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Development of an Interactive Virtual Laboratory for Modern Physics Courses Based on Lectora Inspire

Irsan [1,*)], Nurlina[2], Icha Untari Meidji[1], Sri Nur Astuti B[3]

[1)] Jurusan Fisika, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Negeri Gorontalo Moutong, Kec. Tilongkabila, Kabupaten Bone Bolango, Gorontalo, Indonesia
[2)] Program Studi Pendidikan Fisika, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Sulawesi Barat Jalan Prof. Dr. Baharuddin Lopa, SH., Talumung, Majene, Sulawesi Barat, Indonesia
[3)] Jurusan Pendidikan Guru Sekolah Dasar, Fakultas Ilmu Pendidikan, Universitas Negeri Gorontalo Jl. Jend. Sudirman No.6, Dulalowo Tim., Kec. Kota Tengah, Kota Gorontalo, Gorontalo, Indonesia

*E-mail Corresponding: irsan@ung.ac.id

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Abstract

This study aimed to develop a modern physics virtual laboratory based on Lectora Inspire and to determine the feasibility of the developed media as well as students' responses to its implementation in modern physics learning. The developed product consists of four experimental modules, namely the Millikan oil drop experiment, blackbody radiation, hydrogen atomic energy levels, and the photoelectric effect. This research employed a Research and Development (R&D) approach using the ADDIE development model, which comprises the stages of Analysis, Design, Development, Implementation, and Evaluation. The research instruments included expert validation questionnaires and user response questionnaires. Expert validation was conducted to assess the aspects of functionality and usefulness, visual and audio quality, typography, and language. Meanwhile, user responses were collected to evaluate the ease of use, media attractiveness, and learning activities facilitated by the virtual laboratory. The results indicated that the developed virtual laboratory was categorized as feasible based on expert validation assessments. The aspects of functionality and usefulness, typography, and language received high ratings, indicating that the media is suitable for use as a learning resource in modern physics courses. Furthermore, student responses revealed positive perceptions of the virtual laboratory, with the majority of evaluations falling within the "Good" and "Very Good" categories across all assessment aspects. Students reported that the virtual laboratory was easy to use, engaging, and effective in facilitating their understanding of abstract modern physics concepts through interactive simulations. Therefore, the Lectora Inspire-based modern physics virtual laboratory can serve as an alternative learning medium to support modern physics practical activities in higher education institutions.

INTRODUCTION

The rapid advancement of information technology has exerted a significant influence on teaching and learning processes in higher education, including in the domain of physics instruction [1],[2]. The integration of technology in education enables students to acquire more interactive and flexible learning experiences [3]. One notable form of such technological integration is the use of virtual laboratories as simulation-based practical media. Virtual laboratories have the potential to serve as alternative solutions in physics education, particularly for subject matter that is difficult to observe directly through conventional laboratory practice[4],[5].

In modern physics courses, the conduct of laboratory practicals frequently encounters numerous constraints, including the limited availability of laboratory equipment, high procurement costs, and the abstract and microscopic nature of the subject matter. These conditions render it difficult for students to comprehend modern physics concepts when instruction is delivered solely through theoretical explanation. Topics such as the Millikan oil drop experiment, blackbody radiation, hydrogen atomic energy levels, and the photoelectric effect require effective visualization in order for students to grasp the interrelationships among concepts more concretely. Accordingly, the use of virtual laboratories becomes crucial in supporting students' conceptual exploration through interactive simulations [6].

A number of prior studies have demonstrated that virtual laboratories are capable of enhancing conceptual understanding, learning motivation, and student engagement in the physics learning process [7], [8], [9]. Furthermore, simulation-based learning media have been shown to be effective in assisting students in understanding physical phenomena that are otherwise difficult to visualize through real laboratory experiments [10], [11], [12]. Nevertheless, previous research has generally focused on developing simulations for a single specific topic and has seldom presented an integrated modern physics virtual laboratory that consolidates multiple experimental units within a single learning medium.

Based on this review, the present study introduces a novel contribution through the development of a Lectora Inspire-based modern physics virtual laboratory that integrates four experimental units within a single interactive learning medium [13]. The virtual laboratory developed in this study does not merely contain experimental simulations, but is also equipped with experiment objectives, brief theoretical content, procedural steps, observation results, and evaluation questions that can support independent practical activities by students [14], [15]. The integration of multiple experimental units within a single medium is expected to provide a more systematic learning experience and to facilitate students' understanding of the interrelationships among modern physics concepts [16].

The research questions addressed in this study are: (1) How can a feasible modern physics virtual laboratory be developed as a learning medium for students? and (2) What are students' responses toward the use of the developed medium? Accordingly, this study aims to develop a Lectora Inspire-based modern physics virtual laboratory and to determine the level of media feasibility and student responses toward its use in modern physics learning.

METHOD

This study constitutes a Research and Development (R&D) investigation aimed at producing a Lectora Inspire-based modern physics virtual laboratory as a learning medium for university students [17]. The developed product comprises four experimental units, namely the Millikan oil drop experiment, blackbody radiation, hydrogen atomic energy levels, and the photoelectric effect. The development model employed follows the ADDIE framework, which encompasses the stages of Analysis, Design, Development, Implementation, and Evaluation.

During the Analysis stage, the learning needs for the modern physics course were identified, along with the limitations of physical laboratory practicals. The Design and Development stages involved planning the media interface, content, simulations, and interactive features using Lectora Inspire software. The Implementation stage was carried out through a trial of the virtual laboratory with students, while the Evaluation stage was conducted to assess the quality, feasibility, and effectiveness of the developed medium based on expert validation results and user responses.

The developed product was subsequently validated by media experts to determine the level of feasibility of the virtual laboratory with respect to the aspects of functionality and usefulness, visual and audio quality, typography, and language. Validation was conducted by three experts who are lecturers in the Department of Physics, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Negeri Gorontalo. Following the revision stage, the virtual laboratory was implemented with students enrolled in the Bachelor's Program in Physics Education at Universitas Negeri

Gorontalo to obtain user responses regarding the developed medium. The trial was conducted with 17 students enrolled in the odd semester of the 2024/2025 academic year. The research instruments consisted of expert validation questionnaires and user response questionnaires to assess the feasibility and practicality of the developed virtual laboratory.

Data hasil validasi ahli dan respon pengguna dianalisis menggunakan analisis deskriptif persentase. Hasil penilaian kemudian dikategorikan ke dalam kriteria sangat baik, baik, cukup, kurang, dan sangat kurang untuk mengetahui tingkat kelayakan serta penerimaan pengguna terhadap laboratorium virtual fisika modern yang dikembangkan.

RESULTS AND DISCUSSION

A. Development Results of the Modern Physics Virtual Laboratory

This study produced a learning medium in the form of a modern physics virtual laboratory developed using Lectora Inspire. The virtual laboratory was designed as an interactive learning medium to assist students in understanding abstract modern physics concepts through virtual experiment simulations. The developed product comprises four experimental units, namely the Millikan oil drop experiment, blackbody radiation, hydrogen atomic energy levels, and the photoelectric effect.

The virtual laboratory was designed with a simple and user-friendly interface accessible to students. The main page features a navigation menu consisting of experiment objectives, brief theoretical content, procedural steps, simulation, observation results, and evaluation questions. Each experimental unit is structured systematically so that students may study the material independently or under guided instruction during lecture sessions.

(1) Millikan Oil Drop Experiment Unit

The Millikan oil drop experiment unit was developed to assist students in understanding the concept of the elementary charge of the electron through the observation of oil droplet motion in an electric field. In the simulation component, students are able to adjust the potential difference and observe the movement of oil droplets between two charged metal plates.

In addition to the interactive simulation, this unit is complemented by brief theoretical content explaining the fundamental principles of the Millikan experiment, as well as the relationship between electric force and gravitational force acting on the oil droplets. The particle motion visualization assists students in understanding the concept of electron charge, which is otherwise difficult to observe directly in a real laboratory setting.

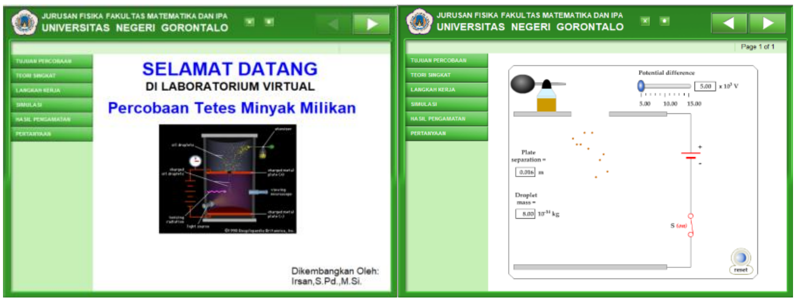

Figure 1. Display of the Millikan Oil Drop Experiment Unit

(2) Blackbody Radiation Experiment Unit

The blackbody radiation experiment unit was developed to assist students in understanding the relationship between the temperature of a body and the intensity of the radiation it emits. In the simulation, students are able to modify temperature values and observe changes in the blackbody radiation spectrum curve.

The content in this unit addresses the concepts of thermal radiation, the Stefan–Boltzmann law, and Wien’s displacement law. The interactive simulation assists students in understanding the changes in energy distribution with respect to wavelength as the temperature of the body increases.

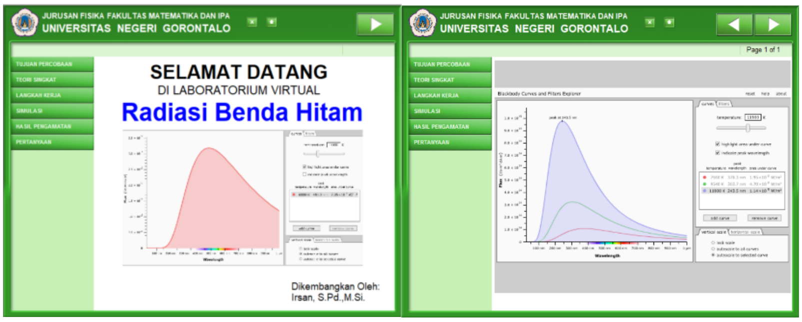

Figure 2. Display of the Blackbody Radiation Experiment Unit

(3) Hydrogen Atomic Energy Level Experiment Unit

The hydrogen atomic energy level experiment unit was developed to assist students in understanding electron transitions between energy levels in the hydrogen atom. The simulation enables students to observe the processes of electron excitation and emission, as well as the resulting light spectrum.

The brief theoretical section explains the Bohr atomic model, electron energy levels, and electron transition processes. Visualization of electron orbits and energy changes facilitates students' comprehension of the concept of energy quantization in the hydrogen atom.

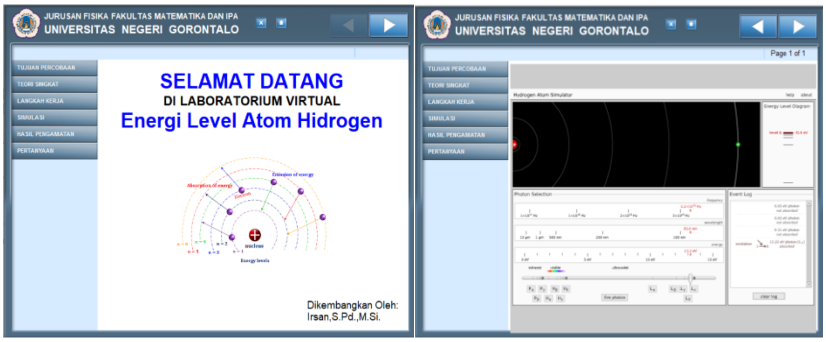

Figure 3. Tampilan Unit Percobaan Energi Level Atom Hidrogen

(4) Unit Percobaan Efek Fotolistrik

Unit percobaan efek fotolistrik dikembangkan untuk membantu mahasiswa memahami hubungan antara frekuensi cahaya, fungsi kerja logam, d an energi kinetik elektron. Pada simulasi, mahasiswa dapat mengubah frekuensi cahaya dan mengamati pelepasan elektron dari permukaan logam.

Teori singkat pada unit ini menjelaskan konsep foton, energi ambang, serta persamaan efek fotolistrik menurut Einstein. Simulasi memungkinkan mahasiswa memahami bahwa pelepasan elektron dipengaruhi oleh frekuensi cahaya, bukan intensitas cahaya semata.

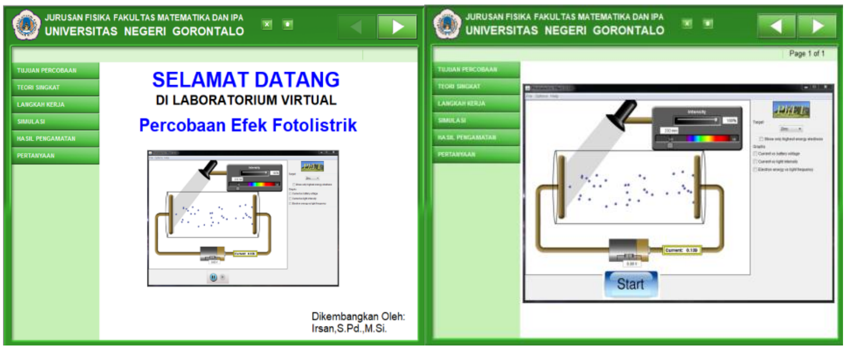

Figure 4. Display of the Hydrogen Atomic Energy Level Experiment Unit

B. Validasi Ahli

The expert validation stage was conducted to determine the level of feasibility of the modern physics virtual laboratory developed using Lectora Inspire. Validation was performed by media experts who assessed several aspects, namely functionality and usefulness, visual and audio quality, typography, and language for each experimental unit of the virtual laboratory.

1) Validation of the Millikan Oil Drop Experiment Unit

The expert validation results for the Millikan oil drop experiment unit indicated that the virtual laboratory received predominantly “Agree” category ratings. The functionality and usefulness aspect received a percentage score of 88.89%, the visual and audio media aspect scored 50.00%, the typography aspect scored 77.78%, and the language aspect scored 88.89%.

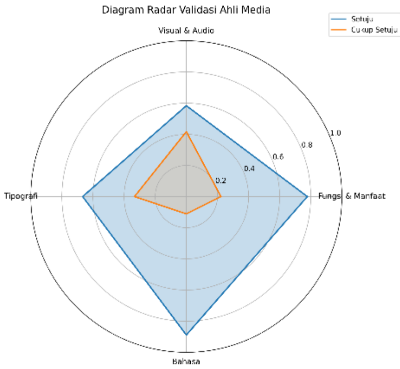

Figure 5. Expert Validation Results of the Photoelectric Effect Experiment Unit

Based on these validation results, Based on Figure 5, the validation results indicate that the virtual laboratory for the Millikan oil drop experiment unit was assessed as meeting the feasibility criteria as a learning medium. The validators affirmed that the medium is capable of assisting students in understanding the concept of electron charge through the interactive simulations presented. The interface design was evaluated as adequately well-developed, and the media navigation was found to be user-friendly for students throughout the learning process.

The functionality and usefulness aspect received high scores because the medium was considered effective in supporting virtual laboratory activities. The simulation of oil droplet motion in an electric field assists students in visualizing abstract concepts that are difficult to observe in a real laboratory setting. Furthermore, the language used in the medium was assessed as clear and comprehensible, thereby facilitating students in following the procedural steps of the experiment.

Nevertheless, validators provided several suggestions for improvement with regard to the visual and audio aspects, particularly concerning the refinement of animation display and color combinations to render the medium more visually appealing and interactive.

2) Validation of the Blackbody Radiation Experiment Unit

The expert validation results for the blackbody radiation experiment unit similarly indicated that the medium received predominantly “Agree” category ratings, confirming that the virtual laboratory is suitable for use as a learning medium in modern physics instruction for students.

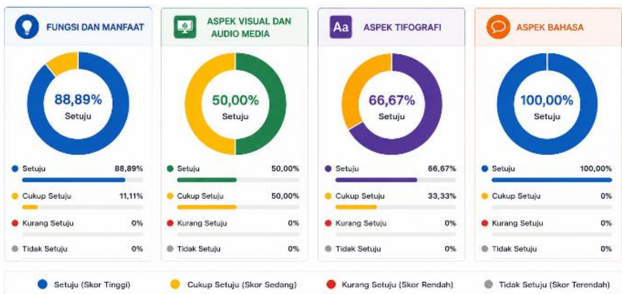

Figure 6. Expert Validation Results of the Blackbody Radiation Experiment Unit

Based on figure 6, radar diagram of validation results, the language aspect received the highest score compared to other aspects. This indicates that the presentation of material and usage instructions in the virtual laboratory were composed in communicative and comprehensible language for students. In addition, the functionality and usefulness aspect also received high ratings, as the blackbody radiation simulation was considered effective in assisting students to understand the relationship between temperature and radiation intensity more concretely.

With respect to the typography aspect, validators assessed that the font type, text size, and media layout were adequately good, facilitating students in reading the material and comprehending the information presented. Meanwhile, the visual and audio aspect received lower scores compared to other aspects; however, it remained within the feasibility category.

Overall, the expert validation results indicate that the developed modern physics virtual laboratory fulfills the media feasibility requirements and can be utilized to support modern physics instruction on the topics of the Millikan oil drop experiment and blackbody radiation.

3) Validation of the Hydrogen Atomic Energy Level Experiment Unit

The validation results demonstrated that the functionality and usefulness aspect achieved the highest percentage at 88.89% in the "Agree" category and 11.11% in the "Fairly Agree" category. This indicates that the virtual laboratory medium is considered capable of supporting the learning process, facilitating conceptual understanding, and effectively supporting students' practical activities. The language aspect similarly achieved a score of 88.89% "Agree" and 11.11% "Fairly Agree", signifying that the language employed in the medium is clear, communicative, and easily comprehensible.

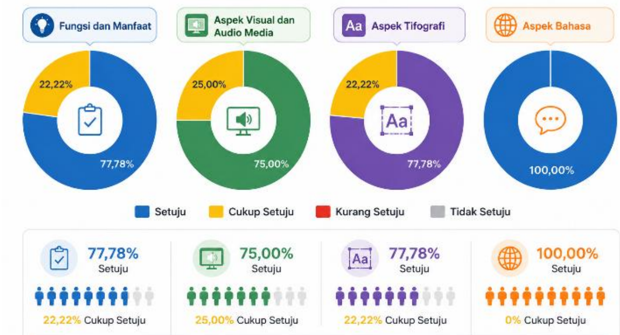

Figure 7. Expert Validation Results of the Hydrogen Atomic Energy Level Experiment Unit

In figure 7 the typography aspect, the medium received 77.78% "Agree" and 22.22% "Fairly Agree". These results indicate that the font type, size, and text layout are adequately good and support the readability of the medium. Meanwhile, the visual and audio aspect received the lowest score at 50.00% "Agree" and 50.00% "Fairly Agree". Although still within the feasible category, these results suggest that the visual display and audio quality require further development to enhance the attractiveness and interactivity of the medium and to provide an improved learning experience for users.

Overall, the expert validation for the hydrogen atomic energy level experiment unit indicates that the virtual laboratory medium has met the feasibility criteria, with a predominance of ratings in the "Agree" category. The medium can therefore be used in the learning process with several improvements, particularly with regard to visual and audio aspects.

4) Validation of the Photoelectric Effect Experiment Unit

In the photoelectric effect experiment unit, the expert validation results demonstrated excellent ratings. The language aspect achieved the highest score at 100% "Agree", indicating that the presentation of material, usage instructions, and information within the medium are highly clear and comprehensible to users. The functionality and usefulness aspect received 77.78% "Agree" and 22.22% "Fairly Agree", indicating that the medium is considered effective in assisting students to understand the concept of the photoelectric effect and in supporting virtual practical activities.

Figure 8. Expert Validation Results of the Photoelectric Effect Experiment Unit

In the figure 8 visual and audio aspect, scores of 75.00% “Agree” and 25.00% “Fairly Agree” were obtained. These results indicate that the media display, illustrations, animations, and audio are adequately good in supporting the learning process, although certain components could be further enhanced for optimal performance. The typography aspect also received 77.78% “Agree” and 22.22% “Fairly Agree”, indicating that the font usage and layout in the medium are well-designed and easy to read.

In general, the expert validation results for the photoelectric effect experiment unit indicate that all aspects received “Agree” category ratings, thus rendering the virtual laboratory medium highly suitable for use as a learning medium. These results further demonstrate that the media development succeeded in meeting the needs of modern physics practical learning in a virtual format, particularly in assisting students to understand abstract concepts through interactive simulations.

C. User Responses

Following the expert validation and product revision stages, the modern physics virtual laboratory was subsequently trialed with students to obtain user responses regarding the developed medium. Student responses were collected through a questionnaire encompassing the aspects of ease of use, media attractiveness, and learning activities. The user response results indicate that the virtual laboratory received positive feedback, with a predominance of ratings in the “Good” and “Very Good” categories across all assessment aspects. Students reported that the virtual laboratory was easy to use, visually appealing, and effective in enhancing their understanding of modern physics concepts through interactive simulations. Furthermore, the use of the virtual laboratory provided a more flexible learning experience, as students were able to explore materials and conduct experimental simulations independently without the constraints of physical laboratory equipment.

1) Millikan Oil Drop Experiment Unit

The user response results for the Millikan oil drop experiment unit indicated that the virtual laboratory received positive feedback from students. Based on the user assessment questionnaire results, the ease of use aspect received a “Good” category rating of 55%, the media attractiveness aspect received a “Good” rating of 53%, and the learning activity aspect received a “Good” rating of 57%. Furthermore, some students also assigned ratings in the “Very Good” category, with respective percentages of 23% for ease of use, 32% for media attractiveness, and 25% for learning activities.

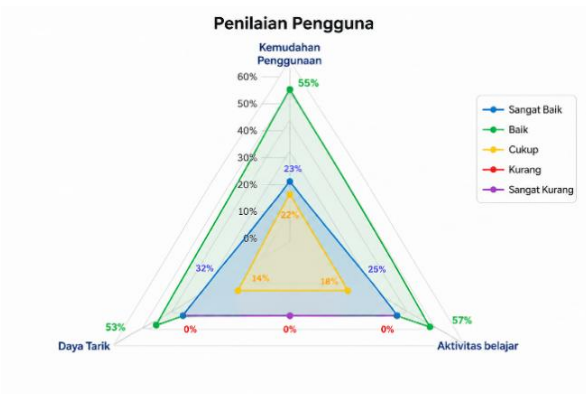

Figure 9. User Response Diagram for the Millikan Oil Drop Experiment Unit

These results figure 9 indicate that the developed virtual laboratory is user-friendly and capable of assisting students in understanding the concept of electron charge through interactive simulations. The simple interface design and structured navigation facilitate students in independently following the procedural steps of the experiment.

With respect to the learning activity aspect, students indicated that the virtual simulation assisted them in more concretely understanding the relationship between potential difference, electric field, and the motion of oil droplets. The use of visualization and interactive simulation encouraged students to be more actively engaged in conducting observations and exploring experimental parameters. In addition, the virtual laboratory enhanced students' interest in studying modern physics material, which had previously been considered abstract and difficult to comprehend through conventional instruction.

These findings are consistent with prior research indicating that the use of virtual laboratories can enhance learning motivation, conceptual understanding, and student engagement in the physics learning process [8], [9]. Simulation-based learning media enable students to conduct experiments flexibly without the constraints of physical laboratory equipment. Accordingly, the Millikan oil drop virtual laboratory can serve as an effective and interactive supporting medium for modern physics instruction for university students.

2) Blackbody Radiation Experiment Unit

Based on the user response questionnaire results, the virtual laboratory for the blackbody radiation experiment unit received favorable assessments from students. The majority of students provided responses in the "Good" category across all assessed aspects, with ease of use at 58%, media attractiveness at 54%, and learning activities at 56%. In addition, the "Very Good" category also received a relatively high percentage, particularly for the media attractiveness aspect at 27%. These results indicate that the developed medium is capable of providing a positive learning experience for students.

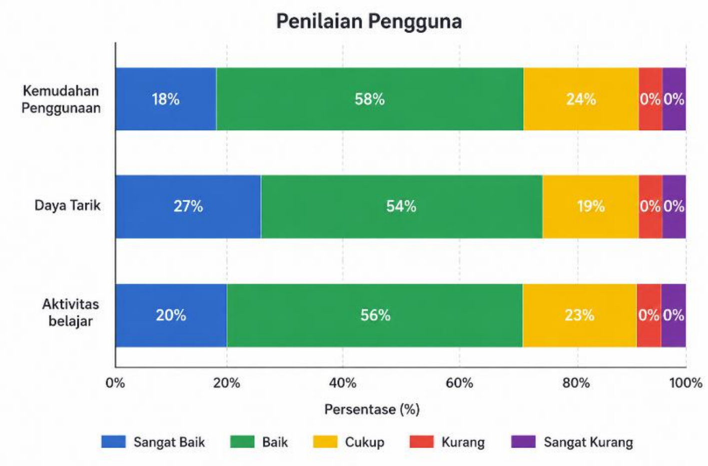

Figure 10. User Response Diagram for the Blackbody Radiation Experiment Unit

Base on figure 10, Students assessed that the blackbody radiation simulation presented in the virtual laboratory assisted them in understanding changes in the radiation spectrum resulting from changes in body temperature. The real-time visualization of radiation curves enabled students to more readily connect theoretical concepts with the physical phenomena under study. Furthermore, the interactive features of the simulation allowed students to conduct independent exploration, rendering the learning process more active and dynamic.

These findings support the results of prior research indicating that virtual laboratory-based learning media can enhance student engagement and facilitate comprehension of abstract concepts in modern physics [18], [19]. The use of virtual simulations also provides students with the opportunity to conduct practical without constraints of equipment and time, thereby rendering the learning process more flexible and effective.

3) Hydrogen Atomic Energy Level Experiment Unit

Based on the user assessment results, the virtual laboratory for the hydrogen atomic energy level experiment unit received favorable responses from students across all evaluated aspects. The ease of use and learning activity aspects achieved the highest percentages in the “Good” category at 59%, while the media attractiveness aspect received a percentage of 51%. Additionally, the “Very Good” category also received a notably high percentage, particularly for the media attractiveness aspect at 30%. These results indicate that the virtual laboratory is capable of providing an engaging and comprehensible learning experience for students.

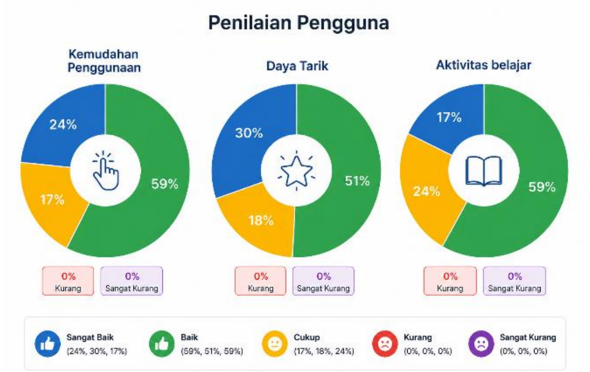

Figure 11. User Response Diagram for the Hydrogen Atomic Energy Level Experiment Unit

Figure 11 Students assessed that the simulation of electron transitions between energy levels assisted them in understanding the concept of the hydrogen atomic spectrum, which had previously been regarded as abstract. The interactive visualization of electron transitions and energy changes facilitated students in more readily understanding the relationship between atomic energy levels and the wavelength of the resulting light. Furthermore, the independently operable simulation feature provided students with the opportunity to explore concepts in greater depth.

These findings demonstrate that the use of virtual laboratories can create a more active and interactive learning environment in comparison to conventional instructional methods [6] [7]. The results are also supported by prior research indicating that virtual simulation media are effective in assisting students to understand microscopic and abstract concepts in modern physics. Accordingly, the hydrogen atomic energy level virtual laboratory can serve as an alternative learning medium to enhance students’ conceptual understanding.

4) Photoelectric Effect Experiment Unit

Student responses toward the use of the virtual laboratory in the photoelectric effect experiment unit demonstrated positive outcomes across all evaluated aspects. The majority of students assigned ratings in the “Good” category, with 57% for ease of use, 51% for media attractiveness, and 53% for learning activities. Furthermore, the “Very Good” category also received a relatively high percentage, particularly for the media attractiveness aspect at 27%. These results indicate that the developed virtual laboratory is capable of providing an engaging and user-friendly learning experience for students.

Figure 12. User Response Diagram for the Photoelectric Effect Experiment Unit

Figure 12 Students assessed that the photoelectric effect simulation assisted them in understanding the concept of light–metal interaction more clearly. Through the simulation, students were able to observe the influence of light frequency on electron release and the resulting kinetic energy of the electrons. The direct visualization of the experimental process rendered the abstract concept of the photoelectric effect more comprehensible. In addition, the interactive media display and simple navigation further facilitated students in independently exploring the subject matter.

These results indicate that simulation-based virtual laboratories can enhance student engagement during modern physics instruction. The findings are consistent with prior research demonstrating that virtual learning media are capable of improving conceptual understanding, learning activity, and student motivation with respect to physics material that is difficult to visualize through conventional laboratory practice [20], [21], [22]. Accordingly, the photoelectric effect virtual laboratory can serve as an effective alternative learning medium to support modern physics instruction in higher education institutions.

CONCLUSION

This study successfully developed a Lectora Inspire-based modern physics virtual laboratory comprising four experimental units, namely the Millikan oil drop experiment, blackbody radiation, hydrogen atomic energy levels, and the photoelectric effect. The expert validation results indicated that the developed medium was categorized as feasible, particularly with respect to the aspects of functionality and usefulness, typography, and language. Furthermore, the student response assessment results demonstrated positive feedback, with a predominance of "Good" and "Very Good" categories across the aspects of ease of use, media attractiveness, and learning activities. These findings indicate that the virtual laboratory is capable of assisting students in understanding abstract modern physics concepts through interactive simulations, and can serve as an effective alternative for practical activities in modern physics learning.

Future research is recommended to develop virtual laboratories with more advanced interactive features, such as three-dimensional visualization, augmented reality (AR) or virtual reality (VR) technology integration, and automated evaluation systems to further enhance students' learning experience. In addition, experimental studies examining the effectiveness of virtual laboratories with respect to improvements in learning outcomes, science process skills, and conceptual understanding should be conducted with larger and more diverse samples. Such efforts would yield stronger empirical evidence regarding the impact of virtual laboratory use in modern physics instruction.

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