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Development of Virtual Laboratory as an Interactive Medium to Address Physics Misconceptions on the Doppler Effect Topic

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Abstract

This study aimed to develop a virtual laboratory as an interactive learning medium to address students' misconceptions in physics, particularly on the Doppler Effect topic. Conducted at SMA Negeri 1 Telaga during the 2024/2025 academic year, the research employed a Research and Development (R&D) approach using a 4D model (Define, Design, Develop, Disseminate), which was implemented up to the Develop stage. The developed media was created using Lectora Inspire 18 and included simulations, theoretical content, and interactive components. Validation involved media experts, content experts, and instructional tool assessment, resulting in high validity scores (average 3.75 for media and 3.50 for content). Practicality was evaluated through classroom implementation and student feedback, both yielding very positive results, with 100% implementation and strong student approval across five evaluation aspects. Effectiveness was measured through student activity observation, misconception analysis, and N-Gain testing, which revealed medium to high improvement in conceptual understanding. The findings demonstrate that the virtual laboratory is valid, practical, and effective in enhancing learning and reducing misconceptions. This study supports the integration of virtual laboratories in physics education to improve conceptual mastery and student engagement in abstract scientific topics.

Keywords: Virtual laboratory; Interactive media; Doppler effect; Misconception; Physics education

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INTRODUCTION

Education is a fundamental element in human life and plays a crucial role in improving the quality of a nation's human resources. The advancement of information and communication technology, particularly the internet, has facilitated various aspects of life, including the field of education. Through education, Indonesia is expected to keep pace with the rapid development of science and technology. Education serves as a process for developing students' potential in response to future challenges and in producing high-quality human capital (Khasanah, 2010; Nesti et al., n.d.). For developing countries such as Indonesia, education also represents a strategic investment to increase global competitiveness through the improvement of human resource quality. In this context, science education—especially physics—plays a vital role in understanding natural phenomena and in driving the advancement of scientific knowledge. Therefore, effective education is required to produce a generation that is competent and adaptable to technological progress.

Physics, as a branch of Natural Sciences (IPA), inherently requires experimental or practical activities to help students verify scientific concepts and hypotheses. One of the major challenges in learning physics is the occurrence of misconceptions, which refer to students' incorrect understanding of scientific concepts.

Misconceptions arise when learners fail to properly connect new concepts with their prior knowledge, thereby hindering comprehension of more advanced theories. If not addressed early, misconceptions can persist and interfere with students' ability to grasp related content in the future (Respasari et al., 2022). Misconceptions pose a significant obstacle to the learning process and reduce the overall effectiveness of conceptual understanding in physics.

Several factors can lead to misconceptions in physics, including students' limited prior knowledge, inappropriate teaching methods, and lack of adequate instructional materials. Another contributing factor is teachers' insufficient mastery of the subject matter, which may result in incorrect delivery of concepts. Additionally, textbooks or instructional approaches that emphasize only a single aspect of a concept may trigger misunderstandings among learners (Prasetyo, 2020). To overcome these issues, educators must adopt more diverse and flexible teaching strategies that do not rely solely on a single instructional method (Amalia & Samsudin, 2022).

One of the physics topics known to have a high level of student misconception is the Doppler Effect. Practical activities in science education, particularly in physics, are essential for enhancing students' conceptual understanding. However, the implementation of practical experiments in schools often encounters constraints such as limited time, inadequate laboratory facilities, and a lack of tools and materials. To address these challenges, the use of virtual laboratory media presents an effective alternative. Virtual laboratories allow students to simulate experiments that enhance understanding of abstract concepts. In addition to serving as substitutes for physical labs, virtual labs can complement traditional instruction by enabling students to repeat simulations when conceptual difficulties persist. One of the tools suitable for developing interactive learning media is Lectora Inspire, a software application that integrates multimedia components such as images, audio, and video to enhance content delivery (Azani et al., 2024).

This research and development study aims to design and assess the feasibility of an interactive virtual laboratory to assist students in modeling the concept of the Doppler Effect. Based on the background described above, this study proposes the development of a virtual laboratory as an interactive medium to support physics learning and reduce misconceptions in the Doppler Effect topic. The research addresses the following questions: (1) How can a virtual laboratory be developed as an interactive learning medium for the Doppler Effect topic? and (2) How effective is the virtual laboratory in reducing student misconceptions in learning the Doppler Effect?

The outcomes of this study are expected to provide meaningful contributions to teachers, students, and the advancement of educational technology. For teachers, this research contributes to the theory and practice of physics education, particularly in applying digital technologies to overcome misconceptions. For students, the virtual laboratory is expected to simplify the understanding of the Doppler Effect through visual simulations that resemble real-life scenarios. In terms of educational technology development, this research produces a virtual laboratory product that can be implemented in schools and other educational institutions to support technology-enhanced physics learning.

METHOD

This study was conducted at SMA Negeri 1 Telaga during the even semester of the 2024/2025 academic year. The research subjects consisted of 30 eleventh-grade students. The study employed a quantitative approach using the Research and Development (R&D) method, aiming to develop a virtual laboratory as an interactive learning medium to reduce physics misconceptions related to the Doppler Effect.

The development model implemented in this study was the 4D model, consisting of four stages: Define, Design, Develop, and Disseminate (Permatasari & Hardiyan, 2018). However, due to limitations in time and budget, the study was conducted only up to the Develop stage.

The Define stage involved a preliminary analysis to identify learning problems specific to SMA Negeri 1 Telaga, as well as analysis of student characteristics, concept mapping, and formulation of learning objectives. The results of this initial analysis indicated the presence of persistent misconceptions among students regarding the Doppler Effect topic.

The Design stage focused on developing research instruments, selecting the appropriate media, and determining the layout and presentation format of the media. The learning media was designed as a virtual laboratory using the Lectora Inspire 18 software, integrating text, images, audio, and simulations into a cohesive digital module. The final product was packaged into a single simulation file to ensure ease of use and continuity across sessions without being divided into separate meetings.

The Develop stage included media validation by two expert validators—one specializing in instructional media and the other in subject content—to assess the validity of both the media and research instruments. A limited trial was conducted with 30 students in class XI at SMA Negeri 1 Telaga to evaluate the practicality and effectiveness of the virtual laboratory. The trial lasted for four sessions and involved a One Group Pretest-Posttest Design (Sugiyono, 2015), consisting of a pretest, media-based learning sessions, and a posttest.

The research instruments used in this study included expert validation sheets, classroom implementation observation forms, student response questionnaires, student activity observation sheets, and a three-tier multiple-choice misconception test. Misconception analysis was carried out using the answer combination analysis technique adapted from Arslan et al. (2012).

Data analysis was conducted quantitatively using descriptive statistics to evaluate the validity, practicality, and effectiveness of the developed media. The validity of the media was determined based on expert evaluations using criteria outlined by Rosdiana (2018). Practicality was assessed through classroom implementation observations and student responses, following the criteria of Yakop et al. (2024). The effectiveness of the media was evaluated based on student activity levels and the results of the misconception test, using the normalized gain (N-Gain) formula proposed by Hake (1998).

The media was categorized as valid if the average expert validation score was ≥ 3.5, practical if both learning implementation and student response scores reached $\geq 76\%$ (classified as good), and effective if the N-Gain score indicated a medium to high level of conceptual improvement.

RESULTS AND DISCUSSION

This research was a Research and Development (R&D) study aimed at developing a virtual laboratory as an interactive learning medium to reduce physics misconceptions related to the Doppler Effect among eleventh-grade students in the even semester. The study was conducted at SMA Negeri 1 Telaga, involving 30 students in the 2024/2025 academic year. The evaluation of the media focused on three main aspects: validity (expert judgment), practicality (implementation and student responses), and effectiveness (student activity and conceptual understanding).

Define Stage

This stage included initial analysis, concept analysis, task analysis, and formulation of learning objectives. Observations revealed that students had low understanding of the Doppler Effect and were generally passive, although they showed interest in technology-based learning. Therefore, a virtual laboratory was selected as the most appropriate medium. The Doppler Effect topic was chosen due to its abstract nature and the limited availability of suitable learning media. The instructional model emphasized student engagement through worksheets (LKPD) and simple experiments, aiming to enhance students' ability to explain, calculate, and analyze Doppler Effect concepts using simulations.

Design Stage

This stage focused on test development, media selection, formatting, and initial design. A multiple-choice test was developed based on the task analysis. The selected medium was a virtual laboratory developed using Lectora Inspire 18 due to its accessibility and appealing visuals. The media design was aligned with the teaching module, instructional materials, and LKPD, and included observation sheets and questionnaires to measure practicality and effectiveness.

Virtual Laboratory Development Results

The developed product was a virtual laboratory-based learning media utilizing Lectora Inspire 18, featuring interactive components such as an introductory menu, theory, experiment procedures, simulations, observations, and follow-up questions. It was supplemented with a teaching module, instructional materials, and LKPD. A limited trial was conducted with 30 students from class XI-1. The results indicated that the virtual lab met the criteria for being valid, practical, and effective.

a. Validity

Validation covered the learning media, content, instruments, and instructional tools. Expert validation ensured the appropriateness of the virtual lab, content alignment with student needs, and instrument usability after revisions.

Media Expert Validation

Figure 1 presents the results of the validation assessment of the virtual laboratory learning media based on four key aspects: text display, image display, media functionality, and media usefulness. The highest validation score was achieved in the text display aspect, which received a perfect score of 4.00, indicating excellent clarity, readability, and consistency in the use of text throughout the media. The functionality of the virtual laboratory media followed with a score of

3.75, suggesting that the media features operated well and supported the intended learning objectives effectively.

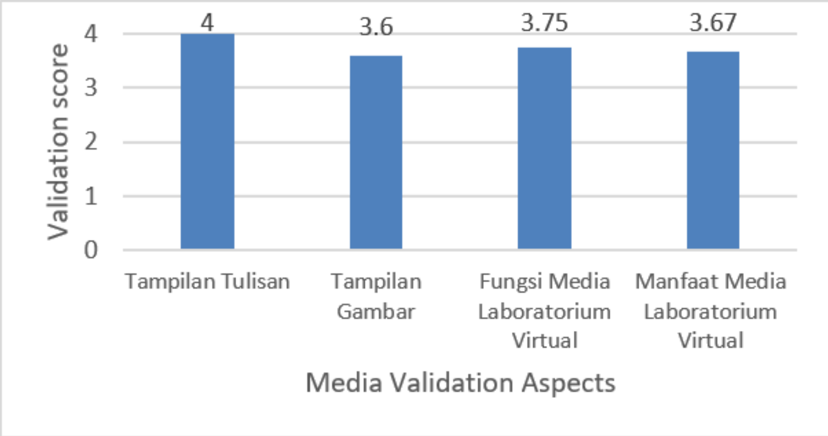

Figure 1. Results of the learning media validation assessment

The usefulness of the virtual laboratory media received a score of 3.67, which reflects its relevance and perceived benefits in supporting students' learning processes. The lowest score was found in the image display aspect, with a score of 3.60, though still categorized as valid. This suggests minor room for improvement in the visual elements, such as clarity, resolution, or aesthetic appeal of the graphics used. Overall, the validation results confirm that the virtual laboratory media meets high standards of quality and functionality, qualifying it as a valid and appropriate tool for use in physics education.

Material Expert Validation

Figure 2 shows the results of the learning material validation assessment based on two main aspects: content accuracy and content relevance. The content relevance aspect received the highest validation score of 3.75, indicating that the material aligns well with the learning objectives and is appropriate for the target students' level of understanding. This suggests that the material is contextually and conceptually suitable for facilitating the intended physics learning outcomes, particularly on the topic of the Doppler Effect.

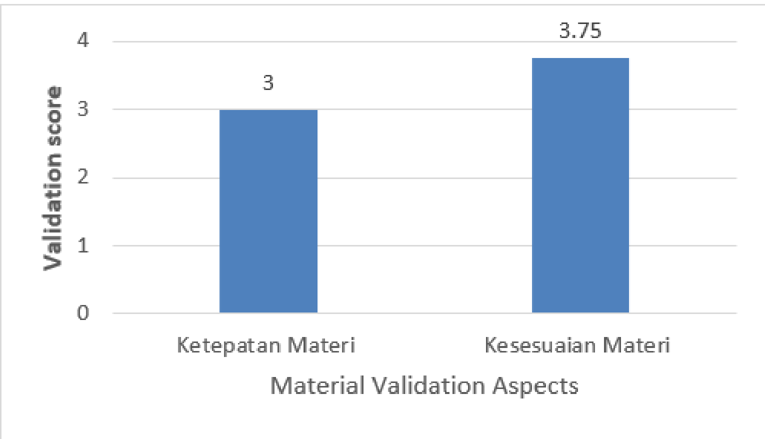

Figure 2. Results of the learning material validation assessment

In contrast, the content accuracy aspect received a lower score of 3.00, which, while still within the valid range, indicates the presence of some issues that may require revision or refinement. These may include minor errors, ambiguities, or misalignments with the latest scientific standards. Overall, the results suggest that while the material is generally valid and relevant, improvements to the accuracy of the content could enhance the instructional quality of the virtual laboratory media.

Instrument Validation

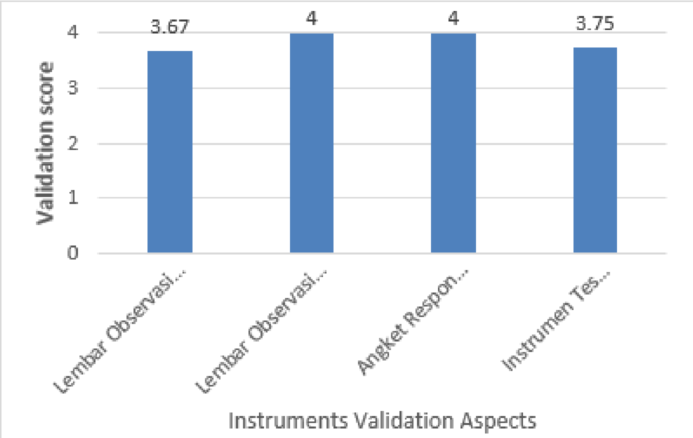

Figure 3. Results of the research instrument validation assessment

Based on the results of the research instrument validation shown in Figure 3, the highest validation scores were obtained for the learning implementation observation sheet (teacher activity) and the student response questionnaire, both scoring 4.00 and categorized as very valid.

Learning Tool Validation

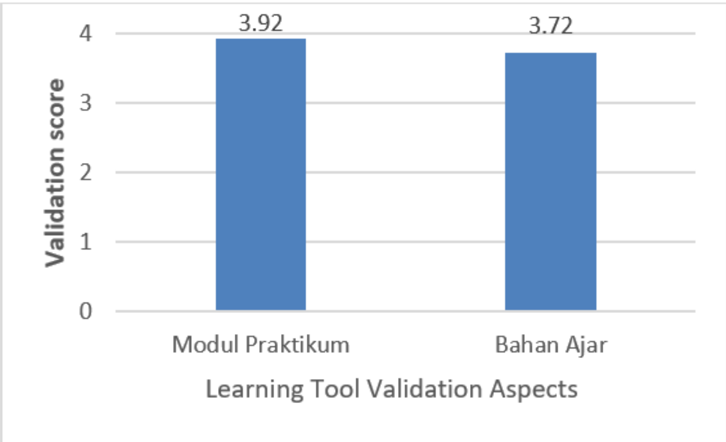

Figure 4. Results of the learning tool validation assessment

Based on the results of the learning tool validation assessment shown in Figure 4, the highest validation score was found in the practicum module item, which received a score of 3.92 and was categorized as very valid. The second highest score was in the teaching material item, with a score of 3.72, categorized as valid. Overall, the average validation score for the learning tools was 3.82, which falls into the very valid category.

b. Practicality

The practicality of the virtual laboratory learning media was assessed through observations of learning implementation and student response questionnaires. The observation results indicated that the implementation of learning in both sessions reached 100%, falling into the very good category. In addition, student responses to the use of the virtual laboratory were also categorized as very good, indicating that the media is practical and easy to use in the learning process.

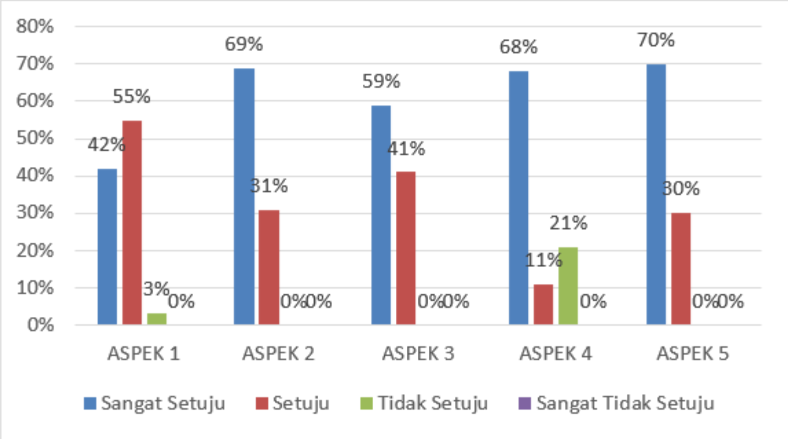

Figure 5. Student response questionnaire

Figure 5 illustrates the results of the student response questionnaire on five aspects of the virtual laboratory learning media: visual and aesthetic design, media interactivity, content quality, accessibility and ease of use, and overall learning impact. The majority of students gave positive responses across all aspects, with "Strongly Agree" dominating in Aspect 2 (69%), Aspect 4 (68%), and Aspect 5 (70%). Aspect 1 and Aspect 3 also showed strong approval, with a combination of "Strongly Agree" and "Agree" responses reaching 97% and 100%, respectively. A small portion of students (21%) disagreed on Aspect 4, suggesting minor difficulties with accessibility or usability, but no students selected "Strongly Disagree" for any aspect. These results indicate that the virtual laboratory was well-received in terms of design, functionality, and effectiveness in supporting student learning.

c. Effectiveness

The effectiveness of the virtual laboratory as an interactive learning medium for the Doppler Effect topic in Grade XI at SMA Negeri 1 Telaga was assessed through observations of student learning activities over two meetings, as well as through the results of a misconception test.

Observation of Student Activities

Figure 6 presents the results of student activity observation during the first meeting, divided into three categories: introductory, core, and closing activities. The highest level of engagement was observed in the introductory activities, which reached 95.82%, indicating excellent student readiness at the beginning of the lesson. Closing activities followed with a score of 93.3%, reflecting active student involvement in summarizing and concluding the session. Core activities showed slightly lower engagement at 91.85%, yet still within a very good category. These results demonstrate that students were consistently active throughout all phases of the lesson, supported effectively by the virtual laboratory media.

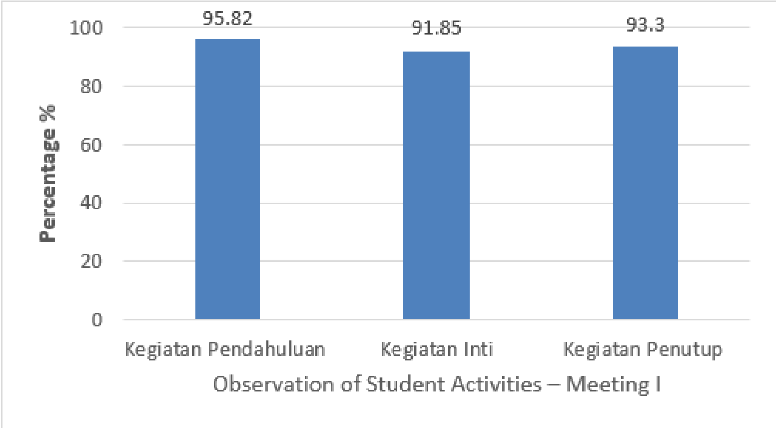

Figure 6. Observation of student activities – meeting I

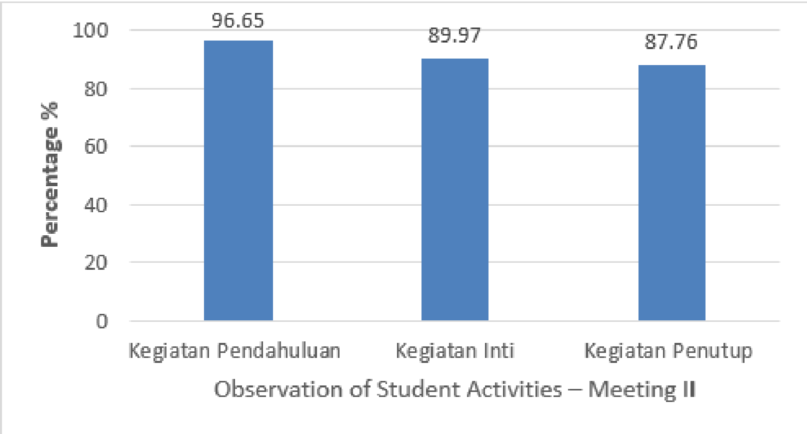

Figure 7. Observation of student activities – meeting II

Figure 7 displays the observation results of student activities during the second meeting, covering three key phases: introductory, core, and closing activities. The introductory activities received the highest engagement score at 96.65%, indicating excellent student responsiveness at the beginning of the lesson. The core learning activities followed with a score of 89.97%, while the closing activities recorded a slightly lower score of 87.76%. Although there was a slight decrease in student activity compared to the first meeting, all components remained within the high engagement category. These results suggest that the virtual laboratory continued to support active student participation across the lesson structure.

Misconception Identification

– *Misconception Identification by Test Item*

Based on Figures 8 and 9, it can be observed that the frequency of misconceptions for each test item decreased after the implementation of the virtual laboratory in the physics lesson on the Doppler Effect topic. This indicates that the use of virtual laboratory media contributed to reducing students' misconceptions across individual test items.

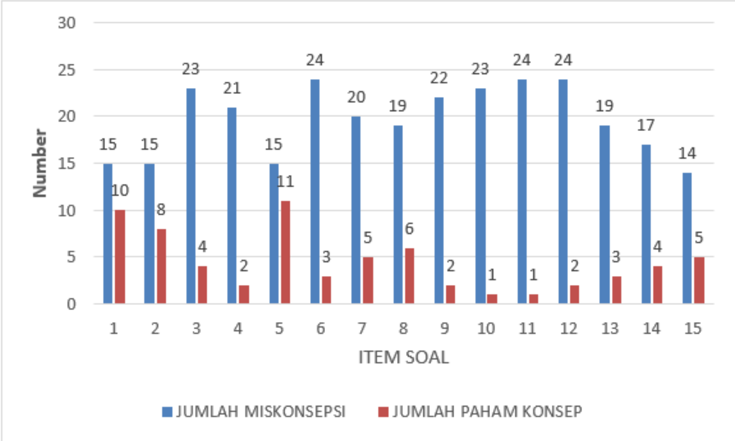

Figure 8. Misconception identification by test item – pretest

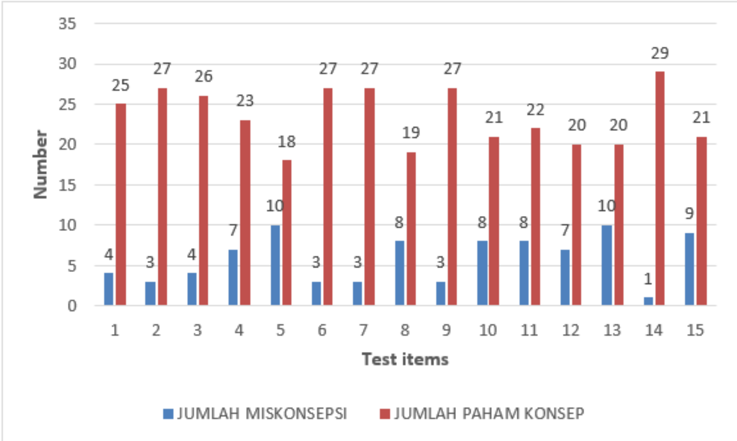

Figure 9. Misconception identification by test item – posttest

– *Analysis of Misconception Frequency Reduction per Student*

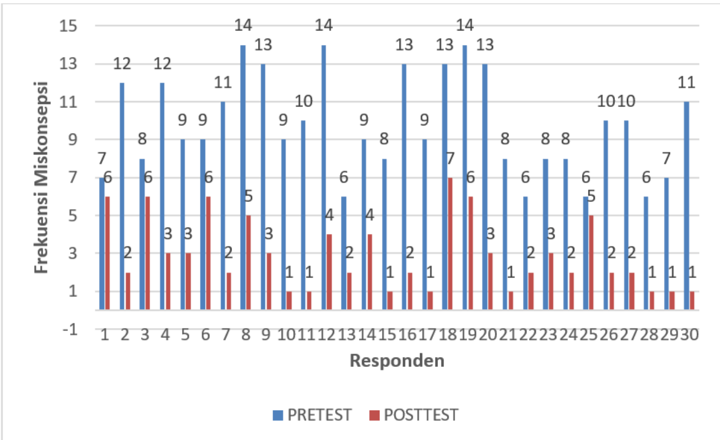

Figure 10. Analysis of misconception frequency reduction per student

The analysis results indicate that the use of the virtual laboratory in the Doppler Effect topic was effective in reducing student misconceptions. The percentage data show an increase of 4.27% in the "Understands Concept" category, while the

"Misconception," "Guessing," and "Does Not Understand" categories decreased by 0.70%, 0.61%, and 1%, respectively. These findings demonstrate that the virtual laboratory successfully enhanced students' conceptual understanding.

N-Gain Test

The analysis of single-student normalized gain revealed that out of 30 students, 21 experienced an improvement in conceptual understanding categorized as high, while 9 students showed moderate improvement. These results indicate that the use of the virtual laboratory in learning the Doppler Effect significantly enhanced students' conceptual understanding.

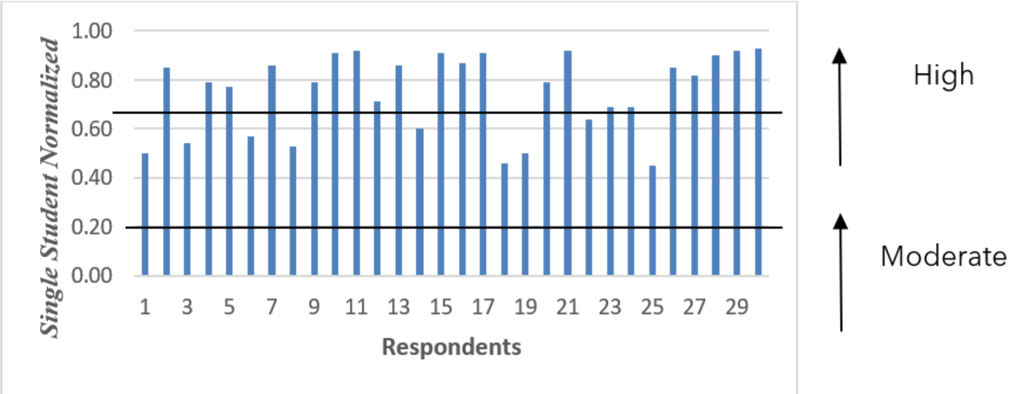

Figure 11. N-Gain Test Results

Figure 11 illustrates the normalized gain scores for individual students following the implementation of the virtual laboratory on the Doppler Effect topic. The majority of students—21 out of 30—achieved gain scores within the high category (above 0.70), indicating substantial improvement in conceptual understanding. The remaining 9 students fell within the moderate category (between 0.30 and 0.70), with none in the low category. This distribution demonstrates that the virtual laboratory was highly effective in facilitating learning gains, with all students showing measurable improvement and the vast majority achieving significant conceptual mastery.

Discussion

This study aimed to develop a virtual laboratory as an interactive learning medium to reduce physics misconceptions on the Doppler Effect topic among eleventh-grade students at SMA Negeri 1 Telaga. The research employed a Research and Development (R&D) approach, focusing on three main aspects: the validity, practicality, and effectiveness of the learning media.

The validation results indicated that the virtual laboratory media received an average expert score of 3.75, categorized as very valid, while the material validation achieved an average score of 3.50, categorized as valid. The highest scores were observed in the aspects of text display and content relevance, while the lowest score was found in image accuracy. These findings show that the developed media met the eligibility criteria for content, presentation, and functionality. This result is in line with Rosdiana (2018), who stated that instructional products are considered feasible if validation scores approach or exceed 3.00. Similarly, Ridwan (2015) highlighted that learning media with validation ratings above 95% are suitable for classroom use. Thus, the virtual laboratory developed in this study meets the standards of validity and is appropriate for implementation in physics learning.

Observation of the learning implementation showed 100% completion across two sessions, categorized as excellent. This result indicates that all learning activities were conducted as planned. It supports the findings of Yakop et al. (2024), who reported that digital media-based learning tools can be practically implemented in classroom settings.

Student responses to the virtual laboratory were also highly positive. The five evaluated aspects—visual design, interactivity, content quality, ease of access, and instructional impact—were all rated in the very good category. These findings support the work of Puspitasari, Wiyono, and Lestari (2022), which emphasizes that engaging user interfaces can enhance student motivation. The results are also consistent with Herga et al. (2016), who found that virtual media interactivity fosters active student participation in learning activities.

From a content perspective, students found the material in the virtual laboratory to be easy to understand and relevant to real-life situations, in line with findings by Arista and Kuswanto (2018). Accessibility was another key factor contributing to students' positive reception of digital media, as highlighted by Setiawan and Wahyudi (2022). In terms of instructional impact, students reported feeling more motivated and confident when conducting virtual experiments, which aligns with the findings of Yakop, Siregar, and Lestari (2024). Therefore, the virtual laboratory media can be categorized as practical and capable of creating an engaging, active, and meaningful learning environment.

The effectiveness of the virtual laboratory was evidenced by increased student activity and improved conceptual understanding. Observations revealed that student participation reached 93.6% in the first session and 91.46% in the second, both considered very good. These results support the claim by Sukardi (2018) that learning is effective when more than 75% of students are actively engaged.

Furthermore, the virtual laboratory proved effective in reducing misconceptions and enhancing conceptual understanding in physics. Pretest and posttest results showed a decrease in the “Misconception,” “Guessing,” and “Do Not Understand” categories, and an increase in the “Understands Concept” category. This is consistent with Mukhlisa (2021), who emphasized the importance of early misconception identification to guide appropriate instructional intervention.

The findings also support research by Andriani, Ramalis, and Suhandi (2018), which identified poor data interpretation and scientific reasoning skills as major causes of student misconceptions. The virtual laboratory helped students visually and interactively explore abstract concepts like the Doppler Effect, improving their understanding.

The N-Gain analysis further confirmed significant learning gains, with most students falling into the medium to high categories of conceptual improvement. This supports Sujono et al. (2023), who concluded that virtual laboratories promote active learning, clarify complex concepts, and make instruction more engaging and meaningful.

CONCLUSION

This study demonstrated that the virtual laboratory learning media on the Doppler Effect topic is suitable for use in physics instruction. Based on the validation results, the media was categorized as very valid (average score of 3.75), practical, as evidenced by 100% implementation and highly positive student responses, and effective in improving conceptual understanding and reducing misconceptions. The use of the virtual laboratory was proven to support interactive learning, enhance student motivation, and facilitate the understanding of abstract physics concepts.

RECOMMENDATION

The virtual laboratory is recommended as an alternative learning medium to assist students in understanding abstract physics concepts, particularly the Doppler Effect. Teachers are encouraged to integrate this media with interactive learning models to optimize learning outcomes. Schools are expected to support the implementation of virtual laboratories by providing adequate facilities, and future researchers are advised to develop similar media for different topics and educational levels.

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REFERENCES

Amalia, S., & Samsudin, A. (2022). *Penerapan Model Pembelajaran Berbasis Konflik Kognitif Untuk Mereduksi Miskonsepsi Siswa Pada Materi Gelombang. Jurnal Pembelajaran Fisika, 11(2), 108–114. Https://Doi.Org/10.26877/Jpf.V11i2.10687*.

Andriani, N., Ramalis, T. R., & Suhandi, A. (2018). *Pengaruh Penggunaan Media Simulasi Interaktif Terhadap Kemampuan Representasi Multiple Siswa Pada Materi Gelombang Bunyi. Jurnal Pendidikan Fisika Dan Teknologi, 4(2), 137–144*.

Arista, F. S., & Kuswanto, H. (2018). Virtual Physics Laboratory Application Based On The Android Smartphone To Improve Learning Independence And Conceptual Understanding. *International Journal Of Instruction*, *11*(1), 1–16. Https://Doi.Org/10.12973/Iji.2018.1111a

Arslan, H. O., Cigdemoglu, C., & Moseley, C. (2012). A Three-Tier Diagnostic Test To Assess Pre-Service Teachers' Misconceptions About Global Warming, Greenhouse Effect, Ozone Layer Depletion, And Acid Rain. *International Journal Of Science Education*, *34*(11), 1667–1686. Https://Doi.Org/10.1080/09500693.2012.680618

Azani, H., Antoni Musril, H., Zakir, S., & Efriyanti, L. (2024). Perancangan Media Pembelajaran Teknologi Informasi Dan Komunikasi Menggunakan Lectora Inspire Di Mts Tarbiyah Islamiyah Canduang. *JATI (Jurnal Mahasiswa Teknik Informatika)*, *7*(4), 2600–2604. Https://Doi.Org/10.36040/Jati.V7i4.7195

Hake, R. R. (1998). Interactive-Engagement Versus Traditional Methods: A Six-Thousand-Student Survey Of Mechanics Test Data For Introductory Physics Courses. *American Journal Of Physics*, *66*(1), 64–74. Https://Doi.Org/10.1119/1.18809

Herga, N. R., Cagran, B., & Dinevski, D. (2016). Virtual Laboratory In The Role Of Dynamic Visualisation For Better Understanding Of Chemistry In Primary

School. *Eurasia Journal Of Mathematics, Science And Technology Education*, *12*(3), 593–608. Https://Doi.Org/10.12973/Eurasia.2016.1224a

Khasanah, N. (2010). *Penggunaan Pendekatan Konflik Kognitif Untuk Remediasi Miskonsepsi Pembelajaran Usaha Dan Energi"[Tesis]. Surakarta: Universitas Sebelas Maret Surakarta*.

Mukhlisa, N. (2021). *Miskonsepsi Pada Peserta Didik. SPEED Journal : Journal Of Special Education, 4(2), 66–76. Https://Doi.Org/10.31537/Speed.V4i2.403*.

Nesti, E. W., Medriati, R., Purwanto, A., Fisika, P. P., & Keguruan, F. (N.D.). *Analisis Kebutuhan Pengembangan Media Pembelajaran Fisika Berbasis Aplikasi Lectora Inspire Abstrak*.

Prasetyo, A. P., & W. (2020). *Analisis Miskonsepsi Siswa Pada Materi Usaha Dan Energi Menggunakan Three-Tier Test. Jurnal Inovasi Pendidikan IPA, 6(2), 183–192. Https://Doi.Org/10.21831/Jipi.V6i2.33594*.

Puspitasari, D., Wiyono, K., & Lestari, A. (2022). *Pengaruh Virtual Lab Terhadap Motivasi Belajar Siswa SMA. Jurnal Pendidikan Dan Pembelajaran, 29(2), 134–142*.

Respasari, B. N., Santika, H. D., Hasana, Y., Hikmawati, H., & Rokhmat, J. (2022). Analisis Miskonsepsi Siswa Pada Topik Pelajaran Tentang Gaya Gesek. *Jurnal Penelitian Dan Pembelajaran Fisika Indonesia*, *4*(2). Https://Doi.Org/10.29303/Jppfi.V4i2.187

Ridwan. (2015). *Dasar-Dasar Statistika. Bandung: Alfabeta*.

Rosdiana, R. (2018). Pengembangan Media Pembelajaran Berbasis Komputer. *Al-Khwarizmi: Jurnal Pendidikan Matematika Dan Ilmu Pengetahuan Alam*, *1*(2), 87–100. Https://Doi.Org/10.24256/Jpmipa.V1i2.95

Setiawan, H., & Wahyudi, A. (2022). Pemanfaatan Media Digital Dalam Pembelajaran Di Era Revolusi Industri 4.0. *Jurnal Teknologi Pendidikan*, *24*(1), 45–58.

Sugiyono. (2015). *Metode Penelitian Kuantitatif, Kualitatif, Dan R&D. Bandung: ALFABETA*.

Sujono, R. N., Maryati, M., & Jumadi, J. (2023). Science Virtual Laboratory Implementation To Improve Students' Critical Thinking Skills: A Content Analysis. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 190–195. Https://Doi.Org/10.29303/Jppipa.V9i6.2810

Sukardi. (2018). Metodologi Penelitian Kualitatif: Kompetensi Dan Praktiknya. *Bumi Aksara*, 306. Https://Books.Google.Com/Books?Hl=En&Lr=&Id=Gjo

Yakop, S., Siregar, R., & Lestari, D. (2024). *Kepraktisan Laboratorium Virtual Dalam Pembelajaran Fisika SMA. Jurnal Inovasi Pendidikan, 10(1), 44–52*.

Yakop, S. S., Yusuf, M., & Buhungo, T. J. (2024). Analisis Kepraktisan Penggunaan Model Problem Based Learning Berbasis Phet Simulation Untuk Meningkatkan Pengetahuan Konseptual Fisika Pada Materi Elastisitas & Hukum Hooke. *Jurnal Jendela Pendidikan*, *4*(03), 257–265. Https://Doi.Org/10.57008/Jjp.V4i03.794