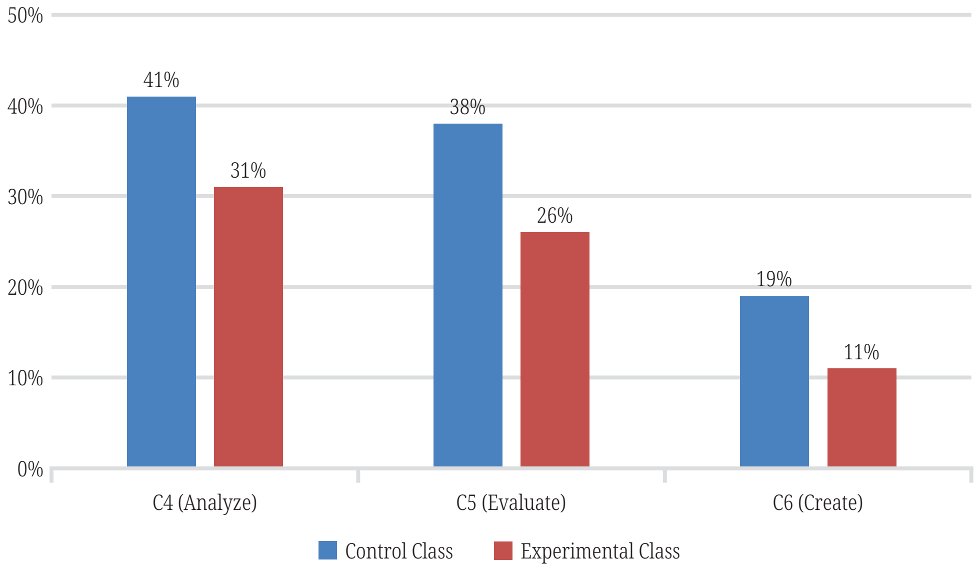


Fig. 4. Experimental class and control class pretest results for each aspect

As depicted in Figure 4, the average HOTS score of students in the experimental group, particularly in the analysis indicator (C4), stands at 31%, categorizing it as insufficient. Conversely, in the control group, the average is 41%, falling into the sufficient category. Regarding the evaluation indicator (C5), both the experimental and control groups have average student scores of 26% and 38%, respectively, both of which are deemed insufficient. Moving on to the creation indicator (C6), the average score was 11% for the experimental group and 19% for the control group. Both scores require revision. The outcomes of the descriptive analysis indicate that the average prior knowledge score of the control group exceeds that of the experimental group.

4.2 Post-test results of experimental group and control group

The outcomes of the posttest reveal the HOTS of students after their exposure to the PBL model with e-scaffolding procedures in the experimental group, compared to the PBL model without e-scaffolding procedures in the control group. Details regarding the statistical results of students in both the experimental and control groups are presented in Table 3.

Table 3. Data description of higher order thinking skills (post-test)

Group	N	Mean	Std Dev	Min Score	Max Score
Experimental	31	46.77	13.51	20	70
Control	29	36.55	15.41	10	70

Based on Table 3, it is evident that the control group has a higher mean score compared to the experimental group. Within the 0–80 range, the mean score for the experimental group is 46.77, whereas for the control group, it is 36.55. Details regarding the HOTS of students in both the experimental and control groups for each aspect can be observed in Figure 5.

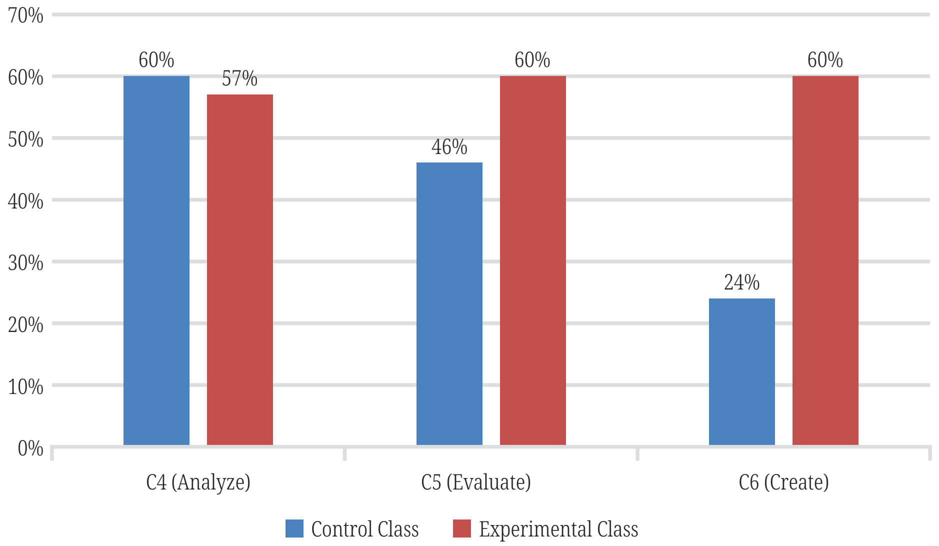


Fig. 5. Experimental and control group post-test results for each aspect

Based on Figure 5, in both the experimental and control groups, it is evident that the HOTS of students, particularly at the analysis level (C4), are classified as sufficient. The mean score for students is 57% in the experimental group and 60% in the control group. Regarding the evaluation indicator (C5), the average student score is 60% in the experimental group and 46% in the control group, indicating a classification as sufficient for both groups. Additionally, in the creation indicator (C6), the experimental group, with an average score of 60%, falls within the sufficient category, whereas the control group's 24% is deemed insufficient. The findings from the descriptive analysis indicate that the average HOTS in the experimental group surpasses those in the control group.

4.3 ANCOVA results

The ANCOVA test was used to analyze differences in HOTS between the experimental and control groups, with the pretest serving as a covariate. The outcomes of the ANCOVA test for both classes are presented in Table 4.

Table 4. ANCOVA test results

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	12451.163[a]	2	6225.582	284.531	.000	.909
Intercept	5692.569	1	5692.569	260.170	.000	.820
Pretest	10885.421	1	10885.421	497.501	.000	.897
Classes	4545.317	1	4545.317	207.737	.000	.785
Error	1247.170	57	21.880			
Total	118700.000	60				
Corrected Total	13698.333	59				

Note: [a]R Squared = .909 (Adjusted R Squared = .906).

Based on Table 4, the analysis of covariance resulted in an F-value of 207.737 with p = 0.000. Since $p < 0.05$, it can be inferred that the null hypothesis is rejected. This rejection implies that the HOTS of the experimental group surpass those of the control group. The observed difference is attributed to the treatment, as ANCOVA has effectively controlled for prior knowledge statistically. The partial eta squared value within the class category is 0.785, indicating a moderate effect size. This value indicates that the influence of e-scaffolding in PBL provided to the experimental group on HOTS is 78.5%.

5 DISCUSSION

The researcher chose the PBL model to observe its influence on students' high-order thinking skills. As stated by [11], by using PBL, students can apply their knowledge to real-world scenarios, which is expected to help them develop HOTS. From the data obtained in the study, it was found that during the pretest, the average HOTS scores of students in the control group were higher than those in the experimental group. During the pretest, many mistakes were observed among students in both the experimental and control groups. Many students needed help understanding the meaning of the questions. This is because students were not trained to use HOTS. Therefore, when faced with physics questions that require these skills, students needed assistance in solving the given problems. This result has also been reported by [31], indicating that students' capacity to solve HOTS problems is influenced by their initial understanding. After the pretest, the experimental group was exposed to the PBL model integrated with e-scaffolding. In contrast, the control group underwent learning using the PBL model without e-scaffolding, while both groups received the same material on standing waves.

The findings from this study suggest that students who participate in learning with e-scaffolding procedures within PBL demonstrate superior HOTS compared to students who undergo PBL without the incorporation of e-scaffolding. Procedural e-scaffolding in PBL positively impacts students' HOTS. Through the PBL model, students become accustomed to actively asking questions and seeking guidance from the facilitator. Successful PBL involves utilizing existing knowledge, encompassing the essential principles of physics, and using mathematical tools. The students comprehend the challenges outlined by the researcher, allowing them to address them promptly. Posttests were administered to both the experimental and control groups to assess students' HOTS following the learning process. This served as a reference point to evaluate the impact of e-scaffolding in PBL on enhancing students' HOTS. After the posttest, the average HOTS of students in the experimental group improved. Students found themselves in a conducive learning environment that offered opportunities for success, fostering motivation to comprehend the subject material better and seek optimal solutions to problems. A conducive environment for educational activities will enhance effective teaching and lead to improved learning outcomes [52]. The above statement also aligns with research conducted by [53], which revealed that problem-solving in the PBL model using HOTS can be done by students individually or in groups (teams). This setting promotes engagement and fosters a proactive approach to learning, ensuring that students actively participate in the learning process rather than passively receiving information. A study by [35] stated that PBL activities place students at the center of the learning process, enhancing their understanding, skills, and knowledge.

Procedure scaffolding in the form of questions also helps during the learning process. Using questions makes students more focused when analyzing data and accelerates the process of analyzing data from scientific investigations. Learning through e-scaffolding in PBL offers convenience and fosters deep understanding for students for the following reasons: (1) students can address problem orientations online, making it more practical; (2) students address problem orientations individually, thereby honing their creativity and independence; (3) students are more active in exploring and discussing the results of experiments and conclusions in various experimental groups; and (4) students participate in both online and offline learning, enriching their insight and depth of understanding of the material. In interactive classroom learning, the use of e-scaffolding provides an effective platform for students to actively engage in collaborative tasks focused on achieving successful problem-solving. Prompt questions for organizing investigation activities help students become more conscious of the steps that need to be taken to ensure that they do not impact the outcomes of scientific investigations. Hints on data analysis guide students in analyzing data by providing clues, enabling them to draw conclusions from experimental activities and comprehend the learned concepts more easily. These results align with a study by [54], which found that e-scaffolding has a positive impact on reducing difficulties in students' concept comprehension during the implementation of PBL. It assists students in avoiding misconceptions and ensures that their problem-solving abilities are maximized. When compared to manual scaffolding, the use of e-scaffolding is more flexible and effective. This occurs because e-scaffolding can assist students in working independently, making it easier to detect the difficulties they experience [42]. Several previous studies also demonstrate that e-scaffolding enhances learning effectiveness and efficiency in enhancing students' cognitive abilities [27], [45].

Challenges faced by the researcher in this study included many students exhibiting low curiosity, some students being disruptive during the learning process, and others feeling initially perplexed when given questions that they found very challenging. Providing procedural scaffolding can also lengthen the work steps, which may pose a challenge for students accustomed to quick solutions and who prefer to avoid lengthy steps in problem-solving. As a result, students tend to focus solely on using e-scaffolding to complete the task rather than leveraging it to comprehend the concepts embedded in the assignment. To address these issues, the teacher took an intensive approach with students who displayed low curiosity and guided those who began to feel confused, ensuring that the classroom environment remained orderly and conducive.

6 CONCLUSION

Integrating e-scaffolding procedures into PBL has the potential to enhance students' HOTS. The experimental group demonstrates superior higher-order thinking skills compared to the control group. The Partial Eta Squared value in the class category, 0.785, supports this fact. This value indicates that the impact of e-scaffolding applied to the experimental class on higher-order thinking skills is 78.5%. E-scaffolding serves as an effective platform for students to actively participate in collaborative tasks focused on efficient problem-solving, showcasing a remarkable success rate. Therefore, it is recommended to prioritize the utilization of e-scaffolding as a fundamental strategy in fostering higher-order thinking skills.

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