

The Implementation of PhET Simulation Media to Improve The Understanding of Physics Concepts

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Article Info	Abstract
Article history: Received: August 24, 2025 Accepted: October 28, 2025 Published: November 5, 2025 Keywords: Conceptual understanding PhET simulation Physics learning Sound waves This article is licensed under a creative commons attribution-share alike 4.0 international license © 2025 Jurnal ilmiah Pendidikan Fisika	Physics material is often considered a difficult subject because it is abstract, while the limitations of laboratory facilities are also an obstacle in the learning process. In addition, conventional learning media that are still predominantly used make students less motivated and less likely to explore concepts independently. This research aims to determine the improvement in students' conceptual understanding of physics after the implementation of PhET simulation media on the topic of sound waves. The research employed a quantitative approach with a pre-experimental design, specifically a one-group pretest-posttest design. The research subjects were 30 students from class XI-2 of SMAN 20 Gowa. The instrument used was an essay test administered before and after the treatment to measure the level of students' conceptual understanding. The data were analyzed descriptively to observe the changes in pretest and posttest scores, and the N-Gain formula was used to evaluate the effectiveness of the learning process. The results showed an increase in the average score from 6.9 (pretest) to 20.17 (posttest). The average N Gain score was 0.74, which falls into the high category. These findings indicate that the use of PhET simulation media contributes positively to improving students' conceptual understanding in physics. Therefore, it can be considered an effective and interactive learning alternative, particularly for abstract topics such as sound waves. The implications of this research confirm that the use of PhET simulation media is not only effective in improving students' understanding of physics concepts but can also be integrated more widely as an alternative learning strategy to overcome the limitations of practicum facilities in schools. To cite this article: NS, I., Usman, U., Dahlan, A., & Setiawan, T. (2025). The implementation of phet simulation media to improve the understanding of physics concepts. <i>Jurnal Ilmiah Pendidikan Fisika</i>, 9 (3), 411-424.

INTRODUCTION

Physics is the science that explores the fundamental principles, characteristics, and behaviors of the universe. An understanding of these basic concepts of physics is very important because of its broad application in the analysis of natural phenomena and their

practical applications ([Dewi & Primayan, 2019](#); [Thees et al., 2020](#); [Zahara et al., 2024](#)). If you study physics in more detail, it includes concepts and theories that are relevant to daily life ([Kallesta, 2017](#)). Conceptual understanding in physics plays an important role in developing learners' high-level thinking skills, allowing them to creatively solve everyday problems ([Putranta & Supahar, 2019](#)). For this reason, physics needs to be taught by providing facts that are relevant to daily life ([Rasyid et al., 2025](#); [Yalcin & Emrahoğlu, 2017](#)).

The concept of physics, according to [Puri & Perdana \(2023\)](#), is a way to explain and understand the natural phenomena that occur around us. Students' success in learning physics is determined by their level of conceptual understanding, which refers to their ability to restate physics concepts and principles ([Puspitasari et al., 2021](#)). Studying physics concepts should not only involve memorizing formulas but also understanding the meanings behind these concepts, as well as being able to apply them in various situations ([Ningsih, 2022](#); [Isti'annah et al., 2024](#)).

Conceptual understanding is the ability of students to grasp ideas thoroughly and deeply, including their relationships with other concepts and their applications in various situations. In line with this, [Jusman et al. \(2024\)](#) stated that understanding concepts also involves classifying them into relevant events or objects during the learning process. Thus, students who understand concepts well are not only able to reinterpret the concepts in their own words but can also apply them in various contexts appropriately.

The indicators of concept understanding according to Anderson & Krathwohl ([Hermawati et al., 2019](#)) are grouped into seven categories, namely: (1) interpreting; (2) exemplifying; (3) classifying; (4) summarizing; (5) concluding; (6) comparing; and (7) explaining. However, in this study, the researcher only used five of the seven indicators of concept understanding, namely explaining, exemplifying, classifying, comparing, and concluding. The selection of these five indicators is based on considerations of relevance to sound wave material and the achievement of indicators in the form of essay test questions. The other two indicators were not used because they were considered inappropriate to be developed into representative essay questions in the context of the material being studied. Thus, the selection of these indicators aims to ensure that the test instruments prepared are able to measure students' understanding of concepts optimally and contextually.

Based on the results of direct interview observations of physics teachers at SMAN 20 Gowa, information was obtained that there were obstacles experienced by them when carrying out the teaching and learning process in class XI MIPA. Some of the obstacles experienced by the physics teacher affect the physics learning outcomes of students, the majority of whom are below the Minimum Completeness Criteria (KKM). This means that most students in the class do not fully understand the theory and concepts covered in the physics material taught by the teacher.

The low understanding of the concept among students at SMAN 20 Gowa can be influenced by several factors, one of which is the limited learning pattern, which still focuses on delivering material in one direction. In practice, teachers tend to explain more, while students often act as listeners with limited space to explore ideas or engage in discussion. The learning media used are still limited to whiteboards and textbooks, so students' learning experiences have not been able to foster their curiosity or encourage active engagement fully. [Lubis et al. \(2025\)](#) stated that previous research shows physics learning in schools is often done conventionally, relying heavily on lectures and textbooks, which tend to be less engaging for learners.

Laboratory activities are very important in learning physics ([Gunawan et al., 2018](#)). According to [Rafiqah et al. \(2022\)](#), the utilization of laboratories in practicum activities contributes positively to physics education, as it enhances students' understanding of

concepts and stimulates their motivation to study. However, the implementation of physics practicum at SMAN 20 Gowa is still limited because there is no adequate physics laboratory. Additionally, the availability of practicum tools remains incomplete, making it challenging for teachers to present in-depth or complex experimental activities. This condition has an impact on students' limited experience in directly observing physical phenomena, resulting in a lack of optimal understanding of basic concepts and the relationships between concepts in physics learning.

If students' low understanding of physics concepts is not addressed immediately, this can hinder the understanding of advanced material and reduce learning motivation due to a lack of confidence. Therefore, teachers need to understand the condition of students and choose learning media that are in accordance with the school situation. Effective learning is not enough to rely only on conventional methods that are centered on teachers; interesting and interactive media are needed so that students can be more active in the learning process.

One of the efforts to overcome the low understanding of physics concepts at SMAN 20 Gowa is to utilize technology as an alternative learning resource. According to [Ravi & Polonia \(2022\)](#), the use of virtual laboratories enables students to conduct experiments digitally that closely resemble real laboratory practices, thereby improving their understanding of concepts through interactive visualization and independent experimental simulations. According to [Fatimah et al. \(2020\)](#), virtual laboratory media provide a learning environment that resembles real-world situations with text elements, graphics, animations, sounds, and meaningful assignments and serve as a solution to the limitations of practicum facilities in schools.

A virtual simulation, or virtual laboratory, is a laboratory where students have access to laboratory tools and materials through a computer program, allowing them to conduct practical exercises. It can also be interpreted as a learning process where learners use smartphones or computer media to learn certain subject matter, but they do not have enough laboratory equipment or lack experience ([Masita et al., 2020](#)).

Physics Education and Technology (PhET) is a virtual simulation platform created by the University of Colorado in the United States, designed to provide an interactive learning experience for learners. PhET is a simulation of science developed with advanced computer technology. This simulation is made as interesting as possible in the form of moving images (animations), interactive, and similar to games, so that students can learn by exploration ([Badriyah et al., 2023](#); [Salame & Makki, 2021](#)).

PhET is a virtual laboratory that can be used to improve students' understanding of concepts through independent learning. The use of PhET enables learners to interact with virtual objects and discover concepts through the experiments conducted by [Budi et al. \(2022\)](#). This is supported by [Theasy et al. \(2021\)](#), which shows an improvement in understanding of physics concepts after using the PhET virtual laboratory. The PhET simulation strengthens the understanding of physics concepts through an interactive and dynamic learning experience ([Budi et al., 2021](#); [Mahtari et al., 2020](#); [Maulani et al., 2018](#)). Students can conduct virtual experiments independently, following the guidelines. This activity helps them formulate and explain physics concepts based on the results of direct observations in simulations. Thus, PhET encourages more meaningful and exploratory learning.

Based on the problems previously described, such as limited laboratory facilities, lack of interactive learning media, and teacher-centered instruction, the use of PhET simulation media is considered an appropriate solution. Through interactive visualization and virtual experimentation, PhET enables students to actively explore abstract concepts and connect theory with observable phenomena. This media not only addresses the absence of real laboratories but also promotes active, engaging, and student-centered learning that supports

the improvement of conceptual understanding in physics.

Virtual labs have advantages and disadvantages. The advantage is that it allows learners to simulate anywhere and anytime without the need for equipment or materials, and they can see the smallest details; it provides opportunities for learners to visualize ideas at the macroscopic, submicroscopic, and symbolic levels; it demonstrates a dynamic representation of the world of submicromicroscopic particles; it supports a deeper understanding of chemical materials, and serves as a motivational tool ([Fatimah et al., 2020](#)). The disadvantage is that students may lose their motor skills because experiments are rarely conducted in real-world contexts ([Sanimah et al., 2024](#)).

SMAN 20 Gowa has facilities that support the use of learning media based on PhET simulation technology, including projectors, computer laboratories, and policies that permit the use of mobile phones. Physics teachers also support the use of simulation as a solution to the limitations of practicum tools, indicating the readiness of schools to implement PhET-based learning.

PhET simulations can provide opportunities for learners to learn the material at any time and can be repeated until learners understand the concept ([Rumakur et al., 2023](#)). Research conducted by [Sugiana et al. \(2016\)](#) reported that the application of generative learning models supported by virtual laboratory media was able to enhance both conceptual understanding and creativity among students in physics experiment classes. In addition, Rizaldi et al. (2020) highlighted that (1) PhET simulation media serve as an effective tool for supporting teachers and students in the process of learning physics concepts, (2) it is very good combined with inquiry learning, and (3) it is effective in explaining abstract physics concepts.

Understanding physics concepts can be enhanced through PhET virtual simulations, as they allow learners to interactively explore these concepts through virtual experiments that closely resemble the real world ([Rararati et al., 2025](#)). Through the interaction in the simulation, users can observe the effects of variable changes, understand the relationships between concepts, and test their own hypotheses, thus deepening their understanding of physics concepts ([Natifa et al., 2024](#)). In addition, PhET simulations also provide opportunities for students to experience physical phenomena that are difficult to observe in real-world learning, such as frequency changes in the Doppler effect or sound propagation in various media. The interactive features of PhET allow students to make virtual observations of concepts that are not visible, thus supporting a more concrete understanding. According to [Nurulhidayah et al. \(2020\)](#), the use of PhET simulations enables students to observe physical phenomena that are difficult to observe directly, making it easier for them to identify patterns and understand concepts. Through exploration, observation, and drawing conclusions, students actively build understanding independently.

One of the learning models that is suitable for the learning process using PhET simulations is Problem-Based Learning (PBL). In their journal, [Mayanti et al. \(2022\)](#) wrote that this PBL model encourages students to prepare material before the lesson starts, given an apperception, and then directed to find concepts independently through discussion. After the students' intelligence develops well, the teacher provides practice questions to measure how much the students understand the material through learning outcomes. After the practice stage of the questions is completed, it is hoped that students can make conclusions related to the material. Therefore, the PBL learning model will be very helpful for students in understanding and mastering physics concepts.

This research aims to determine the improvement of students' understanding of physics concepts after the application of PhET simulation media. The research primarily focuses on evaluating the improvement in conceptual comprehension by analyzing pretest and posttest results as well as N-Gain scores. The results of this research are expected to provide an

overview of the effectiveness of PhET simulation media in supporting more contextual and meaningful physics learning in a school environment with limited laboratory facilities.

METHODS

This research is descriptive quantitative research with a one-group pretest-posttest design. This design was used to determine changes in students' understanding of physics concepts before and after being given treatment in the form of learning using PhET simulation media. [Sugiyono \(2017\)](#) noted that pre-experimental research involves providing treatment to students but has not fully met the requirements for experimentation, as it does not utilize a comparison group and does not randomly assign subjects.

The subjects of this research are 30 students in class XI MIPA 2 SMAN 20 Gowa for the 2024/2025 school year. This research used a purposive sampling technique, considering the class's high level of student activity and its accessibility in terms of schedule availability and ease of coordination with the physics teacher, which facilitated the smooth implementation of the research.

The instrument used in this research is a five-question essay test, each representing one indicator of concept understanding: explaining, exemplifying, classifying, comparing, and concluding. The pretest and posttest questions have the same shape but are randomized by the sequence number. Each question is developed based on indicators and has been validated by experts. All items that have been prepared are consulted with the supervisor and then validated to assess the validity of the instrument before being used in the research. The goal is to ensure that this concept comprehension test is valid and trustworthy. The validation process of this instrument was carried out by two physics lecturers, who then analyzed it using Gregory analysis. Based on the results of the Gregory test criteria, a value of $VC = 1$ was obtained, so that the instrument had a very high validity and was declared suitable for use. The test scores of the students were then analyzed using descriptive statistics, which included calculating averages, standard deviations, and categorizing concept understanding. To determine the improvement in conceptual understanding, N-Gain (*Normalized Gain*) analysis was used. Assessment categorization aims to provide a clearer picture of how well students understand the concepts being taught. Table 1 is the categorization guidelines used in this research.

Table 1 Assessment criteria

Percentage Interval	Category
81 – 100	Excellent
61 – 80	Good
41 – 60	Enough
21 – 40	Less
0 – 20	Very less

[Riduwan \(2018\)](#)

The percentage interval is converted into a score interval by multiplying each lower and upper limit of the percentage by the ideal score. To prevent overlap between categories, the conversion results are then rounded. Table 2 presents the results of converting the categorization guidelines for students' concept comprehension scores.

Table 2 Guidelines for categorizing concept understanding

Score Interval	Category
21 – 25	Excellent
16 – 20	Good
11 – 15	Enough
6 – 10	Less
0 – 5	Very less

RESULT AND DISCUSSION

Descriptive Analysis of Concept Understanding of Students in Grade XI-2 SMAN 20 Gowa

This research aims to enhance the understanding of physics concepts among grade XI students of SMAN 20 Gowa through the use of PhET simulation media. An overview of the development of students' concept comprehension skills before and after learning is shown in Table 3.

Table 3 Results of descriptive analysis of pretest-posttest students

Statistics	Pretest	Posttest
Ideal Score	25	25
Maximum Score	12	25
Score Minimum	5	17
Average score	6.90	20.17
Standard Deviation	1.88	2.39
Amount of Data	30	30

There was an increase in students' understanding of physics concepts after learning with PhET simulation media based on the PBL model. This increase reflects a positive change in students' understanding of physics concepts following participation in the learning process. The standard deviation value also increased, indicating a greater variation in scores on the posttest. In general, the learning applied has proven to be effective.

Categorization of Physics Concept Comprehension Scores for Students in Grade XI-2 SMAN 20 Gowa

The results of categorizing students' levels of understanding of physics concepts in sound wave material, based on the pretest results, are presented. This categorization aims to describe the distribution of students' initial understanding before being given learning treatment. Table 4 presents the categorization of students' understanding of physics concepts in grades XI-2 of SMAN 20 Gowa, based on the pretest results.

Table 4 Categorization of pretest scores for students' understanding of concepts

Interval	Category	Frequency	Percentage (%)
21 - 25	Excellent	0	0
16 - 20	Good	0	0
11 - 15	Enough	3	10
6 - 10	Less	21	70
0 - 5	Very less	6	20

Based on Table 4, the results of the pretest indicate that most students fall into the low category in understanding physics concepts. Of the total 30 students, 21 (70%) were in the poor category, and 6 (20%) were in the very poor category. Meanwhile, only three students (10%) were in the sufficient category, and no students were included in the good or very good category. This makes it clear that most students have not understood sound wave material well before being given learning with the help of PhET simulation media, so a more supportive approach is needed to help students understand physics concepts as a whole. These findings are reinforced by research by Puri & Perdana (2023), which explains that the low results of the pretest of students' concept understanding in Bantul are caused by the fact that the material has not been taught before the test is carried out, so that students do not have a sufficient knowledge base.

Furthermore, the posttest results obtained after the learning activities reflect the level of understanding of students' physics concepts regarding sound waves following the treatment. The categorization of these results aims to provide an overview of the extent of improvement in

understanding that occurs compared to the pretest results. Table 5 presents the categorization of students' understanding of physics concepts in grades XI-2 of SMAN 20 Gowa, based on the posttest results.

Table 5 Categorization of posttest scores for students' concept understanding

Interval	Category	Frequency	Percentage (%)
21 - 25	Excellent	11	36.7
16 - 20	Good	19	63.3
11 - 15	Enough	0	0.0
6 - 10	Less	0	0.0
0 - 5	Very less	0	0.0

Based on Table 5, the posttest results show that all students have improved their understanding of physics concepts in a better direction. Student achievement is concentrated in the top two categories, namely good and excellent, which visually show learning success with a positive distribution. There are no more students in the lower category, while emphasizing that PhET simulation media has a real impact in lifting all students to a higher level of concept understanding. These results are in line with research by [Bangun et al. \(2024\)](#), which, in its research on light wave materials, found that PhET simulation-assisted learning has been proven to be more effective than direct learning.

International studies conducted by Banda further support these findings. In contextual research in Malawi, [Banda & Nzabahimana \(2023\)](#) reported that the use of PhET simulations significantly enhanced student learning outcomes and motivation in the topic of waves and oscillations. Meanwhile, in a systematic review of 31 quasi-experimental and experimental studies, [Banda & Nzabahimana \(2021\)](#) showed that the application of PhET simulations consistently has a positive impact on improving understanding of concepts in active physics learning. Both publications confirm that the effectiveness of PhET applies not only in specific contexts but also in broader cross-research studies.

Understanding the Concept of Students by Indicator

The following is an analysis of each indicator of students' understanding of physics concepts as a whole based on the results of the pretest and posttest in class XI-2 SMAN 20 Gowa. This analysis aims to determine the extent to which students understand each concept indicator. Figure 1 presents a bar chart of the percentage of pretest and posttest scores on each indicator of understanding the physics concept of students in grades XI-2 of SMAN 20 Gowa, specifically related to the sound wave material.

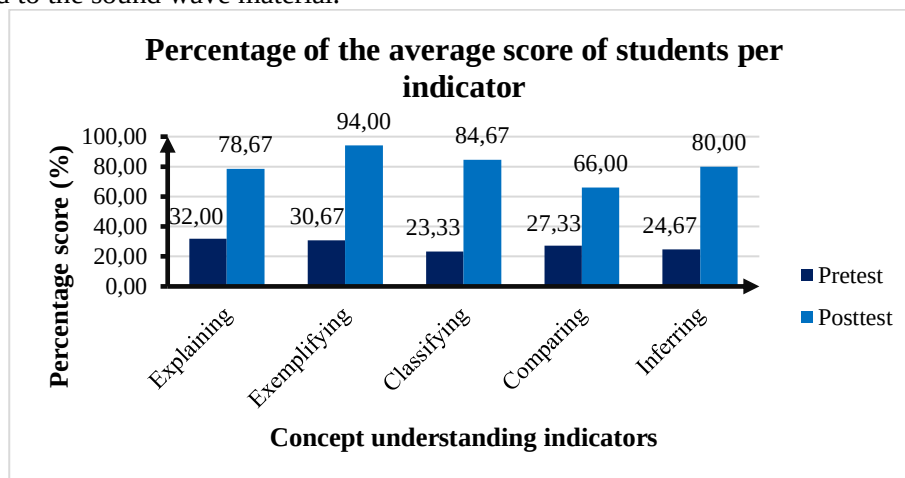


Figure 1 Percentage of average pretest-posttest scores per indicator

Based on Figure 1, it can be seen that all indicators of students' concept understanding have increased significantly from pretest to posttest after learning using PhET simulation media. In the indicator, he explained, the achievement of students increased from 32% to 78.67%. The exemplifying indicator experienced the highest increase, from 30.67% to 94%, indicating that students were able to relate physics concepts to real-world examples more effectively after learning. The classification indicator increased from 23.33% to 84.67%, indicating a significant improvement in understanding the concepts studied and distinguishing and classifying phenomena accordingly. Furthermore, the comparative indicator showed an increase from 27.33% to 66%. This indicates that students are starting to be able to see the differences and similarities between concepts better. Finally, the concluding indicator also experienced a significant increase, from 24.67% to 80%, which demonstrates the students' ability to formulate conclusions based on the results of observation and concept understanding. This proves that PhET media learning is able to increase students' understanding of concepts in all indicators.

The results of the research showed a significant increase in all indicators of students' concept understanding after PhET and LKPD simulation-based learning. In the indicator explanation, students who were initially only able to give simple answers began to relate the length of the string to the frequency and understand the influence of the physical characteristics of the sound source on the waves. In the indicator example, the answer that was originally common became a concrete example within the context, such as the sound of a train on the rails or a conversation in the classroom, thanks to the visualization of the difference in the medium in the simulation. In the classification indicator, students can distinguish events that demonstrate the Doppler effect precisely, such as the sound of an ambulance or an airplane moving relative to the listener. In the comparison indicator, they are no longer just descriptive but are able to explain the difference in sound propagation in quiet and disturbed media. Meanwhile, the indicator of inference, which initially only reiterated the problem, evolved into a comprehensive explanation that linked the power of the sound source, sound strength, distance, and energy per unit of time. Overall, as shown in Figure 2, PhET simulation-based learning encourages the development of students' understanding of concepts as a whole, from initial understanding to conclusion, through the visualization of physical phenomena and real-world context-based problem-solving.

N-Gain Analysis

An N-Gain test was conducted to determine the increase in scores from pretest to posttest. The N-Gain score obtained is then categorized into three classifications, namely high, medium, and low. This categorization aims to see the distribution of the level of improvement in concept understanding in each student. The distribution of frequencies and percentages of the results from categorizing the N-Gain score is presented in Table 6.

Table 6 Categorization of learners' n-gain scores

Range	Category	Frequency	Percentage (%)
$\langle g \rangle > 0.7$	High	14	46.67
$0.3 \leq \langle g \rangle \leq 0.7$	Medium	16	53.33
$\langle g \rangle < 0.3$	Low	0	0

Table 6 shows that none of the students were in the low N-Gain category. Then, as many as 16 students (53.33%) were in the medium category, and 14 students (46.67%) were in the high category. Based on calculations, an average N-Gain of 0.74 was obtained, which is included in the high category. This data shows that all students experience an increase in concept understanding. These results are in line with the research of [Abdi et al. \(2021\)](#), which also demonstrated an increase in concept understanding in the experimental class through the use of PhET simulations, with a gain value of 0.6, higher than that of the control class at 0.5.

The application of PhET simulation media shows a strong contribution to improving students' understanding of concepts on sound wave material. Before learning, students demonstrate a limited understanding, characterized by difficulties in explaining abstract concepts and relating physical phenomena to real-life situations. This is understandable considering that the material has not been formally taught.

After the learning took place, students' conceptual understanding showed a notable improvement. They began to be able to explain concepts better, provide contextual examples, and classify physical phenomena appropriately. Simulation-based learning helps students visualize previously unimaginable phenomena, such as sound propagation and the Doppler effect, making their understanding more concrete and meaningful.

The results of this research are consistent with those of [Agustini et al. \(2018\)](#), who reported that employing PhET-based Virtual Lab media proved to be considerably more effective in enhancing students' understanding of physics concepts compared to conventional learning media at SMAN 1 Marioriwawo. Students who learned with virtual simulations showed higher average comprehension scores and appeared more active and enthusiastic when conducting experiments, as they were able to observe and manipulate concepts visually through PhET.

Based on the N-Gain analysis, the mean score obtained was 0.74, which falls into the high category. There are no students in the low category. As many as 46.67% of students are classified as high N-Gain, and another 53.33% are in the medium category. These findings indicate that all students experience an increase in conceptual understanding after learning, although the level of achievement varies.

The increase in students' conceptual understanding can be attributed to the characteristics of the PhET simulation media itself. PhET provides dynamic visualizations and interactive simulations that make abstract physics concepts more concrete and easier to understand. Through real-time manipulation of variables such as frequency, amplitude, and medium, students can directly observe the causal relationship between physical quantities and wave phenomena. This interactive experience enables students to build mental models of the concepts, which enhances their ability to explain, classify, and compare physical events more accurately.

In this research, the improvement was particularly significant in the "exemplifying" and "classifying" indicators. This is because PhET enables students to observe how sound waves behave under various conditions, thereby helping them connect theoretical concepts with real-world examples. The visualization of sound propagation also supports students in identifying and differentiating phenomena, such as the Doppler effect, more clearly. Meanwhile, during problem-based learning activities, students worked collaboratively to test hypotheses through the simulation, which strengthened their understanding of the "explaining" and "concluding" indicators. These findings suggest that PhET media not only provides visual support but also acts as an active learning tool that guides students through conceptual exploration and reasoning.

These results are in line with the research of [Bangun et al. \(2024\)](#), which reported that PhET-assisted PBL models on light wave materials resulted in higher N-Gain scores (0.70) than in-person learning (0.49), reinforcing that PhET integration can improve conceptual understanding even in more complex physics materials. Support for these findings also comes from [Agustina et al. \(2025\)](#), which shows an increase in the average score from 55 to 80, with an N-Gain score of 0.65 (medium category), indicating that the PhET simulation is effective in improving students' understanding of concepts, particularly in the context of sound wave material.

PhET media provides an interactive learning experience, where learners not only receive information but also engage in the process of exploration and investigation through problem-based LKPD. This process encourages students to actively build knowledge through observation, group discussions, and drawing conclusions. Thus, learning becomes more contextual and is not limited to mere memorization.

The PBL learning model also plays an important role in this improvement. Each syntax in PBL, from problem orientation to group investigation to presentation of results, is designed to train students' critical thinking skills. When combined with PhET simulation media, this model provides an ideal platform for learners to explore concepts in depth and systematically.

The students' progress in understanding concept indicators, such as explaining, modeling, classifying, comparing, and concluding, shows that this combination of methods is effective in overcoming difficulties in understanding physics concepts. The simulation and discussion process not only improves learning outcomes but also shapes scientific skills relevant to 21st-century learning.

These findings suggest that physics learning can be more effective and meaningful if supported by appropriate visual media and active learning strategies. With the right approach, students are not only able to understand concepts but also develop a scientific mindset for solving real-world problems.

CONCLUSION

Based on the results of the analysis and discussion, it can be concluded that before the application of PhET simulation media, students' understanding of physics concepts was in the low category, shown by the initial ability that was still limited in explaining, exemplifying, classifying, comparing, and concluding the concept of sound waves. After applying PhET simulation media in problem-based learning, there was an increase in overall concept understanding across all indicators, characterized by a more concrete and contextual understanding of the material among students. Overall, there was a significant increase in students' understanding of physics concepts after learning, indicating that PhET simulation media effectively supported physics learning, particularly in the area of sound waves. The implications of this research suggest that PhET simulation media can serve as an effective alternative for enhancing students' conceptual understanding of physics, particularly in the context of sound waves. This media also has the potential to be more widely applied in schools with limited laboratory facilities, ensuring that the learning process remains interactive and meaningful. However, this research has certain limitations, as it involved only one class as the research sample, which means the findings cannot be generalized broadly. In addition, the computer laboratory, which was expected to support the learning process, was unavailable at several sessions, requiring students to access the simulation through smartphones with limited display and interaction comfort.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

The authors' contributions to manuscript preparation are defined by the following criteria: conceptualization, methodology, formal analysis, writing—preparation of the original draft, writing the manuscript, and others.

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