

PBL-SETS Effect on Student Conceptual Understanding of Sound Waves

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Abstract. This study aims to analyze the effect of the Problem-Based Learning (PBL) model based on the Science, Environment, Technology, and Society (SETS) approach, as well as to assess improvements in conceptual understanding across each indicator for the topic of sound waves through the implementation of the SETS-based PBL model. Students' understanding of physics concepts was determined using Effect Size (ES) and N-gain values for each conceptual understanding indicator. This study is a quasi-experimental study with a nonequivalent control group design. The sample consisted of 36 students in the experimental class and 36 students in the control class. The instrument used was a multiple-choice objective test comprising 17 items. The results showed an Effect Size of 0.781, indicating that the treatment effect was quite strong. The N-gain value in the experimental class falls into the moderate category (0.4337), which is higher than that of the control class (0.1926), which falls into the low category. The highest achievement was found in the interpretation and inference indicators, while the exemplification and classification indicators fell into the low category due to situational barriers to online learning during the month of Ramadan. These findings indicate that the application of the SETS-based PBL model is quite effective in helping students improve their understanding of physics concepts regarding sound waves, so the SETS-based PBL model can be implemented in other subjects as well.

Keywords: PBL, SETS, conceptual understanding

1. Introduction

Physics is a scientific discipline that studies the various phenomena and properties of objects in the universe; it consists of concepts, theories, facts, and principles that form a process of discovery [1]. The physics learning process emphasizes conceptual understanding, which is closely tied to the fundamental concepts found in each topic. Conceptual understanding is the process of grasping an abstract idea so that one can classify an event or object through the learning process. Anderson and Krathwohl identify seven indicators of conceptual understanding: interpretation, exemplification, classification, summarizing, inference, comparison, and explanation [2]. Thus, students with strong conceptual understanding are able to restate a concept they have learned and apply it.

However, students often view physics as a difficult and intimidating subject because they are frequently confronted with abstract concepts. In addition, it is not uncommon for students to struggle to define a given problem because they are unfamiliar with it or have only recently encountered it [3]. Students' difficulties in learning and understanding physics are not only due to a lack of ability to learn the subject, but also because teachers do not sufficiently relate physics concepts to natural phenomena in the surroundings [4]. Teacher centered learning causes students to become passive, resulting in a lack of interaction between teachers and students, as well as among students themselves. During class, students merely listen, take notes, and copy the material presented by the teacher without understanding the concepts [5].

Teaching methods that tend to be one-sided and focus on lectures or theoretical explanations can make it difficult for students to connect theory with its application in everyday life [6]. One area of physics where students often struggle to grasp the concepts is sound waves [7]. Teaching physics in schools often presents challenges when it comes to explaining abstract concepts such as sound waves. A study conducted by Novitasari on conceptual understanding found that 36.3% of students understood the concept, 29.7% did not understand it, and 34.0% held misconceptions [8]. Based on interviews with teachers and student surveys at two schools, it was found that students' conceptual understanding of physics particularly regarding sound waves remains low. Teachers reported that students' interest in learning is uneven, and students still struggle to grasp abstract concepts due to a lack of literacy and the continued use of conventional teaching methods. On the other hand, the survey results indicate that students are more interested in and find it easier to understand physics when the material is related to everyday life. Therefore, an in-depth analysis of students' conceptual understanding is needed, along with the identification of appropriate learning strategies to improve it.

One effective way to improve students' conceptual understanding is to implement contextual learning, which connects their understanding of a phenomenon to scientific concepts in everyday life [7]. One model of contextual learning that can support the contextual learning process is Problem-Based Learning (PBL). Problem-Based Learning is an instructional model designed to encourage students to take an active role in the learning process, enabling them to benefit from an approach that helps them better understand the subject matter being taught [9]. Learning activities using the PBL model result in greater improvements in problem-solving skills, understanding of physics material, and the ability to connect and build upon different ideas. Additionally, the PBL learning model can also stimulate scientific reasoning skills [10]. The implementation of the PBL learning model is carried out through several steps, beginning with orienting students to the problem, organizing students for learning, guiding individual and group learning [11]. Through hands on experience in solving problems, Problem Based Learning is designed to encourage students to construct their own knowledge. This process makes learning more meaningful and effective, while also strengthening students' conceptual understanding.

In addition to using contextual learning models, various approaches can also be applied to help students analyze crucial concepts in everyday life. One such approach is the SETS (Science, Environment, Technology, and Society) approach. The SETS (Science, Environment, Technology, and Society) approach is a learning approach that integrates the elements of science, the environment, technology, and society. Students not only study natural science theories but also examine real life situations related to those theories [12]. The SETS approach includes several key stages in the learning process: the invitation stage, the exploration stage, the solution stage, the application stage, and the concept consolidation stage [13]. The invitation stage is designed to draw students' attention to issues related to the environment, technology, and society, and to spark their curiosity. Students are asked to investigate the problems at hand, conduct experiments, and gather information during the exploration stage. In the solution stage, students are asked to develop creative solutions. The concept consolidation stage aims to ensure that students understand and internalize the ideas they have learned, while the application stage allows students to apply the ideas they have developed to real world situations.

Instruction using the problem-based learning model supplemented with the SETS approach can be considered an innovation because it focuses on teaching students about science and its development, as well as the impacts of environmental, technological, and social factors, all stemming from a problem. This approach helps students grasp existing physics concepts more easily. Based on these issues, this study aims to analyze the effect of the Problem Based Learning model based on the Science, Environment, Technology, and Society (SETS) approach, as well as the improvement in conceptual understanding for each indicator regarding sound wave material through the implementation of the Problem Based Learning model based on the Science, Environment, Technology, and Society (SETS) approach.

2. Method

2.1. Research Design

This study is a quantitative research using a quasi-experimental design with a nonequivalent control group design. The study aims to determine students' conceptual understanding skills before and after

instruction using the Problem-Based Learning (PBL) model with the Science, Environment, Technology, and Society (SETS) approach on the topic of sound waves. In this study, the implementation of the PBL model based on the SETS approach was given to the experimental group as the comparison group, while the control group only received instruction using the PBL model, to ensure that the differences between the two groups were caused solely by the intervention and not by other factors. The research design is presented in Table 1.

Table 1. Research Design.

Group	Pretest	Treatment	Posttest
Experiment	O_1	X_1	O_2
Control	O_1	X_2	O_2

X_1 represents the implementation of the Problem Based Learning (PBL) model based on the Science, Environment, Technology, and Society (SETS) approach in the experimental group, and X_2 represents the implementation of the Problem-Based Learning (PBL) model in the control group.

2.2. Population and sample

This study was conducted at a madrasah in Tangerang, Indonesia. The study was carried out from February to April 2026. The study population consisted of all 11th-grade students in the second semester of the 2025/2026 academic year. The participants in this study were students in class XI.8 as the experimental class, consisting of 36 students, and students in class XI.6 as the control class, consisting of 36 students. Both classes were in the same school, with class assignments determined randomly by the school. Thus, it can be assumed that the initial conditions of the two groups were the same.

2.3. Instruments

The test instrument was administered to the control group and the experimental group, which served as the research sample. The test items were designed based on Anderson's seven indicators of conceptual understanding: the ability to interpret, exemplify, classify, generalize, infer, compare, and explain. The instrument used was an objective test (multiple choice) consisting of 17 items that had undergone a pilot test involving 12th-grade students who had already studied the topic of sound waves. This instrument was administered as a pretest and a posttest. Validity and reliability calculations were performed by experts in physics education to ensure the instrument is valid and reliable. The results of the validity test, using the product-moment correlation technique, indicated that all 17 questions are valid and suitable for use. Furthermore, the reliability test was conducted using the Cronbach's Alpha formula ($\alpha = 0.642$), confirming that the test instrument possesses high reliability.

2.4. Research Procedure

This study was conducted over a period of 5 weeks, with 5 class periods per week. The study was carried out in three phases: the preliminary phase, the implementation phase, and the final phase. The research procedure is illustrated in Figure 1.

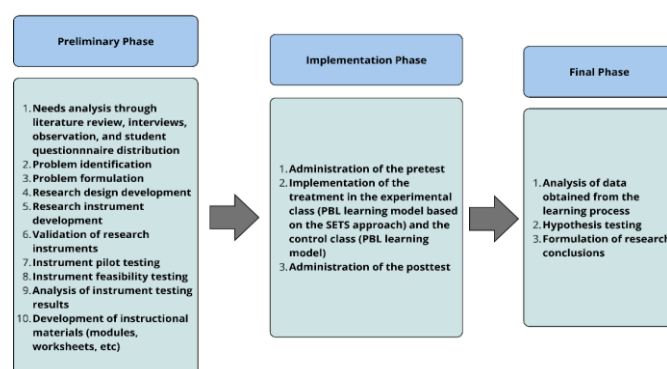


Figure 1. Research Procedure

2.5. Data collection methods

The data for this study were collected in several stages. The data collection methods used in this study are outlined in Table 2.

Table 2. Data collection methods.

Steps	Data Source	Data Type	Data Collection Methods	Instrument
Before the lesson begins	School staff (teachers and students)	Results of interviews with physics teachers and student survey results	Student interviews and surveys	Interview sheets and questionnaires
Implementation of learning	Experimental group and control group	Students' prior learning before intervention	Pretest	Conceptual understanding test items
During the learning session	Experimental group and control group	Students' learning outcomes after receiving the intervention	Posttest	Conceptual understanding test items

3. Results and Discussion

The effectiveness of the SETS based PBL learning model in enhancing students' conceptual understanding was measured using an effect size test interpreted according to Cohen's (1992) criteria[14].

3.1 Posttest Results Data

After the intervention was implemented in the experimental and control classes, the students' post intervention learning outcomes the posttest data were obtained. A comparison of the posttest scores between the experimental and control classes is presented in Table 3.

Table 3. Posttest Results Data

Data	Experimental Group	Control Group	Effect size
Mean	84.96	78.11	0.781
Median	88.24	76.47	
Mode	88.24	88.24	
Highest score	100.00	94.12	
Lowest score	64.71	64.71	
Standard deviation	9.05	10.00	

The table shows the scores indicating improvements in students' conceptual understanding of sound waves in the experimental class (Maks = 100.00; Min = 64.71). The mean score for conceptual understanding in the experimental class (M = 84.96; sd = 9.05) was higher than that in the control class (M= 78.11; sd = 10.00). To assess the magnitude of the effect of the SETS based PBL learning model, an effect size test was conducted, yielding a value of 0.781. This effect size falls into the moderate category. This indicates that the implementation of the SETS-based PBL learning model has a fairly strong impact on improving students' conceptual understanding in the experimental class. This supports the statement by Nasution & Nasution (2026) that the integration of socio-scientific issues enhances conceptual mastery and fosters problem-solving, ultimately cultivating a creative attitude in students when addressing everyday problems.

3.2. Statistical Data to Measure Treatment Effect

To assess the impact of a Problem Based Learning model based on the Science, Environment, Technology, and Society (SETS) approach on students' conceptual understanding of sound waves, the following prerequisite tests must be conducted:

3.2.1. Normality Test

Table 4. Normality test results.

Shapiro-Wilk	Pretest		Posttest	
	Experimental Group	Control Group	Experimental Group	Control Group
df	36	36	36	36
Sig	0.183	0.341	0.800	0.060
Conclusion	Normally distributed	Normally distributed	Normally distributed	Normally distributed

A normality test was conducted to determine whether the data come from a normally distributed population. The normality test was performed using SPSS Statistics 26 software with the Shapiro-Wilk test. The test results are shown in Table 4.

The table 4 shows that the pretest data for the experimental and control classes have a p-value > 0.05 so it can be concluded that the pretest data are normally distributed. The posttest data for the experimental and control classes also have a p-value > 0.05 indicating that the data are normally distributed.

3.2.2. Homogeneity Test

A homogeneity test was conducted to determine whether the two groups were homogeneous or not. The homogeneity test was performed on the pretest and posttest data for both groups. This test was conducted using SPSS Statistics 26 software with Levene's test. The results of the homogeneity test are shown in Table 5.

Table 5. Homogeneity test results.

Data stage	Levene statistic	df_1	df_2	Sig.	Conclusion
Pretest	0.500	1	70	0.482	homogeneous
Posttest	1.260	1	70	0.265	homogeneous

Table 5 shows that the pretest and posttest data have a sig. value ≥ 0.05 . Therefore, it can be concluded that the pretest and posttest data are homogeneous.

3.2.3. Hypothesis testing

The results of the prerequisites test indicate that the pretest and posttest data for the two groups the experimental class and the control class are normally distributed and homogeneous. Therefore, parametric statistical analysis can be used to test the hypotheses regarding the pretest and posttest data. The hypothesis tests for the pretest and posttest were conducted using SPSS Statistics 26 software with the Independent Samples t-test; the results of the hypothesis tests are presented in Table 6.

Table 6. Independent t-test results.

Uji Independent Sample T-Test	Pretest	Posttest
Sig. (two-tailed)	1.00	0.003
α	0.05	0.05
Conclusion	H_0 accepted H_1 rejected	H_0 rejected H_1 accepted

The pretest data, analyzed using an independent samples t-test, showed a Sig. (2-tailed) > 0.05 therefore H_0 was accepted and, H_1 rejected. Based on these results, it can be concluded that there was no difference in the mean scores for conceptual understanding between the experimental and control classes before the intervention was administered. Post-test data analyzed using the independent samples t-test showed a Sig. (2-tailed) < 0.05 therefore H_0 was rejected, H_1 was accepted. Based on the results of the independent samples t-test on the post-test data, it can be concluded that there is a difference in the mean scores of students' conceptual understanding between the experimental and control classes after the intervention was administered.

3.3. Improving Students' Conceptual Understanding

Improvements in students' conceptual understanding of sound waves can be calculated using the N-gain formula. The resulting N-gain scores are classified into three categories of interpretation developed by Hake [15]. The N-Gain results for each class are shown in Table 7.

Table 7. N-gain results.

Group	N-gain	Category
Experiment	0.4337	Medium
Control	0.1926	Low

Based on the calculation of N-gain scores between the experimental class group and the control class group, the results showed that after implementing the Problem Based Learning model based on the Science, Environment, Technology, and Society (SETS) approach in the experimental class, an N-gain score of 0.4337 was achieved, which falls into the "moderate" category, while the control class group only achieved an N-gain score of 0.1926, which falls into the "low" category.

The results indicate that the instructional model with the approach applied in the experimental class is more effective in improving students' conceptual understanding than the one used in the control class. This is consistent with research showing that contextual learning, which directly involves students in learning activities such as discussions, can encourage them to seek information and find appropriate solutions, thereby improving their conceptual understanding [16]. This indicates that a learning model based on the Science, Environment, Technology, and Society (SETS) approach can yield better results in improving students' understanding of physics concepts. The improvement in students' conceptual understanding across each indicator for both classes are shown in Table 8.

Table 8. N-gain Results of Concept Understanding Indicators.

Concept understanding indicators	Experimental Group		Control Group	
	N-gain	Description	N-gain	Description
Interpreting	0.875	High	0.423	Medium
Exemplifying	0.156	Low	0.145	Low
Classifying	0.154	Low	0.077	Low
Summarizing	0.616	Medium	0.125	Low
Inferring	0.778	High	0.084	Low
Comparing	0.546	Medium	0.361	Medium
Explaining	0.391	Medium	0.333	Medium

An analysis of the N-gain scores per indicator is necessary to identify the aspects of conceptual understanding that showed the most significant improvement. Conceptual understanding scores were compared based on N-gain values per indicator between the experimental and control groups. Seven indicators showed higher scores in the experimental class compared to the control class. In the experimental class, two of the seven indicators fell into the high category, including interpretation ($Ng_E = 0.875$) The N-gain value for this indicator indicates that contextual learning using the PBL model based on the SETS approach can support students' interpretation skills by providing real-world contexts as a medium to translate abstract physics concepts into meaningful information related to technology, the environment, and society. This aligns with the research by Pertiwi [17] which states that through the SETS approach, students are equipped with the ability to interpret phenomena holistically, with an emphasis on the four aspects of SETS, thereby providing students with a broader foundation of knowledge and understanding; furthermore, the inference indicator ($Ng_E = 0.778$) through collaboration between the stages of the PBL learning model and the four aspects of the SETS approach creates a complementary relationship with interactions that transform the learning process from mere mastery of theory into a holistic problem solving experience, thereby significantly helping students draw logical conclusions for specific cases based on available data. This proves that the SETS approach plays a role

in increasing students' cognitive demands in making deeper inferences compared to learning in the control class, in line with the research Ana [18].

In the meantime, three indicators fell into the moderate category, including summarizing ($Ng_E = 0.616$), PBL learning based on the SETS approach contributes to the ability to draw general conclusions from various phenomena studied. This is consistent with the findings (Sari et al., 2024)[19] which indicate that the implementation of the SETS based PBL learning model effectively enhances students' ability to construct relationships between concepts through the investigation of real-world problems. For the "comparing" indicator ($Ng_E = 0.546$) two classes were in the "moderate" category; however, the scores in the experimental class were still higher than those in the control class. This indicates that students can establish connections between context and concepts and build interconnected knowledge bases through SETS based PBL. The next indicator is the explaining indicator ($Ng_E = 0.391$) The improvement in conceptual understanding on this indicator aligns with the findings of Sari [19] which states that the implementation of the PBL learning model integrated with the SETS approach significantly improves students' conceptual understanding in explaining scientific phenomena. This indicates that the stages of the SETS-based PBL learning model provide students with the opportunity to construct logical explanations regarding the relationship between scientific concepts and their applications in technology and the surrounding environment.

Two of the seven indicators fell into the low category: exemplifying ($Ng_E = 0.156$) and classifying ($Ng_E = 0.154$). These findings indicate that although students can develop a basic understanding of a concept, their ability to translate that understanding into real life examples is not yet fully developed. This is closely related to the limitations of space and time during the study. The shift to online learning during Ramadan technically limited students' direct interaction in the learning process. The lack of targeted stimuli during online learning made it difficult for students to classify more complex sound phenomena. The limitations of face to face learning and the reduction in class hours caused students' focus to wane, hindering the effectiveness of learning activities; consequently, students' ability to apply concepts through relevant examples did not reach the high category.

The low N-gain scores observed in the indicators of exemplifying (0.156) and classifying (0.154) can be systematically explained through Cognitive Load Theory. The multidimensional integration of science, environment, technology, and society within the SETS framework inherently elevates the complexity of the instructional material. When a student's working memory is severely overloaded, there is a significantly higher risk that the core scientific concepts will be misinterpreted, confused, or fail to be effectively encoded into the long-term memory [20].

In this study, the ill-structured real-world problems presented in the PBL syntax forced students to dedicate most of their cognitive resources to finding practical solutions. When instruction relies on minimal guidance during problem-solving, students' attention becomes heavily focused on solving the immediate problem rather than on learning the underlying scientific techniques or constructing structured schemas [20]. Consequently, the combination of a high intrinsic load from the SETS issues and a high extraneous load from the independent problem-solving process exceeded the students' working memory capacities. This cognitive overload ultimately hindered their ability to construct the hierarchical mental schemas required to successfully classify scientific concepts and generate accurate, novel examples.

To understand the low N-gain in exemplifying (0.156), a validated instrument item from this indicator was analyzed qualitatively. Interestingly, this specific item held the narrowest validity margin and the lowest discrimination index ($r = 0.125$), even though the number of students who answered it correctly was higher (41 students) compared to other items.

Which of the following events is a correct example of the application of sound waves in daily life within the medical field?

- a. Examination of a patient's internal organs using X-rays, which utilize high-frequency sound waves to penetrate body tissues and reflect back to form an image on the screen.
- b. Monitoring a patient's health using radio waves, by transmitting sound vibrations through the air which are then translated into medical data by a receiver.

- c. A doctor uses ultrasonography (USG) to examine a fetus in the womb. The sound waves used have a very high frequency so they can penetrate body tissues and reflect back to the device.
- d. Measuring a patient's body temperature using an infrared thermometer, which works by reflecting sound waves from the skin surface to determine the temperature.
- e. Examination of heart function using an electrocardiograph (ECG), a device that measures the reflection of sound waves from the heartbeat to determine the condition of the patient's cardiac activity

Answer : c

Qualitatively, the low discrimination power indicates that the item struggled to differentiate between high-achieving and low-achieving students. While the SETS context provided familiar, real-world medical keywords that allowed many students to select the correct answer (C) through superficial recognition or guessing, the dense contextual data also triggered cognitive confusion. According to CESE (2017) [20], when working memory is overloaded with multi-dimensional information, high-achieving students tend to overthink the contextual variables and trip over the attractive distractors (which deceptively embed the phrase 'sound waves'). This cognitive overload flattens the performance gap, leading to marginal validity and low discrimination scores despite the high count of correct answers.

To investigate the low N-gain in the classifying indicator (0.154), Item 9 was analyzed qualitatively. Statistically, this item recorded a high success rate (68 students) but a low discrimination index ($r = 0.222$).

Consider the following events or devices:

1. USG (Ultrasonography) is used to monitor the condition of a fetus in the womb.
2. Sonar is used by submarines to measure ocean depth.
3. An echo is heard when shouting in a valley.
4. A speaker converts electrical current into sound waves.

Which group represents the application of sound waves in the field of technology?

- a. 1, 2, and 3
- b. 1, 2, and 4
- c. 2, 3, and 4
- d. 1, 4, and 3
- e. 2 and 3

Answer: b

According to the Conceptual Change Theory, this mismatch occurs because the everyday context embedded in the SETS approach made the correct option appear 'intuitively obvious' to the majority of the class. Students successfully *assimilated* the information using superficial familiarity from their prior daily experiences. However, because the item could be solved through intuition rather than rigorous scientific classification, it failed to trigger *accommodation* the deeper restructuring of concepts needed to distinguish high-performing students from low-performing ones. This lack of conceptual challenge flattened the performance gap, resulting in low discrimination power despite the high volume of correct answers [21].

The improvement in students' conceptual understanding of sound waves in the experimental class resulted from the integration of the PBL instructional model with the SETS approach. The four aspects of the SETS approach were consistently applied in each session, covering different concepts related to sound waves. An example of a learning activity using the SETS based PBL instructional model are shown in Table 9.

In the first stage, problem based learning related to the environment can help students transform abstract information into logical scientific explanations. The four aspects of SETS can be fully implemented in the second stage, where students not only understand group task assignments but also begin to explore the relationships between science, the environment, technology, and society through various media, such as apps that can be used directly in or outside the classroom. Flexible learning can

boost students' motivation to engage in the learning process, which in turn will help them understand physics concepts found in their surroundings not just limited to formulas. This is supported by research by Farisky [22] which states that the use of smartphones in physics experiments offers significant opportunities to enhance the quality of physics education. The SETS approach can also be implemented in various settings, even without the need for laboratory equipment.

Table 9. Example of PBL SETS Learning Activities.

PBL Syntax	SETS Stages	Activity Examples
Student Orientation	Invitation	Students are presented with technical and safety issues related to the use of the “telolet” horn, as well as safety risks associated with bus braking systems. (Concepts of the speed of sound and sound sources)
Organizing students	Exploration	Students are instructed to divide tasks into groups. The teacher then guides them to explore two sound sources with different frequencies using an online binaural beats generator, with the aim of observing the phenomenon of sound interference. (The concept of sound interference)
Conducting an investigation	Solution	Students conducted direct observations and investigations into noise levels at various locations near the school, identifying that environmental noise is a factor that can disrupt learning activities and the comfort of the school community, and used a digital tool the Sound Level Meter app on a smartphone to measure decibel levels in real time. Students then consider the impacts of noise and formulate solutions that benefit the surrounding community. (Concepts of sound intensity, sound intensity levels, and the application of sound waves)
Developing and presenting creative works	Applications	Working in groups, students present the findings from their investigations and observations conducted both in and out of the classroom and propose solutions to the problems assigned in the first stage to their classmates.
Analyzing and evaluating processes	Concept reinforcement	The researcher helps students reflect on the entire inquiry process they have undertaken. The researcher plays a role in correcting various misconceptions held by the students.

During the third stage, several challenges arose in some sessions due to schedule changes during the month of Ramadan. Learning was temporarily conducted online, which prevented the researcher from monitoring the sessions directly as they took place; this resulted in some students not actively participating in the inquiry process. However, the third stage was still carried out during sessions held before and after the month of Ramadan. In this stage, students formulated solutions to a problem. This demonstrates that the “Society” aspect of the SETS approach in physics education can foster a sense of social responsibility. The fourth stage focused on the process of organizing, compiling, and presenting students' work as a representation of solutions to the given problem. Students are required to summarize their findings in a systematic and easily understandable format [23]. In this final stage, the researcher plays a role in correcting various misconceptions held by the students. This aligns with the objectives of evaluation and reflection activities, as described by Khoirunnisa [24] which are to deepen understanding and gather information to determine the best decision for solving a problem. Overall, the researcher believes that the integration of the four aspects of the SETS approach has helped students not only master physics formulas mathematically but also foster technological awareness and social responsibility in formulating solutions to problems in the community.

4. Conclusion

The implementation of the Problem-Based Learning (PBL) model integrated with the Science, Environment, Technology, and Society (SETS) approach has a significant positive effect on students' conceptual understanding of sound waves. This model yields a higher average conceptual understanding score and better N-gain improvement compared to the standard PBL model. While the SETS-based PBL

model is highly effective in enhancing high-order cognitive indicators such as interpreting and inferring, it shows limited effectiveness in exemplifying and classifying indicators. This limitation stems from the heightened cognitive load induced by the multidimensional nature of SETS issues combined with independent problem-solving, which was further compounded by the situational constraints of online learning. Based on these findings, future researchers and physics educators implementing SETS-based PBL should incorporate explicit scaffolding and structured guidance to mitigate extraneous and intrinsic cognitive load, particularly when targeting complex indicators like exemplifying and classifying. Additionally, instructional designs must be carefully calibrated for hybrid or online delivery constraints, ensuring optimized synchronous interactions to sustain student focus and support successful schema construction.

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