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Development of an Interactive Multimedia-Based Science Practicum Guide on Dynamic Electricity

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Abstract: This study aims to develop an interactive multimedia-based science practicum guide on dynamic electricity to enhance students' laboratory skills. The research method used in this study was research and development (R&D), adapted from both Borg & Gall's and Alessi & Trollip's model. The multimedia product was designed to present the dynamic electricity topic with interactive visualization, equipped with easy-to-use navigation to assist students in conducting experiments. As a practicum guide, the main content includes the practicum objectives, theoretical background, tools and materials, step-by-step procedures with animations, and practice questions with automatic assessment. This practicum guide offers three activities that users can choose from: measuring electric current, measuring voltage difference, and determining the relationship between electric current and voltage difference. The findings indicate that the developed practicum guide is highly feasible as a learning medium for 9th-grade students and effectively enhances their laboratory skills.

Keywords: interactive multimedia; practicum guide; laboratory skills; science education; dynamic electricity

INTRODUCTION

The learning process is characterized by changes resulting from learning activities, which can manifest in various forms, such as changes in knowledge, attitudes, behaviours, skills, competencies, habits, and other aspects within the individual learner. Similarly, learning Sciences not only involves the development of knowledge but also the enhancement of work skills and attitudes. Science education in junior high schools fundamentally involves systematically exploring nature, thus Science is not merely about mastering a collection of facts, concepts, or principles, but also about the process of discovery.

One of the topics in science that plays an important role in learning through the process of discovery is dynamic electricity. It is closely related to the discovery process because dynamic electricity has strong relevance to everyday life applications (Guo et al., 2018; Mbonyiryivuze et al., 2019). However, the collection of facts, concepts, and principles in dynamic electricity remains a challenge for students to understand and teachers to teach (Caleon et al., 2018). The challenges in this topic include students' misconceptions arising from faulty intuition, incomplete reasoning, limited abilities, and incorrect preconceptions (Halim et al., 2019). In addition, students' problem-solving skills in this topic are still low, particularly in implementing ideas and evaluating solutions (Apriyani et al., 2019). Students also struggle to understand how to determine the direction of the electric field (Suciatmoko et al., 2018). Meanwhile, the challenge for teachers is understanding misconceptions related to this topic, so that they are less able to divert relevant attention to fix this problem (Caleon et al., 2018; Moodley & Gaigher, 2019). These misconceptions include the current consumption model, superposition model, voltage-current and short circuit, and parallel circuit misunderstandings (Caleon et al., 2018; Doğru, 2021; Moodley & Gaigher, 2019).

The traditional paradigm posits that learning is an interactive engagement between the student and the teacher, aimed at achieving educational objectives, with the teacher often serving as the principal source of knowledge. The instructional content is conveyed by the teacher through communicative symbols, both verbal and non-verbal. Subsequently, students interpret these communicative symbols to derive the intended message. There are instances where this interpretation is successful, while in other cases, it may fail. Failed interpretation indicates the student's inability to comprehend the content that is heard, read, or observed. Such interpretative failures are attributed to barriers or noise in the communication process (Sadiman et al., 2010). The solution lies in selecting appropriate media as a means to maximize the transfer of knowledge by the teacher. This ensures that students do not merely listen to the teacher's discourse but also engage their sensory processes. To achieve optimal results, learning must be enjoyable and stimulate the students' imagination and creativity.

Science instruction extends beyond mere concept delivery to encompass laboratory skills and the cultivation of scientific attitudes (Chiappetta & Koballa, 2014). A frequent challenge in science learning lies in students' difficulty grasping fundamental practicum concepts, such as measuring electric current and potential difference. The limitations of printed media as a practicum guide often prevent students from fully understanding correct procedures, leading to challenges in retaining and applying these foundational concepts. Meanwhile, science learning also requires media capable of explaining abstract concepts clearly.

Considering the use of appropriate media in science learning can significantly enhance students' interaction with the subject matter, which in turn supports a deeper understanding. We suggest an interactive multimedia-based learning medium is needed to make the practicum process more engaging and accessible for students.

Numerous studies have highlighted the use of multimedia not only to enhance learning outcomes and motivation but also to improve users' thinking skills and facilitate students with various learning styles (Harjono et al., 2015; Huang et al., 2019; Husein et al., 2017; Kiat et al., 2020; Parata & Zawawi, 2018; Prastika et al., 2015; Rahmawati & Dewi, 2019; Rubini et al., 2018; Saripudin et al., 2018; Shangguan et al., 2020). As practicum guides, multimedia has been effectively developed into practicum modules (Averina et al., 2021; Hakim et al., 2019; Sudarmanto et al., 2017; Titin et al., 2022). Previous studies have demonstrated that the use of interactive multimedia in practicum activities significantly improves conceptual understanding, learning interest, and student engagement (Rante et al., 2013; Santhalia & Sampebatu, 2020). Furthermore, interactive multimedia allows for the presentation of realistic experimental simulations and systematic delivery of practicum procedures, thereby addressing limitations in equipment and time typically associated with conventional practicums. It also supports science teachers whose academic background is in biology or chemistry in understanding the topic of dynamic electricity (Hakim et al., 2019; Rante et al., 2013; Santhalia & Sampebatu, 2020). Therefore, the development of an interactive multimedia-based practicum guide serves as an innovative solution to support more effective, engaging, and contextually relevant science learning (Huang et al., 2019; Husein et al., 2017).

However, unlike the products resulting from these studies, which were developed to enable users to conduct practicums directly from simulations presented by multimedia programs, the product developed in this research is also designed as a guide to assist users in conducting hands-on practicums in a real laboratory. Dynamic electricity involves abstract concepts such as electric current, potential difference, resistance, and the relationships among them, which are often difficult for students to visualize and understand through traditional instruction alone. Therefore, interactive multimedia-based practicum guide serves as a powerful tool to bridge the gap between abstract theory and concrete practice by providing visualizations, animations, and step-by-step procedures that enhance conceptual understanding. The development of an interactive multimedia-based science practicum guide is important because it not only supports students' cognitive engagement through simulations, but also provides structured guidance for performing real experiments. This dual function helps reinforce theoretical understanding while simultaneously building procedural skills, thus improving students' competence in both conceptual and practical aspects of electricity experiments. Moreover, it ensures that students follow correct procedures in a safe and systematic manner, especially in settings where direct supervision may be limited.

Therefore, this study aims to develop and evaluate the feasibility and effectiveness of an Interactive Multimedia-Based Science Practicum Guide on Dynamic Electricity. The use of this product is expected to help students understand fundamental concepts and laboratory procedures through a more dynamic and immersive learning experience.

RESEARCH METHOD

This research employed a development research design aimed at creating and validating an educational product: an interactive science practical guide for ninth-grade students on the topic of Dynamic Electricity. The development model was adapted from Borg & Gall (1983) and (Alessi & Trollip (2001), categorized and limited into four main stages: preliminary study, model design, product development, and product evaluation.

The preliminary study stage was a research and information collection activity that consisted of two main activities: literature review (including theoretical studies and previous research) and field study to assess students' needs and potential difficulties with the content. It also included competency standard setting, identification of student characteristics, and assessing the feasibility of implementing the developed interactive multimedia product.

The model design stage included the following activities: defining objectives, determining the qualifications of the parties involved in the research and development, formulating the roles and participation of these parties, establishing procedures and feasibility tests. The final result of this stage is a draft of the practicum manual, evaluation tools, and other supporting elements.

In the product development stage, materials were gathered and organized into an interactive multimedia format. This included preparing a storyboard, selecting appropriate programs, assembling materials, and rendering an .exe version of the initial product. In this stage, we use Adobe Flash Professional CS6 to develop the product.

The product evaluation stage consisted of preliminary continuous (ongoing) evaluation by the researcher and two formal testing phases: a) alpha testing: conducted by a media expert and two material experts to validate content and programming of media; and b) beta testing: involving two educators and six students with varying ability levels to assess usability and effectiveness. The product underwent iterative revisions based on feedback from each phase. The final validation, or summative evaluation, was conducted in a real learning environment. At this stage, a one-shot case study experimental design (Fraenkel et al., 2012) was employed, involving thirty-two 9th-grade students from SMP Negeri 2 Kota Kupang. This stage aimed to evaluate the effectiveness of the product in enhancing students' laboratory skills in physics. Participants were selected using purposive sampling based on specific criteria. The main criterion was that they had not yet received any formal lesson on the topic of dynamic electricity in their science curriculum. This ensured that any improvement in laboratory skills could be attributed to the intervention. All participants had equal access to the multimedia practicum guide and received the same learning intervention.

Instruments used in this study were (1) validation sheets for media expert to assess programming and display aspect; (2) validation sheets for material experts to assess learning and content aspect; (3) validation sheets for end-users (teacher) to assess usability, content, and display aspect; and (4) observation sheets used to assess students' laboratory skills during physics experiments using this product, focusing on competencies such as equipment handling, conducting experiments systematically, accurately recording data, analysing data, drawing conclusions, and collaborating effectively.

For data analysis, qualitative data, consisting of critiques and suggestions from media experts, subject matter experts, and users during alpha and beta testing were collected and summarized as guidelines for improving the developed interactive multimedia. Meanwhile quantitative data resulting from the assessments of material experts, media experts, users, and student laboratory performance observation sheets were analysed using qualitative descriptive statistics. The total score from each evaluator and student laboratory performance were then converted to a 100-point scale and subsequently converted into qualitative data on a 5-point scale, as shown in Table 1.

Table 1. Five-scale Actual Score Conversion

Category	Score	
	Formula	Result
Excellent	Xi + 1,8 Sdi < X	80 < X
Good	Xi + 0,6 Sdi < X ≤ Xi + 1,8 Sdi	60 < X ≤ 80
Fair	Xi - 0,6 Sdi < X ≤ Xi + 0,6 Sdi	40 < X ≤ 60
Poor	Xi - 1,8 Sdi < X ≤ Xi - 0,6 Sdi	20 < X ≤ 40
Very poor	< X ≤ Xi - 1,8 Sdi	X ≤ 20

Description:
Ideal Mean Score (Xi) : 1/2 (max. score + min. score)
Ideal Standard Deviation (Sdi) : 1/6 (max. score - min. score)
Empirical score (X)

In this development research, the feasibility value of the product as a science learning media is set at a minimum of the good category for each evaluator, including material experts, media experts, and users. The product is considered effective in improving student laboratory performance if their laboratory performance reaches a minimum score of 80 or falls within the excellent category.

RESULTS AND DISCUSSION

This section describes the developed product, as well as the results of the product evaluation as a physics learning medium and its effectiveness in enhancing students' laboratory skills, and its limitations.

1. Description of Developed Product: Interactive Multimedia-based Science Practicum Guide

The developed product is an interactive multimedia-based science practicum guide called Interactive Guide for Science Practicum: Measuring Electric Current and Voltage. It is designed in an executable (*.exe) format, making it easy to operate on the Windows operating system. Additionally, this product is compatible with Android devices through the support of a third-party application, ensuring greater accessibility and flexibility for users across different platforms.

As a practicum guide, this multimedia product is specifically designed to guide students in conducting hands-on experiments using real equipment. This product allows students to select content by clicking on the screen and presents information interactively through images and animations. They can use the information provided by this product to conduct hands-on experiments, similar to when using paper-based worksheets. The appearance of the multimedia product is presented in Figures 1 to 4 below.

Figure 1. Multimedia main menu

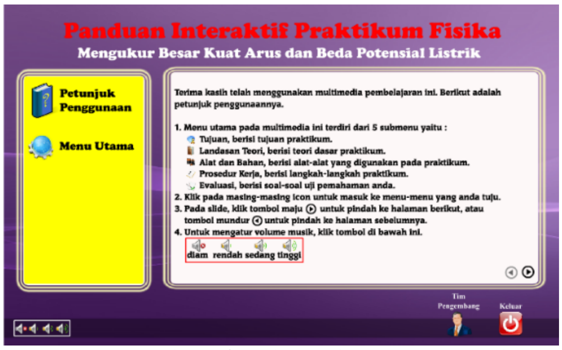

Figure 2. Display of multimedia user manual

Figure 3. Display of theory section

Figure 4. Practicum procedure for activity I

The product main content includes practicum objectives, theory, tools and materials, step-by-step procedures with animations, and practice questions with automatic assessment. The objectives menu outlines the learning outcomes that students are expected to achieve after completing this module. The theory menu provides explanations of dynamic electricity concepts for 9th-grade students and includes instructional materials on how to use a basic meter. All materials are supplemented with images and animations to enhance conceptual clarity. Additionally, the guide features exercises to reinforce students' understanding, providing immediate feedback to support their learning.

This practicum guide offers three main activities that users can choose from: measuring electric current, measuring voltage difference, and determining the relationship between electric current and voltage difference. The tools and materials integrated into this multimedia are adapted to the equipment commonly available in junior high schools, ensuring that students can easily access and utilize the practicum guide in accordance with their school's resources.

To enhance the user experience, this multimedia is also equipped with a comprehensive user manual, which is readily accessible from the main menu. Additionally, the multimedia includes voice narration for each section. Students have the option to either listen to the narration or mute it according to their preference.

2. Feasibility of the Interactive Multimedia-based Science Practicum Guide as a Physics Learning Media

The feasibility of the product as a science learning medium is determined through alpha and beta testing. The results indicate that the interactive multimedia developed as a practicum guide is of high quality and effective for use in the learning process. In the alpha testing, material and media experts evaluated the interactive multimedia. In the beta testing, it was used by teachers and students. Teachers provided assessments based on their opinions of the multimedia, while students' laboratory skills were measured through its use.

The assessment results from both material experts during the alpha testing are presented in Table 2. The material experts assigned the multimedia an average score of 96.67, classifying it in the excellent category. This multimedia meets high-quality standards by offering clear learning objectives, a systematic presentation of content, and comprehensive learning instructions. Furthermore, it provides adequate examples, exercises, reinforcement, feedback, and motivation.

From a content perspective, the inclusion of images and animations enhances the clarity of the material, tools, and procedures. The use of clear language and voice-over further facilitates students' understanding. Consequently, this multimedia can be used independently to guide students in conducting practical activities and comprehending the concept of dynamic electricity. This aligns with the view that effective learning media should enable students to learn autonomously without requiring intensive supervision.

Table 2. Material Experts Validation Test Results

Aspect	Indicator	Mark	
		Validator I	Validator II
Learning	Clarity of learning objectives	5	5
	Consistency between learning objectives, materials, and tests	5	5
	Provision of motivation	4	4
	Systematic presentation of materials	5	4
	Clarity of material explanations	5	5
	Ease of understanding the material	4	5
	Clarity of learning instructions	5	5
	Provision of examples	5	5
	Provision of exercises for concept understanding	4	5
	Provision of reinforcement for correct answers	4	5
	Provision of feedback for incorrect answers	5	5
	Clarity of test instructions	5	5
	Relevance and comprehensiveness of practice exercises and final evaluation	5	5
Content	Clarity of practicum objectives	5	5
	Consistency between practicum objectives, theoretical foundation, tools and materials, work procedures, and tests	5	5
	Accuracy of theoretical concepts	4	5
	Coverage of theoretical concepts	5	5
	Depth of theoretical explanation	4	5
	Logical sequence in presenting theoretical concepts	5	5
	Clarity of theoretical explanations	5	5
	Appropriateness of tool and material selection	5	5
	Proper sequencing of work procedures	5	5
	Text readability	5	5
	Relevance of images and animations in clarifying the theoretical concept, tools and material, and work procedures	5	5
	Clarity of language use	5	5
	Effectiveness of feedback	4	5
	Provision of exercises and final evaluation	5	5
Total Score		128	133
Converted Score		94,81	98,52
Average Converted Score		96,67	

Meanwhile, media experts rated multimedia with an average score of 88.89, which also falls into the excellent category. The assessment results from media experts are presented in Table 3. From programming and design perspectives, the multimedia's strengths include user-friendly navigation, an aesthetically pleasing layout, and the effective use of images and animations to enhance clarity. The visual design is engaging, featuring appropriate font types and sizes, along with a background colour that supports readability.

Suggestions for improvement included adding audio to the equipment and material menu to increase interactivity. This recommendation was subsequently implemented, enhancing the multimedia's engagement and accessibility for students.

Table 3. Media Experts Validation Test Results

Aspect	Indicator	Mark
Programming	Learner interactivity with the program interface	4
	User-friendliness of navigation controls	5
	Accessibility of content menu selection	4
	Autonomy in choosing content menus	5
	Clarity and comprehensiveness of user guidelines	5
	Responsiveness to learner inputs	4
	Operational efficiency	4
Display	Appropriateness of font type and size	5
	Use of spacing (lines, paragraphs, and characters)	5
	Text readability	5
	Visual presentation of images and animations	4
	Placement of images and animations	4
	Appropriateness of music selection	4
	Layout design	4
	Quality and usability of navigation buttons	4
	Consistency in navigation button placement	4
	Harmony between background color and text	5
	Consistency across pages	5
Total Score		80
Converted Score		88,89

During beta testing, the interactive multimedia was rated by two science teachers. They provided an average media rating of 94.28, indicating that multimedia is highly suitable for teaching physics. The multimedia's ease of use, content relevance, and visual appeal support teachers in conveying material more effectively. The assessment results from users are presented in Table 4.

Table 4. End-user Validation Test Results

Aspect	Indicator	Mark	
		Teacher I	Teacher II
Usability	Clarity and comprehensiveness of learning instructions	5	5
	User-friendliness in program initiation	4	5
	User-friendliness in program termination	4	5
	Accessibility of program menu selection	5	5
	Autonomy in choosing program menus	5	3
	Operational ease of program usage	5	5
	Intuitive use of navigation controls	5	5
	Clarity of instructions for exercises and final evaluation	5	5
Content	Clarity of practicum objectives	5	5
	Clarity and accuracy of theoretical concepts	5	5
	Clarity of the tools and materials to be used	5	5
	Alignment between the tools and materials in the program and those available in school	4	4
	Clarity of work procedures	5	5
	Consistency between the work procedures in the program and real practicum conditions	5	4

	Engagement and clarity in delivering theoretical concepts and work procedures for better comprehension	5	4
	Text readability	5	5
	Clarity of questions in the final evaluation	5	5
	Effectiveness of evaluation questions in measuring content understanding	4	4
	Provision of feedback (discussion) in practice exercises to enhance content comprehension	4	5
Media	Visual harmony and balance of the program's screen layout	5	5
	Aesthetic appeal of the background color in the program	5	5
	Aesthetic appeal of the background design in the program	5	5
	Visual appeal of navigation buttons in the program	5	5
	Accuracy of text placement	5	5
	Appropriateness of font type, font size, and text spacing	5	5
	Compatibility between text color and background	4	5
	Relevance of image and animation usage	5	5
	Appropriateness of music selection	3	3
Total Score		132	132
Converted Score		94,28	94,28
Average Converted Score		94,28	

At this stage, the multimedia was also tested on six students who used the developed product to conduct practical activities. While the students reported increased motivation to learn, the teachers assessed their laboratory skills. The results indicate that the use of this interactive multimedia positively impacts students' laboratory competencies, with an average score of 97.5. This improvement is reflected in the students' enhanced abilities to conduct experiments, including proper use of equipment, effective group collaboration, data analysis, and drawing accurate conclusions.

Based on the data from the alpha and beta testing, it can be concluded that the developed product meets the feasibility criteria as a physics learning medium.

3. Effectiveness of the Interactive Multimedia-based Science Practicum Guide in Enhancing Students' Laboratory Skills

The effectiveness of interactive multimedia in enhancing laboratory skills was evaluated during the summative evaluation stage in a real classroom setting. At this stage, students conducted experiments using the developed multimedia, while the teacher assessed their laboratory performance. The results of the students' laboratory skills are shown in Figure 5.

The results reveal that students achieved the lowest scores in data analysis, which can be attributed to the inherently demanding nature of this skill, requiring advanced mathematical proficiency. The test subjects, in general, experienced considerable difficulty in this area. Despite this, the average laboratory skill score was 91.67, reflecting the multimedia's substantial effectiveness in enhancing students' laboratory competencies. These findings underscore that the developed multimedia not only facilitates a deeper conceptual understanding but also enables students to conduct experiments systematically and independently in alignment with the provided practicum guide.

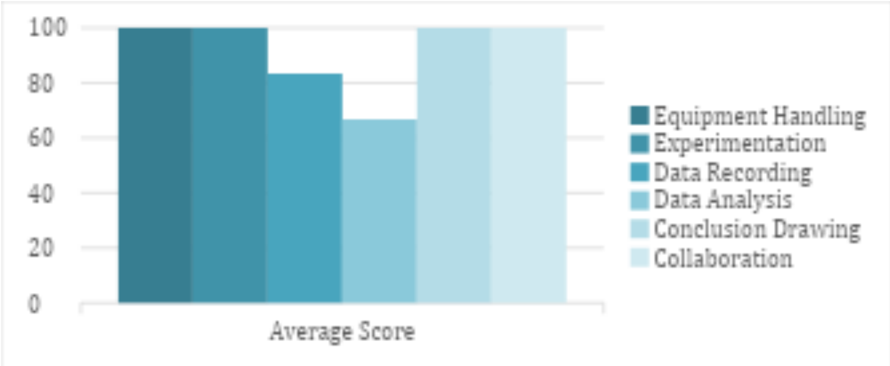

Figure 5. Students' Performance Score

Students demonstrated enthusiasm while using the multimedia for practical activities. The multimedia assists them in recognizing laboratory equipment, assembling circuits, reading measurement scales, and developing other essential skills. When students encountered difficulties, such as reading measurement scales, they could easily revisit the theoretical section to reinforce their understanding. This feature reduces the need for constant teacher intervention, allowing educators to focus on other instructional tasks and improving the overall learning experience.

Overall, the results of this study are consistent with the theory proposed by Walker & Hess (1984), which states that high-quality educational multimedia should be engaging, relevant, easy to use, and capable of positively influencing the teaching and learning process. The findings indicate that the developed multimedia-based practicum guide is effective in enhancing students' laboratory skills in dynamic electricity. This supports previous studies (Lee & Osman, 2012; Sugiarto et al., 2022; Widyaningsih et al., 2020) that highlight the benefits of multimedia in science education. The implementation of interactive multimedia fosters student motivation to engage more deeply with the material and simplifies the understanding of experimental procedures through animated simulations, as opposed to relying solely on static images. A key advantage of this multimedia is its flexibility, allowing it to be used effectively in both classroom instruction and independent learning. The inclusion of clear user instructions further ensures that students can navigate the multimedia with ease, facilitating self-directed learning.

The use of appropriate media in science education plays a critical role in enhancing students' interaction with subject matter, which subsequently fosters a deeper understanding of scientific concepts. In this context, interactive multimedia-based learning tools present a promising solution by integrating various components, such as visualizations, simulations, and interactive tasks, which accommodate diverse learning styles. The incorporation of multimedia elements, such as animations and simulations, enables students to visualize abstract scientific phenomena more effectively, bridging the gap between theoretical concepts and practical applications. Unlike printed materials, multimedia provides a dynamic representation of complex scientific processes, making them more accessible and comprehensible for students.

Moreover, interactive multimedia offers real-time feedback, allowing learners to identify and correct misconceptions immediately, thus fostering a more comprehensive understanding of the subject. This approach not only enhances conceptual comprehension but also supports the development of essential scientific skills and attitudes. By integrating technological advancements into science education, the learning environment becomes more immersive and effective, surpassing the limitations of traditional methods. This immersive approach facilitates both knowledge acquisition and the cultivation of critical scientific competencies.

The results of this study indicate that multimedia can function not only as a virtual laboratory through manipulable simulations but also as a practical guide to assist students in performing hands-on experiments using available school equipment. This dual functionality ensures that the integration of multimedia in laboratory activities does not diminish students' hands-on skills but instead enhances them by reinforcing procedural accuracy and fostering a deeper understanding of scientific concepts. The inclusion of interactive simulations and animations allows students to visualize abstract phenomena, which may be challenging to observe directly through traditional experimentation.

4. Limitations of the Interactive Multimedia-based Science Practicum Guide

One limitation of this practical guide is its potential to encourage a procedural approach similar to following a recipe, where students merely replicate the provided steps without fully understanding the underlying concepts or reasoning. This approach may hinder the development of students' critical thinking and analytical skills. Nevertheless, this guide remains valuable in introducing fundamental competencies, such as the proper use of electrical measuring instruments and the execution of basic experimental procedures. To mitigate this drawback, future implementations could incorporate inquiry-based learning strategies or open-ended tasks, encouraging students to engage more deeply with the scientific process. Additionally, the guide can be adapted and expanded to align with specific learning objectives and instructional designs, providing greater flexibility in its application.

Another limitation of this multimedia is the restricted scope of content, which currently focuses solely on the topic of dynamic electricity. While this specialized focus allows for in-depth exploration, it limits the multimedia's applicability across broader scientific domains. Future research should prioritize the development of similar multimedia resources covering a wider range of physics and other science topics. Expanding the content would offer a more comprehensive and interactive learning experience, fostering both conceptual understanding and practical skill development across diverse scientific disciplines.

CONCLUSION

Based on the research conducted, it can be concluded that the Interactive Multimedia-based Science Practicum Guide was successfully developed using the R&D method as an effective science learning medium to enhance students' laboratory competencies in the topic of dynamic electricity. These results indicate that the developed practicum guide enables 9th-grade students to integrate their theoretical understanding with interactive and practical components, engaging them to actively participate in the hands-on experiments using real equipment.

This study provides a new perspective on the use of educational multimedia, not only as a virtual lab simulation but also as a practical guide to assist students in performing hands-on experiments using available school equipment. The findings challenge the prevailing notion that multimedia use may diminish laboratory skills by demonstrating that, when appropriately designed, multimedia can actually enhance these skills. The key lies in how the multimedia is developed to integrate both virtual and physical learning experiences effectively.

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