JPF | Volume 13 | Number 2 | 2025 | 206 - 224

p - ISSN: 2302-8939
e - ISSN: 2527-4015

Jurnal Pendidikan Fisika

https://journal.unismuh.ac.id/index.php/jpf

DOI: 10.26618/jpf.v13i2.17788

The Effect of Web-based Inquiry Physics Problems on High School Students' Physics Learning Outcomes

Fitria Herliana[1, 2*], Rini Mardila[2], Elmi Mahzum[2], Zainuddin[2], Agus Wahyuni[2], Elisa[2], Dewi Muliyati[3]

[1]Student of Doctoral Education Department, Universitas Syiah Kuala, Banda Aceh, 23111, Indonesia
[2]Physics Education Department, Universitas Syiah Kuala, Banda Aceh, 23111, Indonesia
[3]Science Education and Communication Department, University of Groningen, Groningen, 9700, The Netherland

**Corresponding author: fitriaherliana@usk.ac.id*

Received: January 26, 2025; Accepted: March 25, 2025; Published: April 29, 2025

Abstract – *Physics learning in high schools often faces challenges due to students' low conceptual understanding of abstract topics like sound waves. To address this challenge, this study investigates the effectiveness of Web-based Inquiry Physics Problems (WIPPer), an innovative learning platform that incorporates a problem-based learning approach within a blended learning framework. Using a pre-experimental one-group pretest-posttest design, the research was conducted on 20 eleventh-grade students at State Senior High School 2 Kuta Baro. Data were collected through a learning outcome test comprising 10 multiple-choice items (cognitive levels C1–C4), teacher and student response questionnaires, and observation sheets to monitor engagement throughout the WIPPer implementation. The results showed a medium average N-gain of 0.5116, with 70% of students achieving medium to high improvement categories. Observational analysis demonstrated 89% effectiveness across all learning phases. Teacher responses rated WIPPer as excellent (media: 93.33%, material and evaluation: 100%), while student responses were also highly favorable (media: 86.16%, material: 93.4%, evaluation: 90%). Cross-tabulation analysis revealed a strong correlation between student engagement and achievement, particularly in analytical activities. Students with high engagement demonstrated better ability in answering complex concept application questions (75.76%) compared to students with low engagement (16.67%). The novelty of this research lies in the integration of gradual assessment, virtual laboratory simulations, and adaptive feedback within a problem-oriented digital platform. This research concludes that WIPPer is a feasible and effective tool that enhances learning outcomes by fostering engagement and supporting independent learning. This research contributes to physics education by presenting WIPPer as a feasible and effective model that aligns with digital learning trends and supports the development of adaptive, student-centered instructional approaches.*

Keywords: *blended learning; learning outcomes; problem-based learning; web-based learning; WIPPer*

I. INTRODUCTION

Physics is an essential subject in secondary education aimed at developing students' analytical and problem-solving abilities, which are highly needed in the digital era to understand complex information, adapt to technology, and face challenges creatively. Based on Regulation No. 207/P/2022, high school physics education emphasizes developing the Pancasila student profile through conceptual understanding, scientific skills, and real-life application. This is reinforced by the Minister of Education, Culture, Research, and Technology Decree Number 56/M/PK/2022, which highlights the importance of learning recovery using adaptive and innovative approaches.

Despite clear regulations concerning physics competency standards, actual student learning outcomes remain suboptimal. Previous research revealed that only a small percentage of students truly understand wave concepts: 13% for rope waves, 14% for spring movements, 9% for water waves, and only 6% for wave properties (Devy et al., 2022). Similar findings emerged from a preliminary study at State Senior High School 2 Kuta Baro in March 2024, where students' average pretest score on wave material was merely 22.5 out of 100. Atlabachew & Kriek (2024) identified that students struggle with focusing attention and applying physics formulas in problem-solving. Observations of student engagement such as question-asking, participation in discussions, and task completion also indicated low active involvement, resulting in superficial conceptual understanding.

This gap between expectations and reality is attributed to several factors: limited conceptual understanding due to insufficient engagement, the predominance of conventional teaching methods that fail to visualize abstract concepts, and the underutilization of web-based learning media. Limited engagement and the need for interactive learning activities contribute to low conceptual mastery (Apsari et al., 2023; Kamaruddin et al., 2024). Conventional methods inadequately facilitate meaningful learning experiences. Research in Indonesian high schools shows that web-based learning media can increase student engagement by up to 78% and conceptual understanding by up to 82% (Mardianti et al., 2023). Failure to address these issues risks graduates lacking the competence to face digital-era challenges.

Web-based Inquiry Physics Problems (WIPPer) offers an innovative solution integrating constructivist theory and Problem-Based Learning (PBL). Unlike linear conventional web-based media, WIPPer promotes knowledge construction through authentic problem-solving with step-by-step evaluations and virtual experiment guides. The PBL model in WIPPer includes five stages: problem orientation, learning organization, investigation guidance, results presentation, and problem-solving evaluation (Herliana et al., 2024).

WIPPer is implemented in a blended learning environment that integrates face-to-face and online learning. Blended learning comprises three complementary components: synchronous face-to-face, synchronous online, and asynchronous online learning (Graham, 2018). This approach facilitates classroom experiments and discussions while enabling independent concept exploration and evaluation online. Research indicates that well-designed blended learning enhances flexibility, independence, and personalized learning (Spatioti et al., 2022).

WIPPer's gradual evaluation features address students' difficulties incrementally, while virtual experiment guides aid the visualization of abstract concepts and boost active engagement. This approach has proven effective in improving metacognition and problem-solving skills (Izzati, 2021). Validation showed WIPPer's high feasibility with Aiken V scores of 0.867 for materials and learning design and 0.805 for media (Herliana et al., 2024). Other studies confirm that web-based media aligned with PBL principles enhances physics learning effectiveness (Chimmalgi et al., 2022; Pratami et al., 2023).

Given WIPPer's potential and the urgency to improve physics learning quality, this study aims to analyze its influence on high school students' physics learning outcomes. The goal is to increase student achievement to meet at least the minimum completeness criteria of 75, with 80% of students expected to reach or exceed this benchmark. Unlike previous media development research, this study evaluates WIPPer's effectiveness in real learning contexts. Najib et al. (2022) found that blended learning improves efficiency and understanding. The results are expected to provide empirical evidence supporting web-based, problem-based blended learning and contribute to developing adaptive physics learning strategies aligned with technological advancements. Successful WIPPer implementation at State Senior High School 2 Kuta Baro can serve as a model for technology-based physics education across other schools in Aceh and aid provincial efforts to enhance physics learning quality.

II. METHODS

This study employed a pre-experimental design using a one-group pretest-posttest approach. In this design, initial measurements (pretest) were conducted on the research subjects, followed by an intervention involving learning through WIPPer, and concluded with final measurements (posttest). The design's limitation is the absence of a control group; however, it was chosen because it aligns with the research objective of measuring the extent of learning improvement after WIPPer implementation, analyzed using normalized gain (N-gain). The study was conducted at State Senior High School 2 Kuta Baro, involving 20 eleventh-grade students selected by purposive sampling based on device accessibility and prior experience with web-based physics learning.

Data collection involved three primary instruments. First, a learning outcome test consisting of 10 multiple-choice questions with cognitive levels C1–C4 on sound wave material was administered before (pretest) and after (posttest) the implementation of WIPPer. Second, response questionnaires measuring the practicality of media were given to 2 physics teachers and 20 students, covering aspects of media, materials, and evaluation. Third, observation sheets were used to assess the implementation process of WIPPer during learning. All instruments were validated by three experts prior to use.

The research procedure was divided into three stages. The first stage involved administering the pretest to measure initial student abilities. The second stage implemented WIPPer within a blended learning approach incorporating the PBL model. Implementation followed five PBL stages: problem orientation, learning organization, investigation guidance, development of work results, and problem-solving evaluation (Ali et al., 2023; Septiana et al., 2023). The third stage was administering the posttest to measure learning outcomes after WIPPer implementation. The research flow is illustrated in Figure 1.

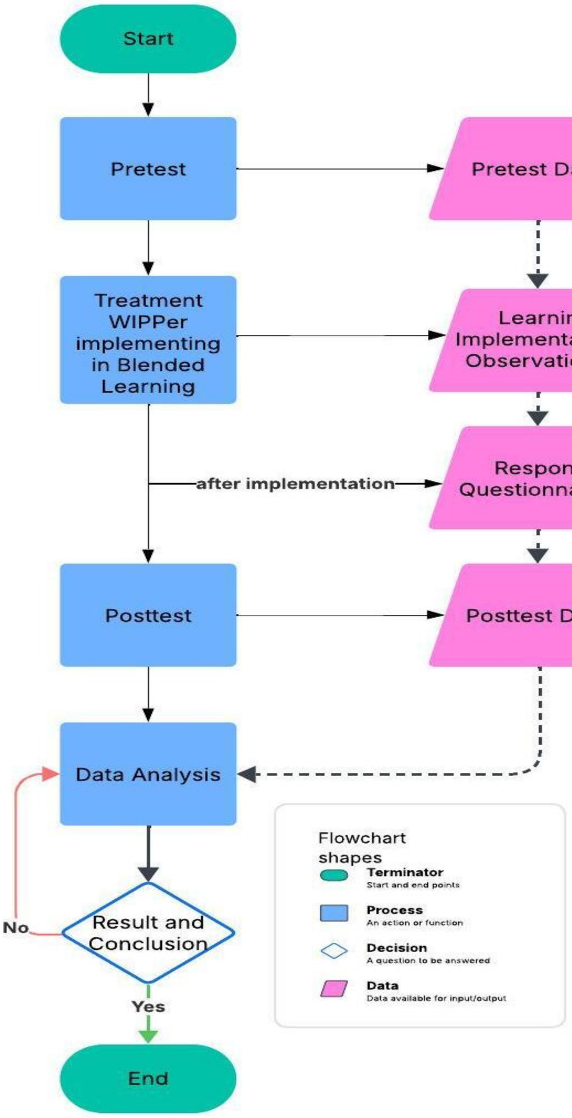


Figure 1. Flowchart of pre-experimental research procedure in this study

Data were analyzed using descriptive statistics. The effectiveness was measured by calculating normalized gain (N-gain) using the formula:

$$\mathrm{N-gain} = \frac{(\mathrm{Spost} - \mathrm{Spre})}{(\mathrm{Smax} - \mathrm{Spre})} \qquad 1)$$

Where S-post is the posttest score, S-pre is the pretest score, and S-max is the maximum score. N-gain results were categorized into three levels as shown in Table 1.

Table 1. Interpretation categories for N-gain scores

No	Score	Category
1	$(g > 0.7)$	High
2	$(0.3 \leq g \leq 0.7)$	Medium
3	$(g < 0.3)$	Low

Teacher and student responses, as well as learning implementation data, were analyzed descriptively using percentage formulas:

$$P = \left(\frac{\Sigma x}{\Sigma xi}\right) \times 100\% \qquad 2)$$

Where P is the response percentage, Σx is the total score obtained, and Σxi is the maximum total score. The results of the response questionnaire percentages were categorized using the criteria as shown in Table 2.

Table 2. Criteria for interpreting response questionnaire scores

No	Score	Category
1	(81-100%)	Very good
2	(61-80%)	Good
3	(41-60%)	Adequate
4	(21-40%)	Poor
5	(0-20%)	Very poor

Meanwhile, the percentage results of the observation sheets to measure student engagement were categorized using the criteria as shown in Table 3.

Table 3. Categories of student engagement levels based on observation scores

No	Score	Category
1	(80-100%)	High
2	(60-79%)	Medium
3	(<60%)	Low

Finally, cross-tabulation analysis was employed to explore relationships between learning outcomes and aspects of WIPPer implementation. This included cross-analysis between N-gain scores and student engagement levels, as well as between learning indicators and participant responses. This method allowed for the identification of trends and correlations that inform both the evaluation and future refinement of WIPPer as a web-based instructional tool (Greenacre, 2015).

III. RESULTS AND DISCUSSION

The impact of WIPPer on student learning outcomes was analyzed through two main aspects: the improvement in learning outcomes and the implementation of WIPPer-based learning. The N-gain analysis showed an average of 0.5116, classified as medium. The distribution of student N-gain scores revealed varied patterns: 4 students achieved the high category (N-gain > 0.7), 10 students were in the medium category (N-gain between 0.3 and 0.7), and 6 students fell into the low category (N-gain < 0.3). Figure 2 shows the distribution of N-gain scores, illustrating the variability in student learning improvements after using WIPPer.

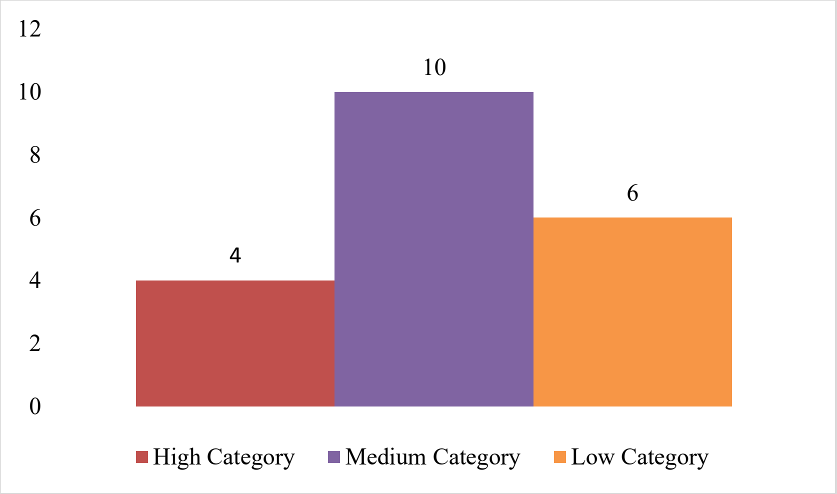


Figure 2. Distribution of n-gain scores for students' physics learning outcomes

The data in Figure 2 confirms that while WIPPer positively influences learning outcomes, its impact varies based on student engagement. These findings support Hrytsenko et al. (2024), who reported that integrating web-based learning media with blended learning can enhance students' understanding of physics concepts, with an average N-gain of 0.54. A detailed analysis showed that students in the high category experienced significant score increases from pretest to posttest, averaging from 20 to 80. This suggests that WIPPer is highly effective for students who actively utilize self-learning features and participate in face-to-face discussions. Conversely, students in the low category generally exhibited minimal improvement, from 20 in the pretest to only 40 in the posttest. This aligns with Chen & Cheng (2020) findings that success in blended learning depends largely on student independence and active use of digital learning resources.

An item-by-item analysis revealed that questions 4, 8, and 9 were most frequently answered incorrectly. Figure 3 shows that these three questions require applying sound wave concepts in more complex contexts, such as the Doppler effect in daily life, and analyzing relationships between variables in sound wave propagation. This difficulty highlights the need for reinforcement in concept application, suggesting that learning strategies should enrich student experience by presenting contextual examples and diverse problem-solving exercises (Reinke, 2019).

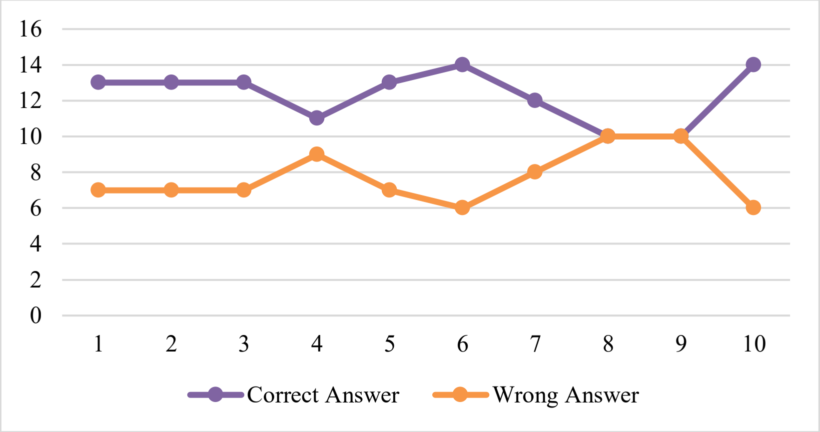


Figure 3. Distribution of students' answer results

The implementation of learning with WIPPer demonstrated effective application of the PBL model within a blended learning environment. Observations showed 89% implementation effectiveness across all learning aspects, covering initial, core, and closing activities in both synchronous and asynchronous modes. Learning activities were structured into three main stages: problem orientation via the online platform (Activity I), discussion and virtual experiments in face-to-face sessions (Activity II), and result analysis and conclusion drawing in both face-to-face and online settings (Activity III). The learning process concluded with an independent evaluation of understanding. Figure 4 illustrates the WIPPer dashboard interface, which facilitated access to content and learning activities.

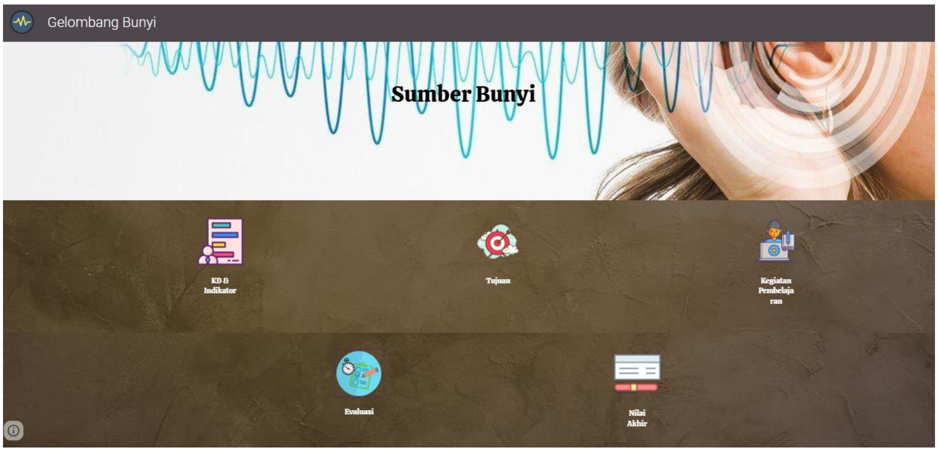
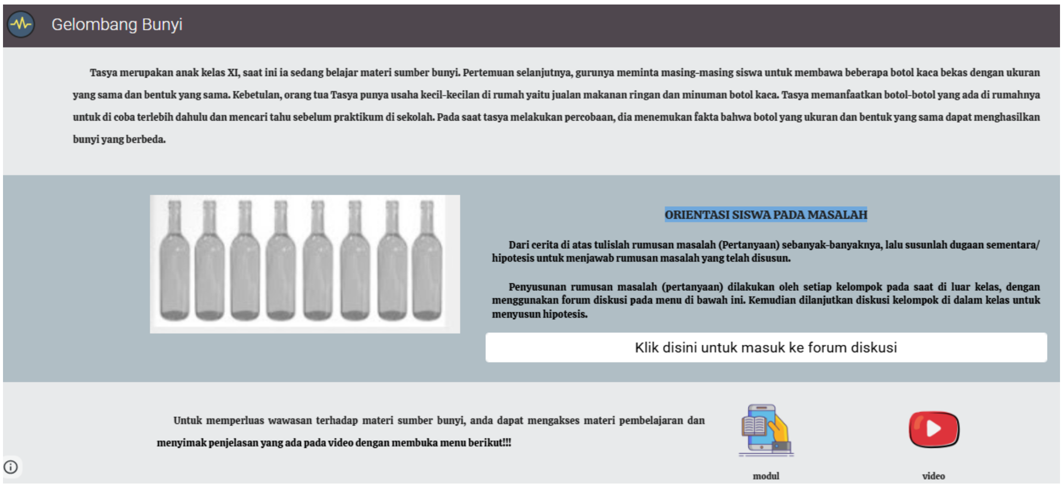


Figure 4. Dasboard of WIPPer

Implementation success was evident from systematic execution at each stage. In initial activities, students accessed learning objectives and initial materials online both during and outside class hours. The flexibility of blended learning allowed students to prepare better before face-to-face sessions (Spatioti et al., 2022). Core activities, including problem analysis, virtual experiments, and presentations, were optimally conducted in both learning modes. Closing activities such as drawing conclusions and evaluations also achieved high implementation, reflecting the effectiveness of WIPPer's feedback system.

Despite positive outcomes, the analysis identified areas needing improvement, particularly in providing scaffolding for complex problem-solving and motivating students with low independence. Web-based media should include gradual assistance and reward systems to maintain self-regulation and motivation (Martha et al., 2023). Blended learning success depends not only on technical implementation but also on the media's capacity to facilitate adaptive learning tailored to individual needs (Graham, 2018).

In the first learning stage (Activity I), students were introduced to problems and learning objectives through online videos and asynchronous tasks. Figure 5 presents Activity I in the WIPPer interface, showing students engaging with orientation materials outside classroom hours. Observation during activity I, which focused on group discussions about sound source material and the Doppler effect, revealed participation gaps. Students with low learning improvements tended to be passive in online and face-to-face discussions, relying on others and reluctant to engage in collaborative problem-solving due to low self-confidence and fear of errors. Active group participation is critical for concept understanding through exchanging ideas and experiences (Apriliani et al., 2024).



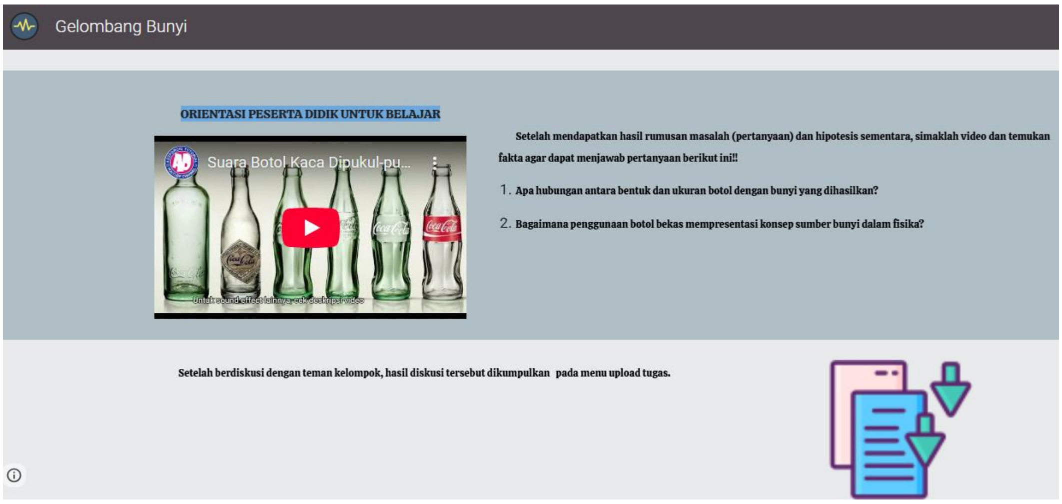
Tasya merupakan anak kelas XI, saat ini ia sedang belajar materi sumber bunyi. Pertemuan selanjutnya, gurunya meminta masing-masing siswa untuk membawa beberapa botol kaca bekas dengan ukuran yang sama dan bentuk yang sama. Kebetulan, orang tua Tasya punya usaha kecil-kecilan di rumah yaitu jualan makanan ringan dan minuman botol kaca. Tasya memanfaatkan botol-botol yang ada di rumahnya untuk di coba terlebih dahulu dan mencari tahu sebelum praktikum di sekolah. Pada saat tasya melakukan percobaan, dia menemukan fakta bahwa botol yang ukuran dan bentuk yang sama dapat menghasilkan bunyi yang berbeda.

ORIENTASI SISWA PADA MASALAH

Dari cerita di atas tulislah rumusan masalah (Pertanyaan) sebanyak-banyaknya, lalu susunlah dugaan sementara/ hipotesis untuk menjawab rumusan masalah yang telah disusun.

Penyusunan rumusan masalah (pertanyaan) dilakukan oleh setiap kelompok pada saat di luar kelas, dengan menggunakan forum diskusi pada menu di bawah ini. Kemudian dilanjutkan diskusi kelompok di dalam kelas untuk menyusun hipotesis.

Untuk memperluas wawasan terhadap materi sumber bunyi, anda dapat mengakses materi pembelajaran dan menyimak penjelasan yang ada pada video dengan membuka menu berikut!!!



ORIENTASI PESERTA DIDIK UNTUK BELAJAR

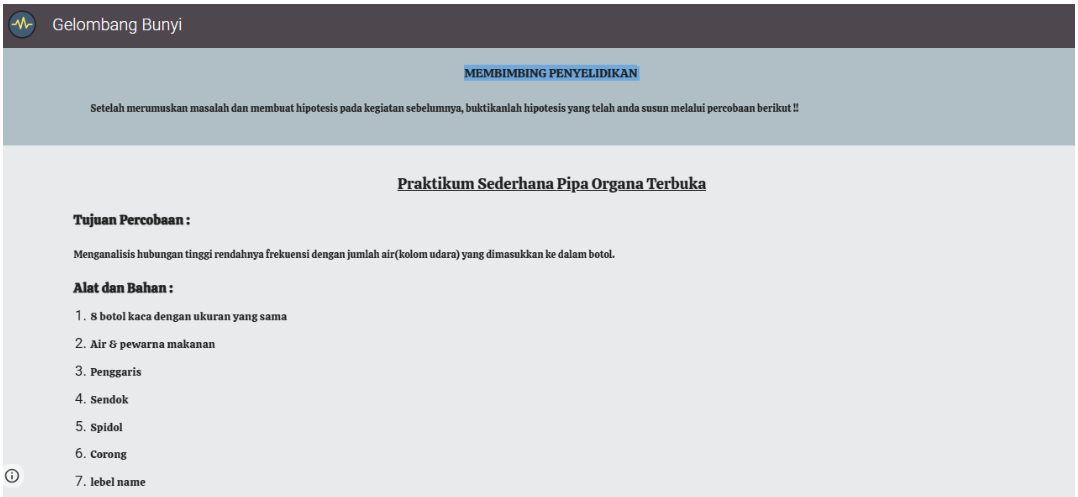
Setelah mendapatkan hasil rumusan masalah (pertanyaan) dan hipotesis sementara, simaklah video dan temukan fakta agar dapat menjawab pertanyaan berikut ini!!

1. Apa hubungan antara bentuk dan ukuran botol dengan bunyi yang dihasilkan?
2. Bagaimana penggunaan botol bekas mempresentasi konsep sumber bunyi dalam fisika?

Setelah berdiskusi dengan teman kelompok, hasil diskusi tersebut dikumpulkan pada menu upload tugas.

Figure 5. The activity I in WIPPer

The second stage (Activity II) involved virtual experiments and collaborative problem-solving. Figure 6 visualizes this activity, showing how students conducted simulations and face-to-face discussions. Observations showed a correlation between adherence to experiment procedures and learning achievement. Students with low learning gains often fail to follow experimental guidelines, resulting in irrelevant data. The discrepancy between experimental results and theoretical concepts hindered their complete understanding. This aligns with (Herliana et al., 2025), who emphasized the importance of consistency between practical experience and theory in physics learning.



MEMBIMBING PENYELIDIKAN

Setelah merumuskan masalah dan membuat hipotesis pada kegiatan sebelumnya, buktikanlah hipotesis yang telah anda susun melalui percobaan berikut !!

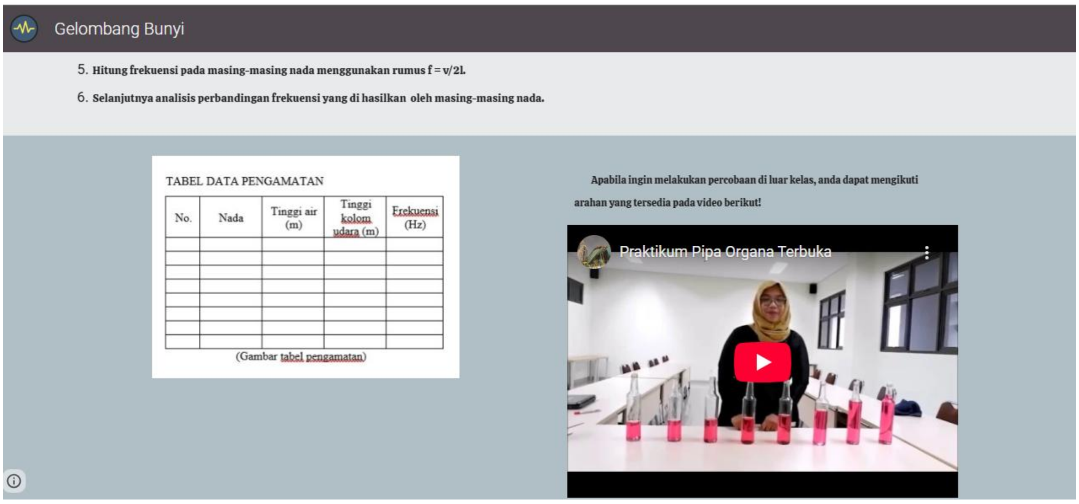
Praktikum Sederhana Pipa Organa Terbuka

Tujuan Percobaan :

Menganalisis hubungan tinggi rendahnya frekuensi dengan jumlah air(kolom udara) yang dimasukkan ke dalam botol.

Alat dan Bahan :

1. 8 botol kaca dengan ukuran yang sama
2. Air & pewarna makanan
3. Penggaris
4. Sendok
5. Spidol
6. Corong
7. lebel name



5. Hitung frekuensi pada masing-masing nada menggunakan rumus f = v/2l.
6. Selanjutnya analisis perbandingan frekuensi yang di hasilkan oleh masing-masing nada.

TABEL DATA PENGAMATAN

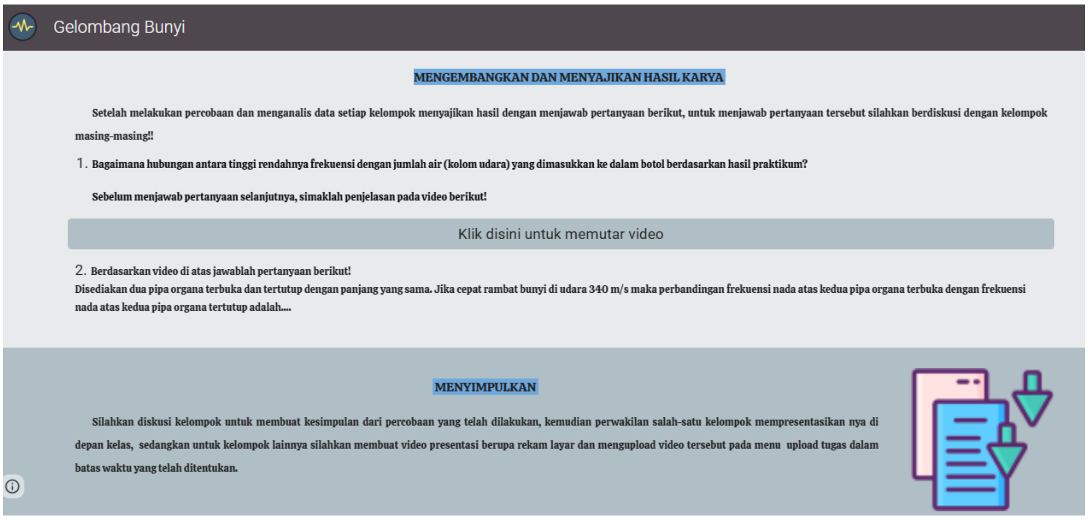
No.	Nada	Tinggi air (m)	Tinggi kolom udara (m)	Frekuensi (Hz)

(Gambar tabel pengamatan)

Apabila ingin melakukan percobaan di luar kelas, anda dapat mengikuti arahan yang tersedia pada video berikut!

Figure 6. Activity II on the learning web

The third stage (Activity III) focused on analysis and conclusion formulation. Figure 7 illustrates this learning phase, where some students, particularly those in the low improvement category, did not complete the online analysis and conclusion tasks. This incomplete process impacted their ability to analyze sound source concepts and the Doppler effect. Concept analysis is essential in building physics problem-solving skills (Maulisa et al., 2024). These findings underscore that WIPPer's success depends not only on media design but also on students' willingness and commitment to active engagement (Kamande & Mungara, 2023). To maximize effectiveness, WIPPer has been designed with attention to appealing visuals, gradual evaluation, and virtual lab guidelines, including experiment videos, enabling students to learn independently with adequate support both inside and outside the classroom.



MENGEMBANGKAN DAN MENYAJIKAN HASIL KARYA

Setelah melakukan percobaan dan menganalis data setiap kelompok menyajikan hasil dengan menjawab pertanyaan berikut, untuk menjawab pertanyaan tersebut silahkan berdiskusi dengan kelompok masing-masing!!

1. Bagaimana hubungan antara tinggi rendahnya frekuensi dengan jumlah air (kolom udara) yang dimasukkan ke dalam botol berdasarkan hasil praktikum?

Sebelum menjawab pertanyaan selanjutnya, simaklah penjelasan pada video berikut!

2. Berdasarkan video di atas jawablah pertanyaan berikut!
Disediakan dua pipa organa terbuka dan tertutup dengan panjang yang sama. Jika cepat rambat bunyi di udara 340 m/s maka perbandingan frekuensi nada atas kedua pipa organa terbuka dengan frekuensi nada atas kedua pipa organa tertutup adalah....

MENYIMPULKAN

Silahkan diskusi kelompok untuk membuat kesimpulan dari percobaan yang telah dilakukan, kemudian perwakilan salah-satu kelompok mempresentasikan nya di depan kelas, sedangkan untuk kelompok lainnya silahkan membuat video presentasi berupa rekam layar dan mengupload video tersebut pada menu upload tugas dalam batas waktu yang telah ditentukan.

Figure 7. Activity III on the learning web

Analysis of teacher responses revealed excellent average scores across all three assessed aspects: media (93.33%), material (100%), and evaluation (100%). The highest ratings in material and evaluation aspects indicate that WIPPer's learning content and assessment system effectively meet educational needs. Web-based learning media with appropriate content and structured evaluation systems can support the achievement of physics learning objectives (Aryani et al., 2019).

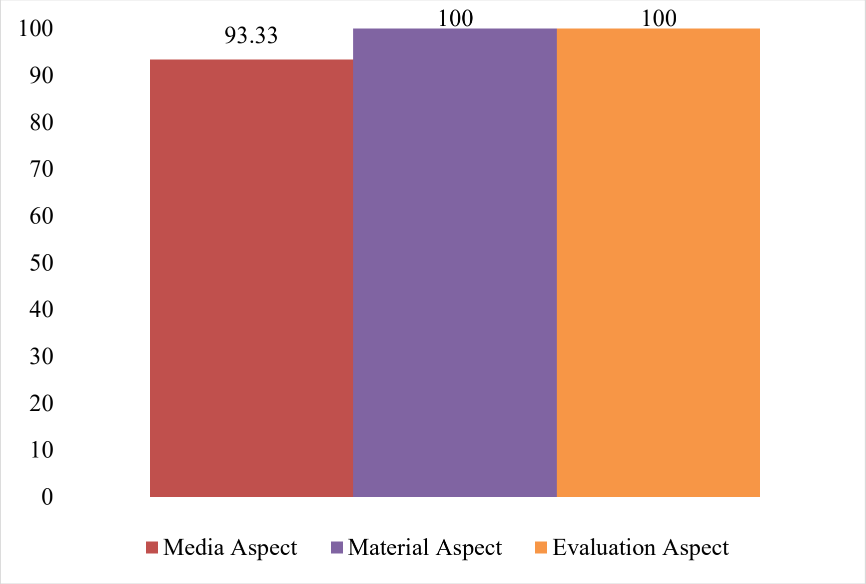


Figure 8. Percentage of teacher response results to WIPPer use

Student responses also showed excellent results, with average percentages of 86.16% for media, 93.4% for material, and 90% for evaluation. On a per-item basis, the highest score for media was on item 4 (90%), related to ease of use, demonstrating WIPPer's high user-friendliness. This aligns with Albet (2023), who stated that ease of use is crucial for the successful implementation of web-based learning media. For material, item 7 scored highest (96%), reflecting clarity in presenting sound wave content.

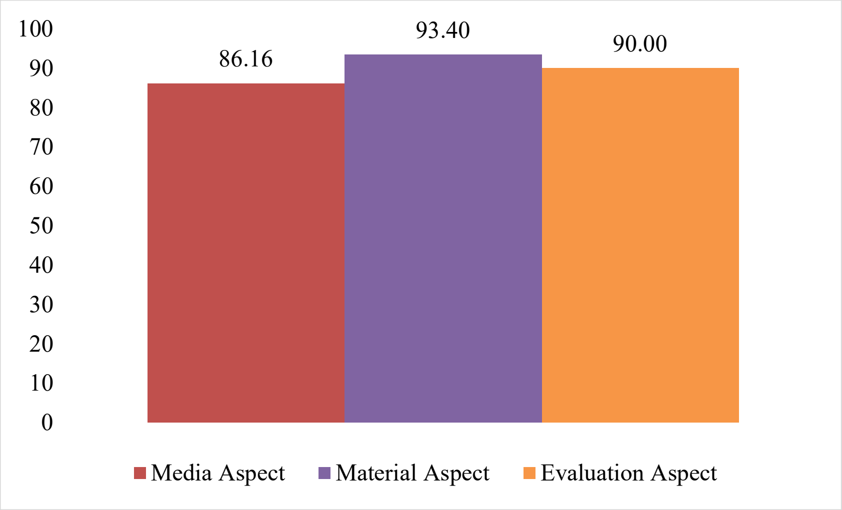


Figure 9. Percentage of student response results to WIPPer use

These findings support Syukri et al. (2023), who found that systematic presentation of digital learning materials enhances students' understanding of physics concepts. The evaluation aspect received the highest score on item 10 (97%), indicating good alignment between questions and learning material. Neo (2024) emphasized that compatibility between evaluation and content is essential for achieving learning goals. Overall, the average student response was 89.85%, categorized as excellent, confirming WIPPer's practicality for physics learning. Despite excellent assessments, some items scored relatively lower, notably media item 2 (76%) concerning background display. This matches teacher feedback suggesting improvements in visual clarity for the Doppler effect subtopic. Clear and relevant visuals are important in supporting concept comprehension (Murwaningsih et al., 2023).

To deepen understanding of WIPPer's effectiveness, cross-tabulation analyses were conducted between key variables. Table 4 presents cross-tabulation between N-gain categories and student responses to WIPPer. Although all students rated WIPPer as very good (>81%), response distributions differed significantly.

Table 4. Cross-tabulation between the n-gain category and student response

N-gain category	**Students' response (%)**			**Total**
	Very good (91-100%)	**Very good (86-90%)**	**Very good (81-85%)**	
High (>0.7)	2 (50%)	2 (50%)	0 (0%)	4
Medium (0.3-0.7)	5 (50%)	3 (30%)	2 (20%)	10
Low (<0.3)	0 (0%)	3 (50%)	3 (50%)	6
Total	7	8	5	20

Students with high and medium N-gain categories tended to provide responses in higher percentage ranges, with 50% in each group rating WIPPer in the highest response bracket (91-

100%). Conversely, no students with low N-gain scored in that range. This pattern indicates a positive correlation between students' perceptions of the media and their learning outcomes. Positive attitudes toward digital learning media strongly predict student success (Fathimah et al., 2024). Students who rated WIPPer highly generally demonstrated greater learning improvements. Table 5 shows the cross-tabulation between N-gain categories and student engagement at different learning stages.

Table 5. Cross-tabulation between the n-gain category and engagement in the learning stages

N-gain category	**Engagement in learning stages (%)**		
	Activity I (Orientation)	**Activity II (Experiment)**	**Activity III (Analysis)**
High (>0.7)	91.7%	100%	100%
Medium (0.3-0.7)	83.3%	96.9%	77.1%
Low (<0.3)	66.7%	82.1%	53.6%

The results of the cross-tabulation analysis between N-gain categories and student engagement across learning stages (Table 5) reveal consistent patterns throughout all stages. Students with high N-gain exhibited excellent engagement in every stage, with the highest participation during experiment activities (100%). In contrast, students with low N-gain showed a progressive decline in engagement from orientation activities (66.7%) to analysis activities (53.6%). Specifically, during orientation (Activity I), there was a 25% engagement gap between high (91.7%) and low (66.7%) N-gain students. Experiment activities (Activity II) recorded the highest participation for all categories: 100% for high, 96.9% for medium, and 82.1% for low N-gain students. The most significant discrepancy occurred in analysis activities (activity III), with a 46.4% difference between high (100%) and low (53.6%) engagement.

This distribution demonstrates a strong positive correlation between student engagement levels and improvements in learning outcomes. Success in blended learning heavily depends on students' willingness and commitment to active participation (Wei et al., 2024). The decline in engagement during analysis activities among low N-gain students aligns with Yang et al. (2024), who emphasize the importance of active involvement in maximizing web-based learning. The high engagement during experiment activities across all groups underscores the value of practical experiences aligned with theoretical content in physics education (Lasmiati et al., 2024). Meanwhile, the significant engagement gap during analysis highlights the critical role of concept analysis in developing physics problem-solving skills.

These findings reinforce that the effectiveness of web-based learning tools like WIPPer depends not only on media design and content quality but also on patterns of student participation. Effective blended learning necessitates active engagement throughout all stages, especially analysis and reflection (Bruijn-Smolders & Prinsen, 2024). Further analysis (Table 6) correlates students' ability to answer specific questions with their engagement levels in corresponding learning stages.

Table 6. Cross-tabulation between ability to answer questions and engagement in related learning stages

Question Number	**Concept Tested**	**Correct Answer (%)**		
		High Engagement	Medium Engagement	Low Engagement
4	Doppler Effect	91.0% (10/11)	20.0% (1/5)	0.0% (0/4)
8	Sound Source	72.7% (8/11)	20.0% (1/5)	25.0% (1/4)
9	Sound Wave Velocity	63.6% (7/11)	40.0% (2/5)	25.0% (1/4)

This table illustrates the relationship between tested physics concepts and the percentage of correct responses relative to student engagement levels. For the Doppler Effect (question 4), students with high engagement showed excellent understanding (91.0% correct), while medium engagement students achieved only 20.0%, and none with low engagement answered correctly. For Sound Source (question 8), high engagement students achieved 72.7%, medium engagement 20.0%, and low engagement 25.0%. For Sound Wave Velocity (question 9), correct answers were 63.6% for high engagement, 40.0% for medium, and 25.0% for low engagement. Overall, a clear positive trend exists between engagement level and conceptual understanding, with high-engagement students consistently outperforming others. This supports Mason and Singh (2016), who emphasize that active engagement, particularly in concept analysis, is essential for developing problem-solving skills. The analyzed questions required applying sound wave concepts to complex real-life contexts, such as the Doppler effect and variable relationships in wave velocity.

These results also align with Chen et al. (2024), who highlight that blended learning success strongly depends on self-regulated learning and active resource utilization. Highly engaged students typically follow the entire learning process thoroughly, from problem orientation to concept analysis, fostering comprehensive understanding. Herliana et al. (2024) emphasize that structured learning combined with consistent monitoring underpins concept mastery. The strong correlation between engagement and the ability to answer complex questions further supports Wei et al. (2024), underscoring that the effectiveness of web-based learning hinges on active student participation. The clear performance disparities across engagement levels demonstrate that the success of interactive media like WIPPer depends not only on media quality but also on the intensity and quality of student interaction with learning content.

Practically, these findings imply several strategies for physics education. First, the engagement pattern underscores the need for gradual scaffolding, particularly during concept analysis, to assist students with low independence. Teachers can implement regular check-ins, such as directed online discussions or formative quizzes, to sustain engagement during blended learning. Second, the positive correlation between experiment engagement and learning improvement highlights the importance of integrating hands-on activities, even in online formats. Teachers might develop simple at-home experiments to complement virtual labs in WIPPer. Third, the observed gaps in answering application questions indicate a need to enhance contextual examples in learning materials. Educators can enrich WIPPer content with physics problems relevant to students' daily lives in Aceh, thus boosting engagement and conceptual understanding.

IV. CONCLUSION AND SUGGESTION

This study confirms the effectiveness of the WIPPer model in improving students' physics learning outcomes of sound waves within a blended learning environment. The application of WIPPer resulted in a medium average N-gain score of 0.5116, with 70% of students showing learning gains within the medium to high categories. High levels of teacher and student approval were recorded, with both groups rating WIPPer as highly effective across media, material, and evaluation aspects. Classroom implementation data indicated an overall effectiveness rate of 89%, with strong correlations observed between student engagement and achievement. Notably, students with high engagement were more capable of solving analytical and application-based problems compared to their less-engaged peers. These findings suggest that the integration of problem-based strategies, adaptive feedback, and virtual experimentation within a web-based platform can significantly enhance physics learning outcomes by fostering inquiry, independence, and conceptual depth.

However, this study is limited by its small sample size, and the evaluation focused primarily on cognitive learning outcomes. Future research should involve larger, more diverse populations and extend the implementation period to examine the sustained impact of WIPPer. Moreover, integrating real-time analytics and expanding the range of content topics could further enhance its instructional value. Overall, this research contributes to physics education by introducing WIPPer as a structured, inquiry-based framework that effectively integrates digital media to make abstract concepts such as sound waves more comprehensible through contextual problem-solving. Its design fosters active engagement, critical thinking, and independent learning, which are core competencies in 21st-century science education. Furthermore, WIPPer serves as a practical model for educators and curriculum developers aiming to implement technology-enhanced, problem-based instructional strategies in secondary-level physics learning.

REFERENCES

Albet, M. (2023). *Pengembangan modul pembelajaran kewirausahaan bermuatan ethnopreneurship berbantuan virtual reality*. Disertasi. Program Studi Doktor Univeritas Lampung

Ali, L. U., Wahyuni, W., Azmar, A., Jumawal, J., & Fitriana, I. M. (2023). Improving science learning outcomes by applying problem-based learning model. *Jurnal Pendidikan Fisika, 11*(2), 173-182. https://doi.org/10.26618/jpf.v11i2.9913

Apriliani, M., Putri, S. A., & Unzzila, U. (2024). Peningkatan partisipasi aktif siswa dalam pembelajaran pendidikan kewarganegaraan melalui model pembelajaran kolaboratif di sekolah dasar. *Jurnal Pendidikan Guru Sekolah Dasar, 1*(3), 1–9. https://doi.org/10.47134/pgsd.v1i3.493

Apsari, M. R., Supardi, Z. A. I., Puspitawati, R. P., & Budiyanto, M. (2023). Improving problem-solving skills with problem-based learning models in optical wave courses. *International Journal of Current Educational Research, 2*(1), 27–38.

Aryani, D. R., Azizahwati., & Zulrfan. (2019). The development of physics education problem-based learning web as physics learning media for vocational high school. *Journal of Physics: Conference Series, 1351*, 1-5. https://doi.org/10.1088/1742-6596/1351/1/012016

Atlabachew, T. K., & Kriek, J. (2024). Using students' critical aspects to deepen understanding of nuclear physics concepts. *European Journal of Physics, 45*(6), 1-5. https://doi.org/10.1088/1361-6404/ad6064

Chen, W., & Cheng, H. N. H. (2020). Analyzing graduate students' behaviors of self-regulated learning in a blended learning environment. *Proceedings of the 2020 8th International Conference on Information and Education Technology*, 53–57. https://doi.org/10.1145/3395245.3396416

Chen, Y., Li, C., Cao, L., & Liu, S. (2024). The effects of self-efficacy, academic stress, and learning behaviors on self-regulated learning in blended learning among middle school students. *Education and Information Technologies, 29*, 24087–24110. https://doi.org/10.1007/s10639-024-12821-w

Chimmalgi, M., Rajesh, S., Kumar, K. V. A., Asha, U. V., Jose, J. E., & Chandrakumari, K. (2022). Problem-based learning using online platforms: An interactive alternative to mandatory e-learning during the covid-19 pandemic. *Journal of the Anatomical Society of India, 71*(3), 178-185. https://doi.org/10.4103/jasi.jasi_13_22

Bruijn-Smolders, M. D., & Prinsen, F. R. (2024). Effective student engagement with blended learning: A systematic review. *Heliyon, 10*(23), 1-16. https://doi.org/10.1016/j.heliyon.2024.e39439

Devy, N. K., Halim, A., Syukri, M., Yusrizal, Y., Nur, S., Khaldun, I., & Saminan, S. (2022). Analysis of understanding physics concepts in terms of students' learning styles and thinking styles. *Jurnal Penelitian Pendidikan IPA, 8(*4), 1937-1943. https://doi.org/10.29303/jppipa.v8i4.1926

Fathimah, N. S., Fiqriansyah, F., Rahman, E. F., & Piantari, E. (2024). Students' intention to accept gamification on web-based interactive multimedia using an active knowledge-sharing learning model. *Journal of Engineering Science and Technology, 19*(3), 957–965.

Graham, C. R. (2018). *Current research in blended learning. In Handbook of distance education (pp. 173–188).* Routledge

Greenacre, M. (2015). Correspondence analysis. *International encyclopedia of the social & behavioral sciences, second edition,* 1–5. https://doi.org/10.1016/b978-0-08-097086-8.42005-2

Herliana, F., Farhan, A., Mutiara, M., Nurulwati, N., Elisa, E., & Mahzum, E. (2025). Development of physics blended discovery learning tools (PBDLT) in alignment with the Merdeka curriculum. *Momentum: Physics Education Journal, 9*(1), 24–36. https://doi.org/10.21067/mpej.v9i1.9816

Herliana, F., Mardila, R., Mahzum, E., Muliyati, D., Susilawati, S., Saputri, M., Musdar, M., & Elisa, E. (2024). Web-based inquiry physics problems (WIPPer) for enhancing physics learning in blended environments. *Journal of Physics: Conference Series, 2866*, 1-8. https://doi.org/10.1088/1742-6596/2866/1/012115

Hrytsenko, V., Popovych, H., Shcherbakova, N., Hrechanyk, N., & Zhukovskyi, S. (2024). Methods of studying web technologies in a blended learning format: Analysis of models in education. *Journal of Curriculum and Teaching, 13*(3), 65-78. https://doi.org/10.5430/jct.v13n3p65

Izzati, L. R. (2021). The effect of problem-based learning to improve students' metacognition skills in solving mathematical problems based on cognitive style. *Journal of Physics: Conference Series, 1918*, 1-6. https://doi.org/10.1088/1742-6596/1918/4/042073

Kamande, M. W., & Mungara, M. W. (2023*). Strategies for student engagement and motivation factors in online learning. In Competence-based curriculum and e-learning in higher education.* Book Chapter. 273–302. IGI Global. https://doi.org/ 10.4018/978-1-6684-6586-8.ch014

Kamaruddin, K., Silangen, P. M., Fitrianingrum, A. M., Rende, J. C., & Londa, T. K. (2024). The effectiveness of teacher training in creating web-based learning media: An analysis of teacher knowledge. *Jurnal Pendidikan Fisika, 12*(1), 43-51. https://doi.org/10.26618/jpf.v12i1.14009

Lasmiati, Y., Herliana, F., Syukri, M., Musdar, M., Wati, N., & Hamid, A. (2024). The effect of blended learning-based problem-based learning on the critical thinking ability of high school students in physics subjects. *Current STEAM and Education Research, 2*(3), 121-130. https://doi.org/10.58797/cser.020301

Mardianti, F., Purnama, D., Zaenab, S., & Rusdiana, D. (2023). Developing website-based interactive learning media integrated with Kirchhoff's law experimental tools. *Jurnal Eksakta Pendidikan (JEP), 7*(1), 39–50. https://doi.org/10.24036/jep/vol7-iss1/755

Martha, A. S. D., Santoso, H. B., Junus, K., & Suhartanto, H. (2023). The effect of the integration of metacognitive and motivation scaffolding through a pedagogical agent on self-and co-regulation learning. *IEEE Transactions on Learning Technologies, 16*(4), 573–584. https://doi.org/10.1109/TLT.2022.3202751

Mason, A. J., & Singh, C. (2016). Impact of guided reflection with peers on the development of effective problem-solving strategies and physics learning. *The Physics Teacher, 54*, 295–299. https://doi.org/10.1119/1.4947159

Maulisa, A., Herliana, F., Mahzum, E., Elisa, E., Farhan, A., & Nurulwati, N. (2024). Development of problem-based learning teaching modules based on blended learning in the implementation of the independent curriculum. *Current STEAM and Education Research, 2*(2), 69–80. https://doi.org/10.58797/cser.020201

Murwaningsih, T., Fauziah, M., & Astuti, D. (2023). Improving concept mastery through learning media with interactive conceptual instruction approach viewed from learning style. *AIP Conference Proceedings, 2621*, 030003. https://doi.org/10.1063/5.0142452

Najib, M. N. M., Yaacob, A., & Md-Ali, R. (2022). Exploring the effectiveness of interactive simulation as blended learning approach in secondary school physics. *Proceedings, 82*(1), 1-9. https://doi.org/10.3390/proceedings2022082103

Neo, S. (2024). *Pengembangan instrumen assessment for learning berbasis problem-based learning untuk mengukur kemampuan literasi sains fisika pada peserta didik.* Skripsi, Fakultas Keguruan dan Ilmu pendidikan Universitas Lampung

Pratami, D., Tripiawan, W., & Puspita, I. A. (2023). The effect of problem-based learning method to student online learning performance during Covid-19. *AIP Conference Proceedings, 2485*(1), 1-7. https://doi.org/10.1063/5.0106572

Reinke, L. T. (2019). Toward an analytical framework for contextual problem-based mathematics instruction. *Mathematical Thinking and Learning, 21*(4), 265–284. https://doi.org/10.1080/10986065.2019.1576004

Septiana, S., Rizal, R., & Makiyah, Y. S. (2023). Development of electronic student worksheet using problem-based learning model with the wizer. me platform on momentum and impulse materials. *Jurnal Pendidikan Fisika, 11*(2), 202-214. https://doi.org/10.26618/jpf.v11i2.10909

Spatioti, A. G., Kazanidis, I., & Pange, J. (2022). A comparative study of the ADDIE instructional design model in distance education. *Information, 13*(9), 1-20. https://doi.org/10.3390/info13090402

Syukri, M., Oktaria, Q., Mahzum, E., Ngadimin, N., Herliana, F., Artika, W., & Saputri, M. (2023). Development of STEM-based physics LKPD with PIRPOSAL engineering design process model to improve creative thinking skills. *Proceedings The 2nd Annual International Conference on Mathematic, Science, Technology and Education*, 277-288. https://doi.org/10.2991/978-2-38476-216-3_29

Wei, Y., Li, J., Yin, P., Shi, Y., & Yang, H. H. (2024). Research on the impact of social presence, academic self-efficacy, and flow experience on students' learning engagement in blended synchronous learning. *In 2024 International Symposium on Educational Technology (ISET)*, 235-239. IEEE. https://doi.org/10.1109/iset59771.2024.10685741

Yang, S., Li, R. Y. M., & Li, J. (2024). Engaging learners in blended learning: Confirmatory factor analysis and bootstrap approaches. *International Journal of Learning in Higher Education, 31*(2), 191-218. https://doi.org/10.18848/2327-7955/CGP/v31i02/191-218