Indonesian Journal of Advanced Research (IJAR)
Vol. 5, No. 8, 2026: 1469-1484

Development of Learning Interactive Media Assisted by Google Sites in the Subject of Light Wave for Increased Learning Outcome and Learning Motivation

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A R T I C L E I N F O

Keywords: Google Sites, Interactive Learning Media, Light Wave, Learning Motivation, Learning Outcomes

Received: 19, June
Revised: 20, July
Accepted: 30, August

A B S T R A C T

The integration of interactive digital media in physics learning is essential to address students' difficulties in understanding abstract concepts such as light waves. This study aims to develop and evaluate interactive learning media assisted by Google Sites for light wave material. The research employed a Research and Development approach using the ADDIE model. The participants were 31 twelfth-grade students and one physics teacher. Data were collected using validation sheets, learning outcomes tests, motivation questionnaires, and response questionnaires. The results indicated that the developed media met the criteria of validity, effectiveness, and practicality. The average validity score reached 97.31%, while the classical completeness of learning outcomes was 96.77% with a mean score of 85.87. Students' learning motivation increased by 18.72%, supported by the Wilcoxon test showing that all students experienced improvement. The practicality was reflected in positive responses from students (83.14%) and teachers (100%). These findings demonstrate that Google Sites-assisted interactive media effectively enhances students' conceptual understanding and learning motivation, particularly in learning abstract physics concepts, and supports the implementation of student-centered learning in the digital era.

DOI: https://doi.org/10.55927/ijar.v5i8.16919
ISSN-E: 2986-0768
https://journal.formosapublisher.org/index.php/ijar

INTRODUCTION

The rapid development of digital technology has significantly transformed educational practices, particularly the integration of information and communication technology into classroom instruction. The use of technology-enhanced learning environments has been shown to improve student engagement and learning outcomes (Bond et al., 2020; Lai & Bower, 2019) In addition, the implementation of the Merdeka Curriculum emphasizes student-centered and flexible learning approaches (Rahmadayanti & Hartoyo, 2022a)

Physics learning, especially in topics such as light waves, often presents challenges due to its abstract nature. Concepts such as interference, diffraction, and refraction require strong visualization skills, which are difficult to achieve through traditional instructional methods. Previous studies indicate that interactive and web-based learning media can significantly improve conceptual understanding in physics (Ismawati et al., 2021; Hamamous & Benjelloun, 2023).

However, classroom practices are still largely dominated by conventional teaching media, resulting in passive learning environments. This gap highlights the need for innovative instructional media that can facilitate active learning. Interactive learning media have been proven to enhance both learning outcomes and motivation (Aulia et al., 2024; Sulistyawati et al., 2024a).

Google Sites offers a flexible platform for integrating multimedia content, including text, videos, and interactive simulations. Several studies have demonstrated its effectiveness in improving students’ learning experiences and engagement (Prayudi & Anggriani, 2022; M Agil Febrian & Muhammad Irwan Padli Nasution, 2024).

This study contributes to physics education by demonstrating the effectiveness of Google Sites-assisted interactive media specifically for abstract concepts such as light waves. Unlike previous studies that primarily focus on general subject areas or partial evaluations, this research integrates a systematic instructional design model (ADDIE) with a comprehensive evaluation framework covering validity, effectiveness, and practicality. Therefore, this study provides a more holistic and empirically supported approach to developing and assessing interactive learning media in physics education.

LITERATURE REVIEW

Interactive Learning Media

Interactive learning media are educational tools designed to foster active student engagement throughout the learning process. According to Meziane Cherif (2025), interactive multimedia has been proven to significantly impact academic achievement and learning behavior through student-centered learning approaches. Furthermore, these media are capable of simplifying complex concepts, increasing cognitive engagement, and facilitating self-paced learning (Meziane Cherif, 2025)

In digital education, these media integrate text, images, audio, and video to create a holistic experience that accommodates diverse learning styles (Malik et al., 2022). The use of interactive elements—such as quizzes, simulations, and educational games—is effective in increasing participation, motivation, and learning outcomes compared to conventional methods (Julaeha et al., 2025;

Sulistyawati et al., 2024; Goode et al., 2022). Beyond material delivery, these media serve as facilitators for 21st-century skills, such as critical thinking and collaboration (Bond et al., 2020; Makransky & Petersen, 2021; Radianti et al., 2020). Furthermore, evaluation features and instant feedback within interactive media allow students to monitor their learning progress independently, which ultimately strengthens self-confidence (Adams et al., 2006)

Google Sites as Learning Media

Google Sites is a website development platform that supports digital learning with responsive design features, specifically the ability to automatically adjust its display across various devices, such as computers, tablets, and smartphones (Bhanarkar et al., 2023; Parlakkiliç, 2022). This flexibility is supported by the integration of the Google Suite ecosystem (Docs, Slides, YouTube), which allows educators to embed various learning resources within a single organized platform (Malik et al., 2022)

The use of Google Sites supports flexible learning, where students can access materials anytime and anywhere. Moreover, its collaborative features enable intensive interaction, such as group discussions and collective content creation, deepening understanding through the construction of collective knowledge (Bond et al., 2020; Kohnke & Moorhouse, 2022; Martin et al., 2020). In the context of the *Merdeka Curriculum*, Google Sites facilitates student-centered learning, where students can take an active role, for instance, in compiling digital portfolios (Ndari et al., 2023; Purdue University, n.d.). Integration with virtual simulations, such as PhET, also assists in concretely visualizing abstract physics phenomena (Rahmadayanti & Hartoyo, 2022b; Saputra, 2025).

ADDIE Development Model

The development of learning media in this study utilizes the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). This model provides a systematic framework for producing effective products (Branch, 2009)

1. **Analysis:** Focuses on identifying the needs and characteristics of learners (Branch, 2009)
2. **Design:** Planning the content structure and learning strategies (Branch, 2009)
3. **Development:** Realizing the product and conducting initial trials (Molenda, 2003).
4. **Implementation:** Applying the product to a real audience to observe effectiveness under actual conditions (Dick et al., 2009)
5. **Evaluation:** Formative and summative assessment to measure the achievement of learning objectives (Reigeluth & Carr-Chellman, 2009)

Media Eligibility Criteria

The eligibility of the media is measured through three aspects: validity, practicality, and effectiveness.

1. **Validity:** Relates to the quality of content and layout. Assessment is conducted by subject matter and media experts to ensure alignment with learning objectives (Daryanto, 2013)

2. **Practicality:** Refers to the ease of use by teachers and students (Plomp & Nieveen, 2013; Ramadani, 2025). Practical media feature intuitive navigation and a layout that facilitates information access (Ihwana et al., 2025; Rantung et al., 2023)
3. **Effectiveness:** Measured by improvements in learning outcomes and student satisfaction (Plomp & Nieveen, 2013). The use of interactive multimedia that encourages active participation contributes positively to academic efficacy and conceptual understanding (Alessi & Trollip, 2001; Rahma & Nawir, 2024; Sharif Nia et al., 2023)

Learning Outcomes and Motivation

Learning outcomes are defined as comprehensive changes in behavior, encompassing cognitive, affective, and psychomotor domains (Bloom & Krathwohl, 1974; Sudjana, 2006). Anderson & Krathwohl (2001) break down the cognitive dimension into levels ranging from remembering to creating, while Gagné (1977) emphasizes five categories of capabilities, ranging from verbal information to intellectual skills. In science education, learning outcomes are measured through conceptual understanding, analytical skills, and application in problem-solving (Arikunto, 1999)

Learning motivation refers to the internal or external drives that influence a student's perseverance and intensity (Schunk, 2012). Motivation is influenced by the need for autonomy, competence, and relatedness (Ryan & Deci, 2000). Indicators of motivation include interest in the material, perseverance in the face of difficulties, clear learning goal setting, and active involvement in collaborative processes (Fredricks et al., 2004; Hidi & Ann Renninger, 2006; Locke & Latham, 2002; Zimmerman, 2002)

Overview of Light Wave Material

Light wave material in Phase F of the *Merdeka Curriculum* requires students to be able to explain the properties of light waves, analyze phenomena (dispersion, interference, diffraction, polarization), and interpret experimental data.

1. **Dispersion:** The phenomenon of white light splitting into a color spectrum through a prism.
2. **Diffraction:** The bending of light as it passes through a narrow aperture, producing bright and dark patterns based on Huygens' principle.
3. **Interference:** The combination of two coherent waves to form a new pattern; in a double-slit, the maximum and minimum patterns depend on the optical path difference.
4. **Polarization:** The phenomenon where some or all of the vibration directions of transverse waves are absorbed.

Conceptual Framework

The development of this conceptual framework is grounded in the demands of education in the digital era and the implementation of the *Merdeka Curriculum*, which provides educators with the flexibility to design innovative learning strategies. The core problem identified is that light wave material is abstract in nature, making it often difficult for students to comprehend and visualize. Furthermore, the utilization of information technology in the classroom remains suboptimal, which contributes to low student motivation and poor learning outcomes.

The solution for this study is to develop Google Sites-assisted interactive learning media using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) development model. This process is expected to yield valid, practical, and effective learning media. The success of this development is measured by improvements in conceptual understanding (learning outcomes) and increases in student learning motivation as the ultimate impact of utilizing the learning media, illustrated in the conceptual framework flowchart below:

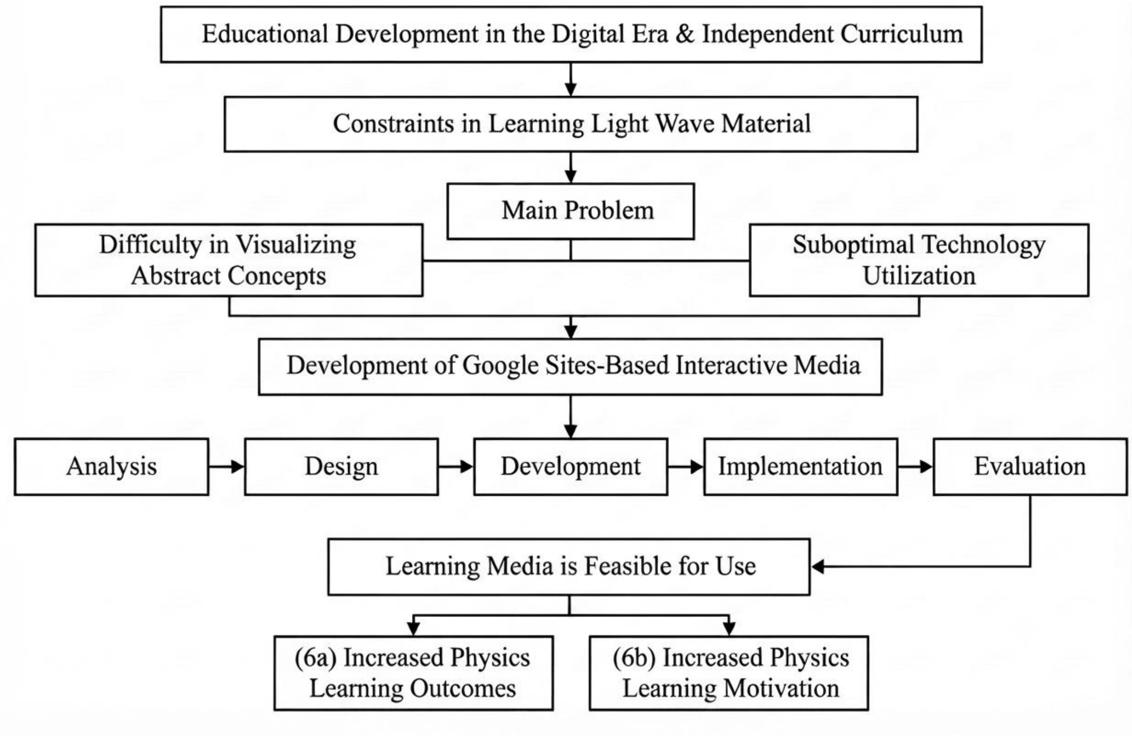

Figure 1. Conceptual Framework

METHODOLOGY

This study applies a Research and Development (R&D) approach using the five-stage ADDIE framework—Analysis, Design, Development, Implementation, and Evaluation—to engineer a Google Sites-based interactive learning platform for physics. The development and empirical field testing were conducted at UPT SMA Negeri 11 Pinrang. The research participants consisted of three expert validators from Universitas Negeri Makassar (two content specialists and one media specialist) who evaluated the platform's architectural integrity, one physics teacher who evaluated operational practicality, and physics students who participated in both the small-group tryouts and the full implementation phase. The development process was structured around the five sequential phases of the ADDIE model.

1. **Analysis:** This phase involved identifying instructional gaps in abstract light wave concepts using student needs questionnaires, conducting unstructured interviews with the physics instructor, and performing a

curriculum analysis to align the content with *Kurikulum Merdeka* deep learning standards.

2. **Design:** This phase focused on mapping the website architecture and user interface layout, selecting multimedia assets (such as instructional videos and HTML5 *PhET Interactive Simulations*), and designing evaluation instruments.
3. **Development:** During this phase, the platform was constructed on Google Sites, reviewed by the expert panel, and revised based on their feedback before undergoing initial small-group tryouts to fix technical bugs.
4. **Implementation:** The finalized platform was deployed in physics classrooms using the school's digital infrastructure (Wi-Fi, LCD projectors, and smartboards). This phase concluded with the administration of a cognitive post-test and a motivation survey.
5. **Evaluation:** This phase combined formative adjustments based on ongoing user feedback with a summative evaluation of student learning outcomes.

Instruments and Data Analysis

Data collection used a mixed-methods approach to assess the platform across three core parameters: validity, practicality, and effectiveness. Content and media validity were evaluated using expert validation sheets (scored on a 1–4 scale) and analyzed using the Gregory content validity index via a 2 × 2 cross-tabulation matrix:

		Expert Rater 1	
		Low Relevance (Items rated 1 or 2)	High Relevance (Items rated 3 or 4)
Expert Rater 2	Low Relevance (Items rated 1 or 2)	A	B
	High Relevance (Items rated 3 or 4)	C	D

Figure 2. Inter-rater Agreement Model for Content Validity Assessment

$$V_C = \frac{D}{A+B+C+D} \qquad (1)$$

In this formula, *A* represents mutual weak relevance, *B* and *C* denote divergent expert ratings, and *D* signifies mutual agreement on strong item relevance. The platform is verified as valid if the index meets the threshold of $VC \geq 0.75$, supplemented by descriptive percentage analysis to classify overall feasibility.

Instructional practicality was measured through teacher and student response questionnaires using a 5-point Likert scale. The platform is considered practical and viable for field deployment if it achieves a descriptive percentage threshold of ≥ 60%.

To evaluate instructional effectiveness, cognitive mastery was measured through a 30-item complex multiple-choice post-test. Individual student performance was benchmarked against the institutional minimum mastery criterion (KKM ≥ 75), while classical cohort mastery was achieved if ≥ 85% of the class successfully passed that KKM threshold. Concurrently, shifts in learning motivation were calculated by administering pre- and post-intervention motivation scales configured to a 4-point forced-choice Likert scale to eliminate neutral response bias. These data were analyzed inferentially using SPSS 25 software. A Paired-Sample t-Test was performed for data adhering to a normal distribution (verified via the Shapiro-Wilk test), whereas the Wilcoxon Signed-Rank Test was utilized as the non-parametric alternative if the normality assumption was violated.

RESULTS

Validity and Feasibility of the Interactive Learning Media

The data obtained from the media and subject matter experts were used to assess the validity and feasibility of the developed interactive learning media. The results of the summary of media and subject matter experts for feasibility are presented in Table 1.

Table 1. Summary of Media and Subject Matter Experts for Feasibility Analysis

Validator	Percentage (%)	Category
Material Expert	96.28	Very Feasible
Media Expert	98.33	Very Feasible
Average	**97.31**	**Very Feasible**

Based on Table 1, the developed learning media achieved an average validity score of 97.31%, which falls into the *very feasible* category. More specifically, the subject matter expert evaluation (96.28%) indicates that the content is well aligned with the concepts of light waves in physics, including conceptual accuracy, depth of material, and curriculum relevance. Meanwhile, the media expert evaluation (98.33%) suggests that the interface design, navigation structure, and multimedia integration meet the principles of effective instructional design.

The high validity score implies that the media is not only suitable for implementation but has also been systematically designed according to established instructional design principles. This finding is consistent with Plomp & Nieveen (2013), who emphasize that validity is a key indicator in determining the alignment of educational products with learning objectives. Furthermore, well-designed multimedia elements play a crucial role in enhancing information delivery and learning effectiveness (Clark & Mayer, 2016)

Table 2. Content Validity Index (Gregory)

Indicator	Value
Validity Index (Vc)	1.00

The Gregory content validity index of 1.00 indicates perfect agreement among the validators across all evaluated aspects. This suggests that there are no significant discrepancies in the evaluators' perceptions regarding both the content quality and the media design.

From a methodological perspective, this result strengthens the findings presented in Table 1 by demonstrating a high level of consistency among expert judgments. Therefore, the developed media can be categorized as having very high content validity, which is an essential prerequisite before proceeding to field testing and effectiveness evaluation.

Effectiveness of Learning Interactive Media

The data used to evaluate the effectiveness of the developed interactive learning media consisted of students' learning outcomes data collected after using the interactive learning media, as well as learning motivation questionnaire data obtained before and after the implementation of the interactive learning media. The data on learning outcomes are summarized as presented in Table 3.

Table 3. Learning Outcomes Summary

Variable	Value
Number of Students	31
Students Passed	30
Classical Completeness (%)	96.77
Mean Score	85.87

Table 3 shows that 96.77% of students achieved learning mastery, with a mean score of 85.87. This high level of classical completeness indicates that the developed learning media effectively supports most students in understanding light wave concepts. From a deeper perspective, this achievement suggests that the media not only performs effectively at a general level but also helps bridge students' difficulties in understanding abstract concepts. This finding supports the theory that interactive and visually enriched media can enhance conceptual understanding by providing more concrete representations of abstract phenomena (Mayer, 2021)

Table 4. Distribution of Learning Outcomes

Category	Percentage (%)
Very Good	36.67
Good	63.33
Others	0

The distribution of learning outcomes in Table 4 indicates that all students fall within the *good* (63.33%) and *very good* (36.67%) categories, with no students classified in lower categories.

This distribution demonstrates that the improvement in learning outcomes is not limited to a small group of students but is evenly distributed across the entire class. Pedagogically, this suggests that the learning media has inclusive effectiveness, benefiting not only high-achieving students but also those with moderate learning abilities.

Table 5. Improvement of Learning Motivation

Variable	**Score**
Before	70.28
After	89.00
Increase (%)	**18.72**

Table 5 shows an increase in learning motivation from 70.28 (high) to 89.00 (very high), representing an improvement of 18.72%. This indicates a significant positive change in the affective domain of students after the implementation of the learning media. Theoretically, this improvement can be explained by self-determination theory, which posits that learning environments that support autonomy and interactivity can enhance intrinsic motivation (Ryan & Deci, 2000). In this context, Google Sites provides flexibility for students to access learning materials independently, thereby increasing their sense of control over the learning process.

Table 6. Wilcoxon Signed-Rank Test

Category	**N**
Positive Ranks	31
Negative Ranks	0
Ties	0

The Wilcoxon test results in Table 6 show that all students (N = 31) are categorized under *positive ranks*, with no *negative ranks* or *ties*. This indicates that no students experienced a decrease or stagnation in learning motivation. Statistically, this finding confirms that the observed improvement in motivation is both consistent and significant across all participants. In other words, the effectiveness of the learning media is not only evident descriptively but is also supported by strong inferential evidence.

Practicality of Learning Interactive Media

The data used to evaluate the practicality of the developed interactive learning media consisted of response questionnaires from students and physics teachers after the implementation of the interactive learning media. The data on user response summary is presented in Table 7.

Table 7. User Response Summary

Respondent	Percentage (%)	Category
Students	83.14	Very Practical
Teacher	100	Very Practical

Based on Table 7, student responses toward the learning media reached 83.14%, while the teacher response reached 100%, both of which fall into the *very practical* category. This indicates that the media is not only effective from an academic perspective but also highly usable in real classroom settings. The positive responses from students suggest that the media enhances engagement and learning comfort. Meanwhile, the exceptionally high response from the teacher indicates that the media can be easily integrated into the instructional process without requiring complex adjustments. From an implementation perspective, this level of practicality is crucial for the sustainability of educational technology, as tools that are difficult to use are less likely to be adopted in the long term (Parlakkiliç, 2022).

The findings of this study demonstrate that Google Sites-assisted interactive media effectively bridges the gap between abstract physics concepts and students' cognitive processing capabilities. From a cognitive theory of multimedia learning perspective, the integration of visual, textual, and interactive elements reduces cognitive load and enhances meaningful learning (Mayer, 2021; Fiorella & Mayer, 2018).

Furthermore, the significant improvement in learning motivation highlights the role of autonomy-supportive learning environments. Google Sites enables students to navigate content independently, which aligns with constructivist learning principles and promotes active knowledge construction. This finding reinforces previous studies emphasizing the importance of learner-centered digital environments (Martin et al., 2020)

A key contribution of this study lies in its specific application to abstract physics concepts, particularly light waves, which are inherently difficult to visualize. Unlike previous studies that tend to focus on general science learning or isolated media use, this research demonstrates that even a relatively simple and accessible platform such as Google Sites can be effectively utilized to support deep conceptual understanding when combined with a structured instructional design approach. This finding highlights the potential scalability and accessibility of web-based learning media in physics education.

However, this study has several limitations. The sample size was relatively small and limited to a single school context, which may affect generalizability. Future research should involve larger and more diverse samples and explore the integration of advanced simulations or virtual laboratories to further enhance learning outcomes.

CONCLUSIONS AND RECOMMENDATIONS

This study demonstrates that the Google Sites-assisted interactive learning media developed through the ADDIE model meets the criteria of validity, effectiveness, and practicality. The high validity score (97.31%) confirms that the media is well-aligned with both conceptual content and instructional design principles. In terms of effectiveness, the classical completeness of 96.77% with a mean score of 85.87 indicates that the media successfully supports students' understanding of light wave concepts. In addition, students' learning motivation increased by 18.72%, with the Wilcoxon test confirming consistent improvement across all participants. The practicality of the media is further supported by positive responses from students (83.14%) and the teacher (100%), indicating that it is easy to use and suitable for classroom implementation.

These findings suggest that integrating interactive multimedia within an accessible web-based platform can effectively enhance both cognitive and affective learning outcomes, particularly for abstract physics topics. The novelty of this study lies in the combined application of a systematic instructional design (ADDIE) with a comprehensive evaluation of validity, effectiveness, and practicality in the context of light wave learning, demonstrating that Google Sites can serve as an effective and scalable tool for physics education.

Future research is recommended to expand the media by incorporating more advanced interactive features and to involve larger and more diverse samples to strengthen the generalizability of the findings.

FURTHER STUDY

Based on the empirical findings, developmental outcomes, and operational constraints identified during the design and implementation of the Google Sites-based interactive learning media on light waves, the following strategic directions are recommended for future research:

1. **Expansion of Physics Content Domains (Content Differentiation)** This study was constrained to the optical properties of light waves (dispersion, interference, diffraction, and polarization). Future investigations should extend the application of the Google Sites platform to other abstract and cognitively demanding physics domains—such as Quantum Mechanics, Special Relativity, or Nuclear Physics—to evaluate the structural consistency and pedagogical efficacy of web-based media across diverse scientific topics.
2. **Integration of Artificial Intelligence for Adaptive Learning** The current iteration of the developed web media utilizes a linear, uniform instructional pathway. Future research should explore the integration of Artificial Intelligence (AI) algorithms or adaptive plug-ins within web-based learning environments. This would enable real-time customization of content sequencing, formative assessment difficulty, and virtual simulation parameters based on individual student learning paces (*self-paced learning*) and cognitive styles.
3. **Assessment of Higher-Order Thinking Skills (HOTS)** While this study focused primarily on baseline cognitive learning outcomes and motivation, future research should align more closely with contemporary global educational standards by explicitly measuring the impacts of interactive web media on higher-order thinking dimensions. Prospective studies should implement specialized evaluation instruments to quantify student

advancements in critical thinking, scientific literacy, and complex problem-solving skills.

4. **Large-Scale Multicenter Evaluation (Extended Dissemination)** The implementation phase of this research was limited to a single institution with a relatively homogenous sample. To strengthen external validity and achieve robust generalizability, future studies should conduct large-scale, multicenter trials (*multicenter studies*) across multiple schools with varied institutional accreditation levels, distinct geographical locations (urban versus rural), and diverse digital infrastructure capabilities.
5. **Longitudinal Analysis of Knowledge Retention** Cognitive learning outcomes in this study were evaluated immediately post-intervention. Future research should employ longitudinal methodologies or delayed post-tests administered several weeks or months following the treatment. This approach is critical to assess the long-term cognitive efficacy of integrated multimedia visualizations and PhET virtual simulations in sustaining student memory retention of abstract physical concepts.
6. **Mitigation of Technical Barriers and Offline Accessibility** Given that the absolute reliance of Google Sites on stable internet connectivity posed a minor challenge for certain participants, future developers should explore the integration of Progressive Web Apps (PWA) architecture or hybrid synchronization systems. Designing platforms that accommodate offline or low-bandwidth functionality will be vital to minimizing the digital divide and ensuring equitable educational accessibility.

AUTHOR CONTRIBUTIONS

All authors contributed equally to the conceptualization, design, data collection, and analysis of this study. All authors have read and agreed to the published version of the manuscript.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to the Universitas Negeri Makassar for their expertise in validating the research instruments. We also extend our appreciation to the Principal and Physics teacher at UPT SMA Negeri 11 Pinrang for their invaluable support and collaboration during the field implementation phase.

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