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Development of Live-Worksheets Technology based on the Problem Based Learning Model in the Horeg Sound Wave Phenomenon

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ABSTRACT

Objective: *Developing interactive Live-Worksheets based on Problem-Based Learning (PBL) on physics material with a contextual phenomena approach.* ***Method:*** *This research is a Research and Development (RnD) study. This type of research uses the 4D method, which includes four stages: define, design, develop, and disseminate.* ***Results:*** *The results of developing live-worksheet technology based on the Problem-Based Learning model with the sound horeg phenomenon have proven to be valid and practical. The implementation of digital technology-based live worksheets using a problem-based learning model has been proven to increase student learning independence and enthusiasm through real-world phenomena such as sound waves. Looking ahead, the integration of intelligent technologies such as AI, VR, and virtual simulations has the potential to strengthen interactive, contextual, and practice-oriented physics learning.* ***Novelty:*** *The integration of technology and problem-based learning models can encourage students to generate new ideas from the problems presented. The use of AI technology in integrated learning media is crucial, and innovation in ethnoscience approaches is needed.*

INTRODUCTION

In an era of rapidly advancing technology, education must adapt to digital developments while simultaneously instilling 21st-century skills, particularly problem-solving (Avdiu et al., 2025). The integration of technology into the learning process serves not only as a tool but also as a means to build more interactive, contextual, and meaningful learning experiences (Saputra et al., 2025). In this context, the application of technologies such as Live-Worksheets is expected to provide students with space to actively participate, explore phenomena, and develop critical and analytical thinking skills through a problem-based learning approach (Sari & Jusra, 2023).

Learning physics as a branch of science plays a crucial role in fostering strong conceptual understanding (Munfaridah et al., 2021). By applying innovative, student-centered learning technologies, it is hoped that students will not only understand physics concepts theoretically but also relate them to real-world phenomena, such as sound waves in the context of Sound Horeg (Lintangesukmanjaya et al., 2025). Therefore, the development of Live-Worksheets technology grounded in the Problem-Based Learning model is a strategic step toward strengthening students' scientific literacy, creativity, and problem-solving skills in the digital era.

Although advances in educational technology have brought many interactive learning innovations, the learning process in schools is still dominated by conventional lecture-and-practice methods (Tuma, 2023). This learning pattern tends to make students passive and less engaged in the scientific thinking process (Rafiq et al., 2023). As a result, opportunities for students to develop critical thinking and problem-solving skills are limited.

This condition is also seen in physics learning, where students often only focus on mastering formulas without understanding the basic concepts underlying them (Lichtenberger et al., 2025). This results in low levels of problem-solving skills among the younger generation, particularly in linking physics concepts to real-world phenomena in their surroundings (Verawati & Nisrina, 2025). Therefore, efforts are needed to develop innovative learning models that increase active student participation and foster higher-order thinking skills by integrating relevant digital technologies.

Based on results from several previous studies, students' problem-solving abilities and learning evaluation instruments in physics remain relatively low, with only around 7.9% achieving optimal levels (Sundari et al., 2025). This indicates that most students are unable to connect physics concepts to their real-world applications. This condition indicates that the applied learning approach still focuses on memorizing formulas and solving routine problems, rather than developing students' higher-order thinking skills and analytical abilities. This occurs because physics is one of the subjects with a high level of difficulty, both in terms of concept and application (Dahlkemper et al., 2023). Many students have difficulty understanding the relationship between theory and real phenomena because learning still rarely utilizes a contextual approach. The limited application of innovative learning models such as Project-Based Learning (PBL), Inquiry Learning, or Problem-Based Learning (PBL) makes the physics learning process less meaningful. As a result, students tend to only memorize formulas without understanding the physical meaning behind the phenomena they observe.

One relevant model for addressing these issues is Problem-Based Learning (PBL). PBL is a student-centered learning model in which the learning process begins with the presentation of a real-world problem that encourages students to think critically, seek information, and find solutions independently and collaboratively (Ni'mah et al., 2024). Through the stages of problem orientation, data collection, analysis, and reflection, students are trained to construct their own knowledge, rather than simply receiving information from the teacher. Implementing PBL in physics learning is expected to help students understand concepts more deeply, relate theory to everyday life contexts, and develop higher-order thinking skills in solving scientific problems.

The integration of technology into the Problem-Based Learning (PBL) model is a crucial step in increasing the effectiveness and appeal of physics learning. The use of technology serves not only as an aid but also as a means to facilitate students' independent exploration, analysis, and problem-solving (Dai, 2021). One relevant innovation is Live-Worksheet, an interactive web-based platform that enables teachers to transform conventional worksheets into a responsive, engaging digital format. Through Live-Worksheets, students can practice problems, explore concepts, and receive immediate feedback, making the learning process more dynamic, interactive, and efficient.

The advantage of Live-Worksheets lies not only in their interactivity but also in their ability to accommodate contextual problem-based learning. By linking the PBL model with the use of Live-Worksheets, teachers can present real-world phenomena, such as sound waves (Sound Horeg), as challenging problems for students to solve. This integration enables students to learn meaningfully because they not only understand physics concepts theoretically but also apply them to everyday situations (Harefa, 2024). Thus, the development of PBL-based Live-Worksheets technology is a strategic innovation in creating interactive, contextual physics learning that is oriented towards developing students' critical thinking skills (Kem, 2022).

This research aims to develop interactive Live-Worksheets based on Problem-Based Learning (PBL) for physics material, using a contextual phenomenon approach. One of the phenomena raised in this research is Sound Horeg, which is a term often used by the public to describe noisy and rumbling sounds that arise due to resonance or reflection of sound waves in closed spaces, such as in schools, places of worship, or concert halls. This phenomenon is a real example of the application of the concept of sound waves in everyday life that can be used as a learning resource to improve the understanding of physics concepts in a more applicable and meaningful way.

The development of PBL-based Live-Worksheets within the context of Sound Horeg is expected to be an innovative digital media alternative that supports 21st-century learning. Through this integration, students can actively participate in the learning process, practice critical thinking, and develop independence in solving scientific problems. Furthermore, this research aims to encourage the application of local phenomena in physics learning, enabling students to see the direct connection between scientific concepts and the realities of their environment. Thus, the developed product is not only academically relevant but also contextual, adaptive to technological advances, and oriented towards strengthening students' scientific literacy.

RESEARCH METHOD

Types of research

This research is a Research and Development (RnD) study. This type of research is a method used to produce a specific product or media, which is then tested for its effectiveness (Putra et al., 2025). This research uses the 4D method, which includes four stages: define, design, develop, and disseminate.

Figure 1. Research design using the 4D method

The research sample for product dissemination comprised 108 eleventh-grade high school students in Lamongan Regency. This research procedure followed the 4D development stages: Define, Design, Develop, and Disseminate. In the Define stage, an analysis of students' initial needs and problem-solving skills was conducted. This aimed to determine the extent to which the live-worksheet media to be developed could be helpful to and suited to their potential. Second, in the Design stage, an initial draft of the live-worksheet was prepared, including components of learning outcomes, objectives, and work steps as a development guide. At this stage, an experimental format was also designed, adapted to the PBL syntax.

Table 1. Syntax PBL (Stepien & Gallagher, 1993; Gallagher, 2015, 2023).

Stage	PBL Syntax	Description of Learning Activities
1	Student orientation towards problems	Teachers present real-life situations or problems relevant to everyday life to foster students' curiosity and interest in learning. The problems presented are open-ended and challenging, encouraging students to think critically, search for information, and find alternative solutions through scientific exploration.
2	Organizing students to learn	The teacher directs students to identify the core of the problem, formulate key questions to be answered, determine learning objectives, and design the steps for activities to be taken in an effort to find a solution to the problem being studied.
3	Guiding student investigations individually and in groups	The teacher acts as a companion and facilitator, guiding the investigation. Meanwhile, students explore independently or in groups through activities such as experiments, information gathering, and data analysis to develop a conceptual understanding of the problem being studied.
4	Develop and present work results	Students organize their research findings into various formats, such as written reports, presentations, or products that illustrate their understanding of the concepts and solutions to the problems being studied. The teacher then provides constructive feedback to deepen their learning and improve their scientific communication skills.
5	Analyze and evaluate the problem solving process	The teacher and students reflect on the entire learning process, review the effectiveness of the problem-solving strategies used, and identify physics concepts that have been mastered and

	those that still need improvement. This reflection activity encourages students to assess their learning progress critically, fosters independent learning, and develops higher-order thinking skills essential for understanding scientific phenomena in depth.

The development stage involves an expert validation process to determine the media's validity. The valid criteria determine the validity value if the percentage obtained is greater than 50%. Meanwhile, the dissemination stage also aims to assess the practicality of the live-worksheet product using student questionnaire responses. These four stages must be carried out systematically to produce a valid and practical live-worksheet based on the Problem-Based Learning (PBL) learning model, supported by the sound horeg phenomenon in physics learning..

RESULTS AND DISCUSSION

Results

In the define stage, an analysis of student needs was conducted in accordance with the research objectives to develop a technology-integrated live-worksheet that applies wave phenomena to sound horeg. It is known that the sound horror phenomenon is often found in several regions, especially in East Java. This phenomenon and activity are already well known in society; even the current younger generation really enjoys the sound of horog. From interviews and observations, it was found that physics learning is still rarely responsive to societal contexts and is not well linked to problem-based learning. Supported by the minimal use of digital learning media in schools.

In the second stage, the design process involves integrating community phenomena or activities into the learning process, incorporating problem-solving values. Live worksheets based on the problem-based learning model of the Horeg sound wave phenomenon are designed as a mobile app for ease of use.

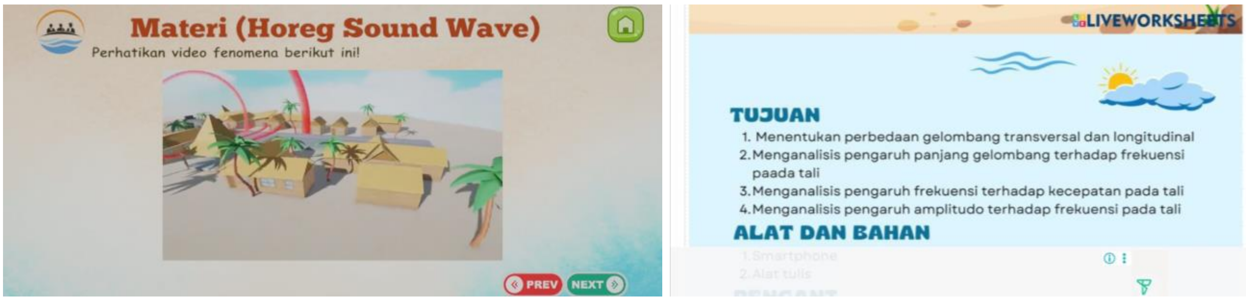

Figure 2. Design based on technology

The next stage is development. The results of the live worksheet can be developed and submitted for validity to three expert validators in their respective fields. Validity is obtained from the content, construction, and display aspects, resulting in the following data:

Table 3. Validation Results

Aspect	Rating Points	Average score of 3 validators	Aspect Value	Reliable (%)	Validity category
Content	Compliance with physics wave learning	3.67	3.53	89	Very Valid
	Use of PBL syntax in worksheets	3.67		88	
	Compilation of contextual material related to the sound horeg phenomenon	3.67		92	
Construction	Systematic arrangement	4.00	3.61	80	Very Valid
	The use and integration of technology supports learning outcomes	3.67		93	
	The learning flow is clearly structured	3.67		93	
Appearance	The quality of the graphics and images used is clear	3.67	3.67	92	Very Valid
	The use of simulation in worksheets is clear	3.33		94	
	The worksheet is attractive in terms of appearance and visualization.	4.00		82	

Based on the results of the expert validation table from the three, the percentage results were obtained with a very valid category so that the live-worksheets that had been created could be tested according to the improvements as suggested.

Discussion

The practicality of live-worksheets based on the Problem-Based Learning (PBL) learning model, grounded in the sound horeg phenomenon, was analyzed through observation sheets documenting learning implementation, including teacher and student activities. The integration of technology into the results of observations of the implementation of teacher learning activities on the developed worksheets showed that the percentage of teacher learning validity scores met the validity criterion of "very valid. Meanwhile, the results of observations of student learning activities showed that the percentage of student activity scores was efficient. The development of live-worksheets based on the Problem-Based Learning model, with the sound horeg phenomenon in the developed physics wave learning, can attract students' interest in learning physics (Harmita et al., 2023). The integration of technology into mobile-based learning can change lessons (Hagos & Lemma). Problem-Based Learning can encourage students to generate new ideas from the problems presented.

The application of digital technology in live worksheets provides significant opportunities for students to develop 21st-century skills, such as critical thinking, collaboration, and digital literacy (Rahmayani & Atmazaki, 2025). Through mobile devices and interactive platforms, students can actively participate in a dynamic, adaptive learning process (Kem, 2022). Technology enables the presentation of physics material, including sound wave phenomena, in easy-to-understand interactive visualizations (Aprilia & Romadhon, 2025). Furthermore, the instant feedback provided by the digital system helps students correct errors independently and enhance conceptual understanding (Torres-Peña et al., 2024). Thus, technology-based live worksheets serve not only as a learning medium but also as a means to develop higher-order thinking skills and foster independent learning.

The Problem-Based Learning (PBL) model focuses on presenting contextual problems that challenge students to think critically and creatively (Hafizah et al., 2024). In the context of sound waves, students are confronted with a real-world situation that requires them to analyze the causes and characteristics of the phenomenon using the concept of sound waves. Through PBL stages such as problem identification, information gathering, and solution formulation, students learn to apply physics concepts in a practical manner (Hidayati et al., 2024). This process encourages more profound conceptual mastery and systematic problem-solving skills (Amanda et al., 2022). Thus, PBL not only strengthens students' theoretical understanding but also fosters scientific thinking skills relevant to the real world.

The use of unique contextual phenomena, such as sound waves, when combined with cutting-edge technologies like Virtual Reality (VR) or virtual simulations in live worksheets, can create a more engaging and immersive learning experience. Through VR, students can directly “experience” sound-wave phenomena in an interactive, three-dimensional environment, thereby enhancing conceptual understanding and curiosity (Chen et al., 2024). Virtual simulations also allow students to conduct experiments that are difficult to conduct in a real laboratory, with flexible variable control and real-time visualization of results (Alnagrat et al., 2022). This technology integration not only enriches the context of physics learning but also increases student motivation, engagement, and retention of the material being taught (Prayogi & Verawati, 2024).

Going forward, the development of technology-based live worksheets can be enhanced by integrating Artificial Intelligence (AI) and practice-based learning approaches. AI can play a role in automatically analyzing student responses, recommending learning activities appropriate to their ability level, and providing adaptive feedback in real time (Strielkowski et al., 2025). Meanwhile, practice-based learning models allow students to apply their theoretical knowledge in real-world experiments or projects. The combination of the two will create a personalized, interactive, and competency-oriented learning system. With AI support, live worksheets will not only serve as a learning tool but also become an intelligent ecosystem that enhances the effectiveness of physics education in the digital era.

CONCLUSION

Fundamental Finding: The results of developing live-worksheet technology based on the Problem-Based Learning model with the sound horeg phenomenon have proven valid and practical. **Implication:** The integration of technology and the Problem-Based Learning model can encourage students to generate new ideas from the problems presented. **Limitation:** This research is limited to the use of 4D model design, with no implementation and no quantitative response results to support previous research. **Future Research:** The use of AI technology in the integration of learning media is essential and there needs to be innovation in the ethnoscience approach.

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AUTHOR CONTRIBUTIONS

Rahmatta Thoriq Lintangesukmanjaya contributed to the conceptual framework, research design, and validation process; **Oktamia Ramadhani** was involved in methodology development, data analysis, sourcing references, and drafting the manuscript; **Dwikoranto** handled data management, project coordination; **Noval Maleakhi Hulu** was manuscript drafting. All listed authors have reviewed and approved the final version of this submission.

CONFLICT OF INTEREST STATEMENT

There are no conflicts of interest.

ETHICAL COMPLIANCE STATEMENT

This manuscript complies with research and publication ethics. The authors affirm that the work is original, conducted with academic integrity, and free from any unethical practices, including plagiarism.

STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING

The authors acknowledge the use of digital tools, including AI-based technologies, as support in the research and writing stages of this article. Specifically, Grammarly was employed for generated and paraphrase. All outputs generated with digital assistance were critically evaluated and revised to ensure academic rigor and ethical standards were upheld. The final responsibility for the manuscript rests entirely with the authors.

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