Journal of Educational Sciences
Journal homepage: https://jes.ejournal.unri.ac.id/index.php/JES

P-ISSN 2581-1657
E-ISSN 2581-2203

E-Learning Development Based on Multimedia Learning Strategies to Improve Learning Outcomes

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ARTICLE INFO

Article history:

Received: 07 Dec 2025
Revised: 02 Feb 2026
Accepted: 27 Feb 2026
Published online: 05 March 2026

Keywords:

E-Learning,
Learning Outcomes,
Learning Strategy,
Multimedia

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Article Doi:

https://doi.org/10.31258/jes.10.3.p.263-280

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A B S T R A C T

Limited instructional time and the lack of interactive learning media have contributed to low Physics learning outcomes, particularly in understanding abstract concepts. These conditions indicate the need for an effective digital learning solution that integrates structured instructional strategies and multimedia support. This study aims to develop and evaluate a multimedia-based e-learning model using the LEARN (Listen, Explore, Apply, Reflect, and Navigate) learning strategy to improve the Physics learning outcomes of 10th-grade students. The research employed a Research and Development (R&D) approach by integrating the Borg and Gall model with the Lee and Owens framework. Data were collected through interviews, questionnaires, expert validation instruments, and learning outcome tests. The developed e-learning model was validated by material, media, and instructional design experts and tested through one-to-one, small-group, and large-group trials. The effectiveness of the model was examined using a quasi-experimental design with experimental and control groups. The results indicate that the multimedia-based e-learning model is highly feasible and leads to higher learning gains compared to conventional learning modules. In conclusion, multimedia-based e-learning can effectively enhance Physics learning outcomes in learning environments with limited face-to-face instructional time.

1. Introduction

The rapid advancement of Information and Communication Technology (ICT) has significantly influenced various aspects of human life, including the education sector. This transformation extends beyond improvements in educational infrastructure to encompass fundamental changes in learning patterns, student behavior, and instructional management. As a result, educational institutions are required to adapt by implementing innovative learning approaches that align with technological developments and the demands of 21st-century education. One

prominent form of ICT integration in education is e-learning, which utilizes digital media to deliver instructional content and facilitate interaction between teachers and learners. E-learning enables learning to take place flexibly, independently, and in a student-centered manner by overcoming the limitations of time and space (Hartono et al., 2025).

The implementation of e-learning is increasingly relevant in educational contexts where learners are accustomed to digital technologies and independent information access. Previous studies indicate that e-learning environments can support learning flexibility, learner autonomy, and continuous access to instructional materials, thereby creating opportunities for more effective and personalized learning experiences (Reigeluth et al., 2017; Clark & Mayer, 2023). These conditions provide a strong foundation for integrating technology-based learning models that respond to students' learning needs and contemporary educational demands.

Numerous previous studies have demonstrated that digital and multimedia-based learning media can enhance students' learning outcomes, motivation, and conceptual understanding. In particular, augmented reality (AR)–based and multimedia-supported learning media have been widely reported to improve students' cognitive achievement and engagement. Khusnunnisa and Andriani (2025) found that AR-assisted interactive multimedia was effective in improving students' learning outcomes, while Septiani et al. (2025) reported significant improvements in students' understanding of atomic theory through AR-integrated learning media. Other studies have also shown that multimedia-based learning media enhance conceptual understanding, reading interest, numeracy skills, and visual communication abilities (Zahro et al., 2024; Jannah et al., 2025; Muti'ah et al., 2024; Masrukhin et al., 2024).

Despite these positive findings, several limitations remain evident in previous research. Most studies have focused primarily on feasibility and practicality testing and have been conducted mainly at the elementary education level, with limited emphasis on comprehensive effectiveness evaluation. Moreover, the integration of digital media with structured instructional strategies remains limited, particularly in Physics learning contexts that require strong visualization support for abstract concepts (Gusmida & Islami, 2017; Syahrir et al., 2025). These gaps indicate the need for further research that develops and evaluates multimedia-based e-learning models supported by clear instructional strategies and applied to specific subject domains.

In practice, the implementation of e-learning in many educational institutions has not yet been fully optimized. Common challenges include low student engagement, limited interaction between teachers and learners, insufficient variation in learning media, and a lack of alignment between instructional strategies and subject characteristics. These challenges are especially evident in Physics learning, which involves abstract concepts, high cognitive demands, and the need for strong conceptual understanding and scientific reasoning skills.

These issues are also observed at the Bintang Pelajar Bogor Training and Course Institution (LKP). Empirical data collected through interviews and documentation studies revealed that only 52.6% of tenth-grade students met the Minimum Mastery Criteria (KKM) in Physics during the 2023/2024 academic year, and 55.7% during the 2024/2025 academic year. Interviews with Physics teachers and institutional administrators indicated that students experienced difficulties in understanding abstract concepts due to limited visual and interactive learning media, insufficient instructional time, low learning motivation, and ineffective learning methods. These findings are consistent with the results of an initial questionnaire showing that 52% of students perceived Physics learning as monotonous and insufficiently supported by multimedia.

The learning conditions at Bintang Pelajar further exacerbate these challenges. Students attend tutoring sessions three times a week, with each subject allocated only one session per week or, in some cases, once every two weeks. This limited instructional time, combined with students' fatigue after full-day school activities, restricts teachers' ability to deliver learning materials comprehensively. Additional learning sessions are difficult to implement due to teachers' tight schedules, students' availability constraints, and increased operational costs. Although teachers have attempted interventions such as additional practice exercises and online consultations, these efforts have proven less effective due to difficulties in monitoring and evaluating students' independent learning progress.

These conditions highlight the need for learning media that support flexible, independent, and engaging learning beyond classroom limitations. Multimedia-based learning strategies, which integrate text, images, audio, video, and animation, have been shown to enhance learning effectiveness by increasing cognitive engagement and reducing cognitive load (Gagné et al., 1992; Clark & Mayer, 2023). Such strategies are particularly relevant in Physics education, where abstract concepts require clear visualization and meaningful representation to support conceptual understanding. Furthermore, the shift in educational paradigms from teacher-centered to student-centered learning, and from passive learning to active and self-directed learning, emphasizes the importance of empowering students to take an active role in constructing their knowledge (Reigeluth et al., 2017; Handayani, 2017). Multimedia-based e-learning supports this paradigm shift by providing learners with greater autonomy, interactive learning experiences, and opportunities for learning beyond classroom boundaries.

Based on the theoretical and empirical considerations outlined above, multimedia-based e-learning emerges as a potential solution to address the limitations of instructional time, learning media, and student engagement in Physics education. Therefore, this study aims to develop and evaluate the effectiveness of a multimedia-based e-learning model in improving the Physics learning outcomes of tenth-grade students at the Bintang Pelajar Bogor Educational Institution.

2. Methodology

Type and Research Approach

This study employed a Research and Development (R&D) approach aimed at developing, validating, and testing the effectiveness of an E-learning model based on multimedia learning strategies in improving students' physics learning outcomes. This approach was selected because the study emphasizes not only outcome evaluation but also the systematic process of instructional product development. The development model used in this study integrates the Borg and Gall model with the Lee and Owens framework, encompassing stages of needs analysis, design, development, validation, product trials, and effectiveness testing.

Research Setting and Participants

The study was conducted from January to July 2025 at Bintang Pelajar Bogor Educational Institution. The research participants consisted of tenth-grade students as the primary users of the developed E-learning system. In addition, physics teachers were involved as instructional partners, while subject matter experts, media experts, and instructional design experts participated in the product validation process to ensure content relevance, media quality, and instructional design appropriateness.

Research and Development Procedures

The research procedure began with a needs analysis stage aimed at identifying physics learning problems, student characteristics, and the need for E-learning–based instructional media. The results of this analysis served as the foundation for designing the E-learning product, which adopted a guided discovery architecture using the LEARN strategy (Listen, Explore, Apply, Reflect, Navigate). The subsequent development stage involved organizing instructional materials, developing multimedia content in the form of animated videos and interactive e-modules, and designing evaluation instruments integrated into the E-learning system. The developed E-learning product was then validated by experts to assess the feasibility of the instructional content, media quality, and alignment of the instructional design with multimedia learning principles. Feedback and suggestions from the experts were used as the basis for revising the product prior to implementation. Product trials were conducted sequentially through one-to-one trials, small-group trials, and large-group trials to obtain information regarding usability and user acceptance. The final stage of the research procedure was the effectiveness testing, which aimed to determine the impact of the E-learning implementation on students' physics learning outcomes.

Data Collection Techniques and Instruments

Data were collected using instruments aligned with the research objectives. Needs analysis data were obtained through interviews and questionnaires administered to students and teachers. Product feasibility data were collected using expert

validation questionnaires developed based on the Learning Object Review Instrument (LORI) standards. In addition, student responses to the E-learning implementation were gathered through questionnaires during the product trials. Students' learning outcomes were measured using pretest and posttest instruments administered before and after the implementation of the E-learning system.

Data Analysis Techniques

The collected data were analyzed using both qualitative and quantitative approaches. Qualitative data in the form of expert feedback and student responses were analyzed descriptively to refine and improve the developed E-learning product. Quantitative data from feasibility assessments were analyzed by converting scores into percentages to determine the level of product feasibility. The effectiveness of the E-learning was evaluated using a quasi-experimental design with a non-equivalent control group. Prior to hypothesis testing, the learning outcome data were examined for normality and homogeneity. Subsequently, appropriate statistical tests were applied based on the data characteristics. Improvements in students' learning outcomes were analyzed using N-Gain scores to determine the effectiveness level of the developed E-learning model.

3. Results and Discussion

Result

This section presents the results obtained from the development, validation, and implementation of the multimedia-based e-learning model designed to improve Physics learning outcomes. The results are systematically organized to reflect each stage of the research process, including the needs analysis, model development, expert validation, product trials, and effectiveness testing. Quantitative data are presented in the form of validation scores, student response percentages, and learning outcome measurements, while qualitative data are derived from expert suggestions and user feedback. All results are reported objectively without interpretation, allowing readers to clearly observe the empirical evidence produced by the study. Tables and figures are used to support data presentation and are consistently referenced in the text. Overall, this section provides a comprehensive overview of the feasibility and performance of the developed e-learning model based on the collected research data.

Results of Needs Analysis

The needs analysis was conducted through document analysis, interviews with Physics teachers and institutional management, and student questionnaires. The results indicate several constraints affecting Physics learning outcomes at LKP Bintang Pelajar. Interview data revealed that students experienced difficulties in understanding abstract Physics concepts due to the dominance of lecture-based teaching methods and the limited use of interactive visual media. Although the curriculum allocates 90 minutes of instruction per week, teachers reported that this

duration was insufficient, as additional tutoring sessions were frequently required to support student understanding. Furthermore, institutional stakeholders highlighted the absence of a structured digital system to support and monitor remote learning activities.

Student questionnaire results further support these findings. As shown in Figure 3, learning motivation, adequacy of study hours, and learning methods received predominantly negative responses. Only 25% of students reported being motivated to learn Physics, 43% perceived the allocated study time as sufficient, and 50% considered the learning methods effective. Two indicators received the lowest responses, as none of the students agreed with the statements regarding the use of multimedia by teachers and their confidence in solving Physics problems independently.

Conversely, teacher quality (95%), teaching materials (70%), and environmental support (70%) received positive evaluations and were therefore not prioritized for improvement, as illustrated in Figure 1. Documentation analysis indicated that essential academic documents, including lesson plans, learning media, assessment records, and student profiles, were available. However, the percentage of students achieving scores above the Minimum Competency Criterion (KKM) remained relatively low, at 52.6% in the 2023/2024 academic year and 55.7% in the 2024/2025 academic year. Overall, the needs analysis data demonstrate the necessity for interactive, varied, and flexible digital learning media capable of supporting student learning beyond direct teacher supervision.

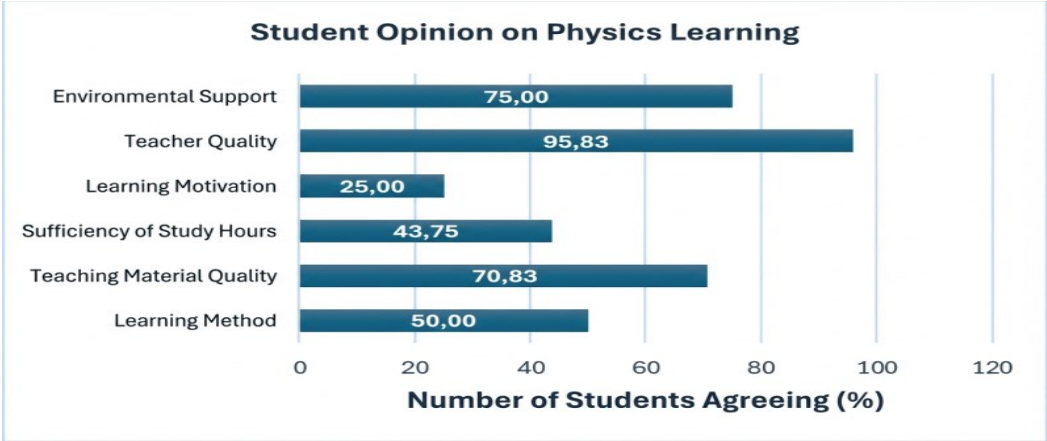

Figure 1. Graph of Student Satisfaction Scores Regarding Influential Factors in Physics Learning

Figure 1 presents student satisfaction levels toward several factors influencing physics learning. Teacher quality obtained the highest level of agreement, followed by teaching materials and environmental support, indicating that these aspects are generally perceived positively by students. In contrast, other factors such as learning motivation, learning methods, and sufficiency of study hours received lower levels of agreement, suggesting areas that require greater attention. These

findings reinforce the need for innovative digital learning media to enhance student engagement and learning effectiveness.

Draft Model Development 1

Based on the needs analysis results, Draft Model 1 was developed as a multimedia-based e-learning system designed to support Physics learning through structured self-directed activities. The model consists of three main components: instructional design, an e-learning platform, and multimedia learning objects. The instructional design adopts the LEARN strategy (Listen, Explore, Apply, Reflect, Navigate), which guides learners through sequential learning stages while maintaining flexibility in asynchronous learning. The application of this instructional framework within the e-learning environment is presented in Figure 2.

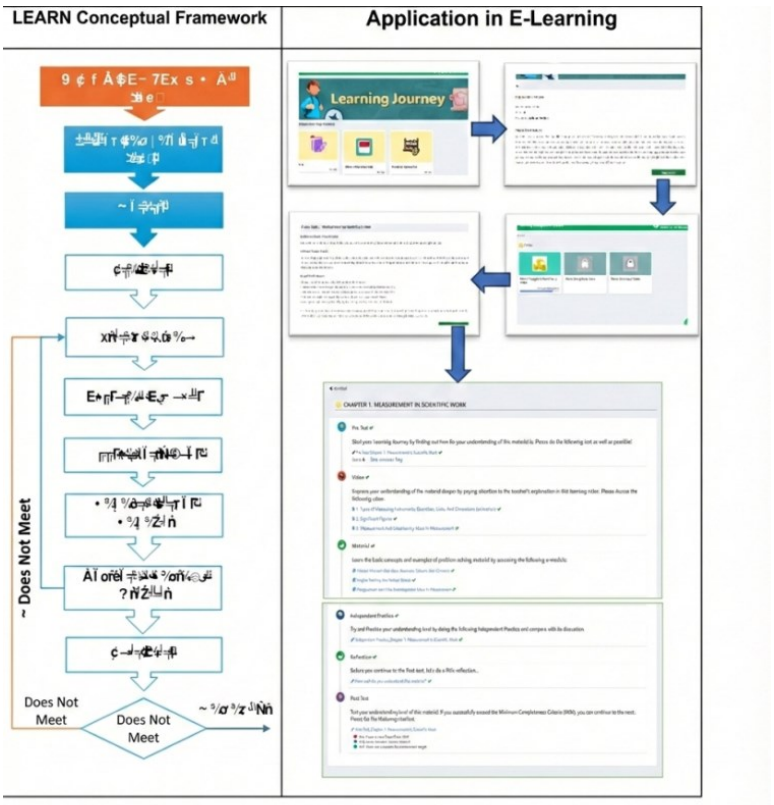

Figure 2. Application of the Conceptual Framework of Instructional Design in E-Learning

The interface design and core features of the developed e-learning system are presented to demonstrate how the LEARN instructional strategy is implemented within the learning process. Rather than displaying all system pages, only essential interfaces that represent the learning stages, assessment mechanisms, and progress monitoring are discussed. The implementation of the LEARN-based learning activities is illustrated in Figure 3.

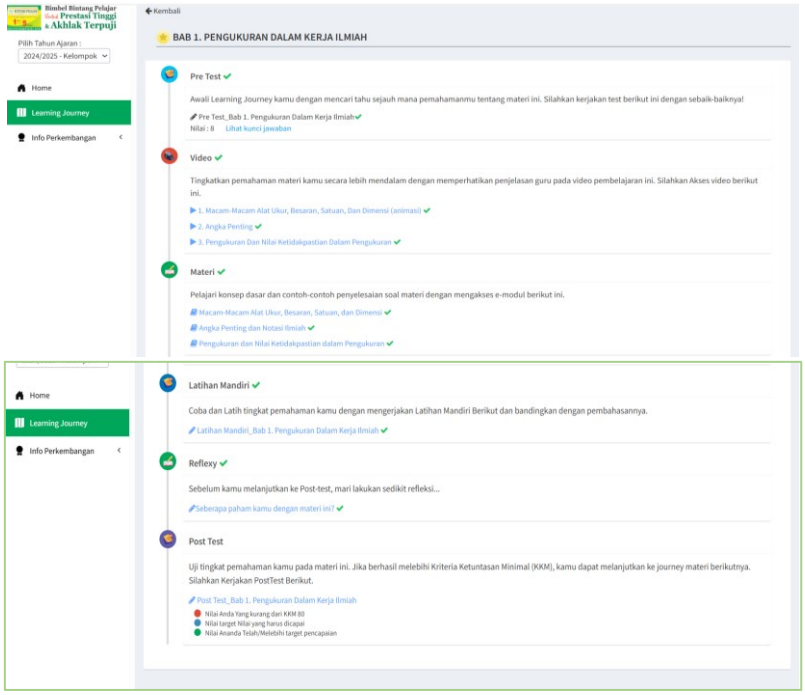

Figure 3. Learning Activity Page Based on the LEARN Instructional Strategy

The main learning activity page integrates the stages of Listen, Explore, Apply, Reflect, and Navigate into a coherent instructional flow, enabling students to engage in structured and interactive learning activities. To evaluate students' learning progress and the effectiveness of the instructional design, the system incorporates assessment features in the form of pretests and posttests. The assessment interface used in this study is presented in Figure 4.

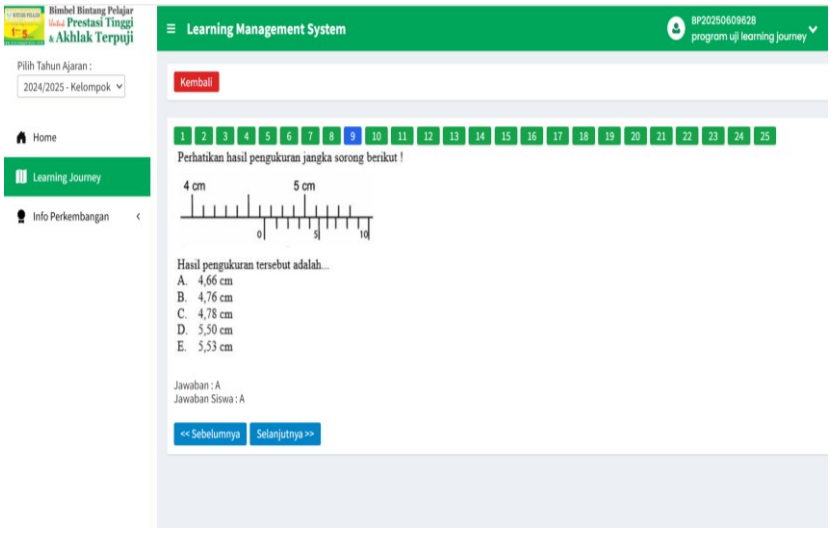

Figure 4. Pretest and Posttest Assessment Interface

This interface allows teachers to measure students' prior knowledge and learning outcomes after completing the LEARN-based learning activities. The delivery of learning materials in the developed system utilizes multimedia resources to support

students' understanding and engagement. The multimedia learning content interface, which includes videos and electronic modules, is shown in Figure 5.

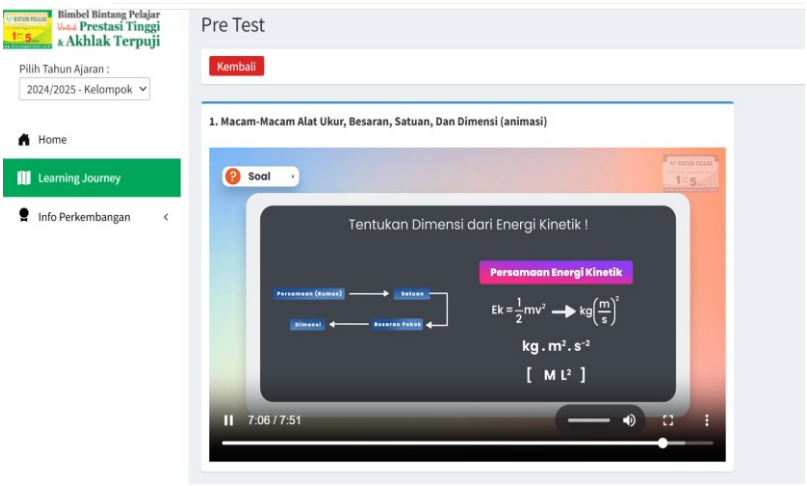

Figure 5. Multimedia Learning Content Interface

This interface supports the Listen and Explore stages of the LEARN model by providing varied learning resources that accommodate different learning styles. After engaging with learning materials, students are encouraged to apply their understanding through interactive exercises. The practice question interface designed to support the Apply stage of the LEARN model is illustrated in Figure 6.

Figure 6. Practice Question Interface for the Apply Stage

Through this interface, students practice applying learned concepts, which helps reinforce understanding and improve problem-solving skills. To promote metacognitive awareness, the system provides a reflection feature that allows students to evaluate their learning experiences. The reflection interface used in the developed e-learning system is presented in Figure 7.

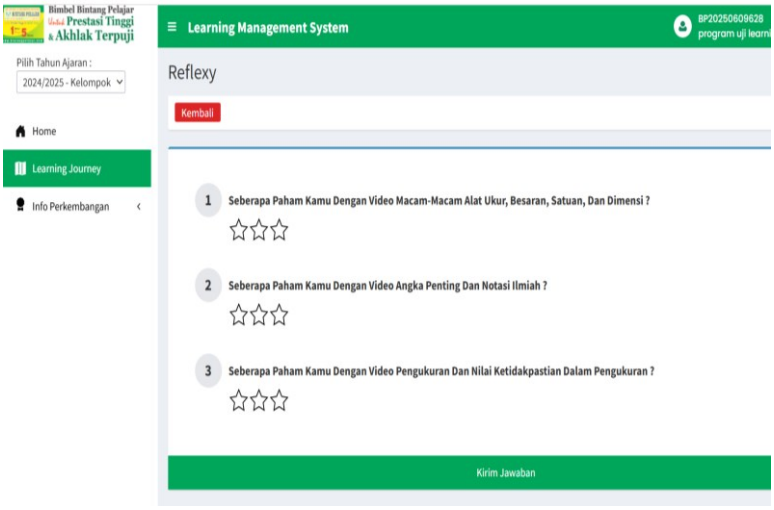

Figure 7. Student Reflection Interface

This feature encourages students to reflect on their learning process, challenges, and achievements, supporting deeper and more meaningful learning. In addition to learning activities and assessment, the system includes a monitoring feature that enables the tracking of students' learning progress. The student learning progress monitoring interface is shown in Figure 8.

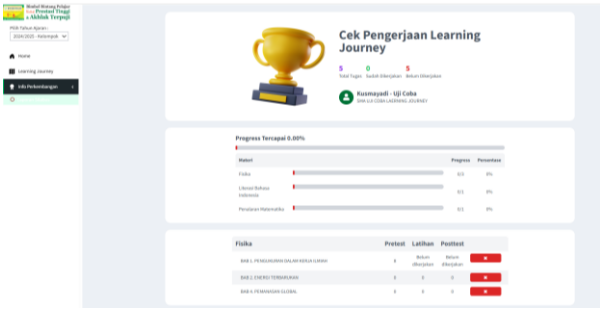

Figure 8. Student Learning Progress Monitoring Interface

This interface provides real-time information on students' performance and progress, supporting formative evaluation and learning motivation.
The e-learning platform was developed using the System Development Life Cycle (SDLC), resulting in structured database, interface, and procedural designs. The system was implemented using PHP and JavaScript with the CodeIgniter framework and a MySQL database and is accessible via standard web browsers.

Development of Multimedia Learning Content

Multimedia learning content in Draft Model 1 includes e-modules, learning videos, and interactive quizzes. All multimedia components were developed based on predefined media specifications and learning objectives to ensure instructional alignment. The e-module focuses on the Grade 10 Physics topic *Measurement in Scientific Work*. Content development involved subject teachers and the research

and development team, followed by verification from the Teacher Quality Improvement Unit. The finalized module was converted into Flip PDF format and structured into three sections corresponding to instructional meetings. The e-module structure includes a cover page, table of contents, concept map, introduction, main material, sample questions, practice questions, and a summary.

Learning videos were developed through a structured process involving script preparation, storyboard development, video recording, and animation production. The final product consists of hybrid animation videos segmented into instructional sections, including opening, content presentation, reinforcement, and closing. Interactive quizzes include pretests, posttests, and independent practice questions. All assessment items were developed by the Academic Research and Development team and underwent validity and reliability testing before implementation.

Draft Model Development 2

Draft Model 2 represents a revised version of Draft Model 1 based on expert validation involving content, media, and instructional design specialists. The content expert evaluated material accuracy and structure, the media expert assessed interface quality and usability, and the instructional design expert reviewed learning flow and alignment with instructional principles. Based on expert recommendations, several revisions were implemented. One major improvement involved enhancing the login page to provide clearer guidance and increase learner engagement. The revised login interface is presented in Figure 9.

Figure 9. Login Page Revision Results

Additional revisions included the inclusion of subject descriptions, learning objectives, syllabus details, communication features, and mastery-based learning mechanisms.

Final Model Development and Feasibility Results

The final model was developed after undergoing one-to-one, small group, and large group trials. The evaluation process focused on identifying aspects related to technical accuracy, usability, and learning convenience, while the core instructional structure of Draft Model 2 was maintained. The suggestions and corresponding revisions obtained from these trials are summarized in Table 1, which presents the

follow-up improvements implemented to enhance the quality and feasibility of the developed e-learning model.

Table 1. Suggestions and Follow-up for Improvement of Trial Results

No.	Suggestions	Revisions
1	There are several pretest and posttest questions with incorrect answer keys.	The answer keys for the questions were corrected immediately.
2	The number of pretest and posttest questions was considered too large by students.	The number of questions was reduced from 25 to 20 while maintaining adequate representation of the material.
3	The font size in the e-module is too small.	The font size complies with Rowntree's module standards (12 pt). Students are instructed to use the zoom in/zoom out buttons to adjust the display size.

In addition to following up on suggestions and feedback from the trial results, improvements made to the final model included improving the responsiveness of the LMS on mobile phones and tablets, allowing students to use e-learning on their mobile devices comfortably and smoothly. The following image shows the e-learning display on a mobile device. The final model was further improved by optimizing LMS responsiveness for mobile devices, allowing students to access learning materials comfortably using smartphones and tablets in Figure 10.

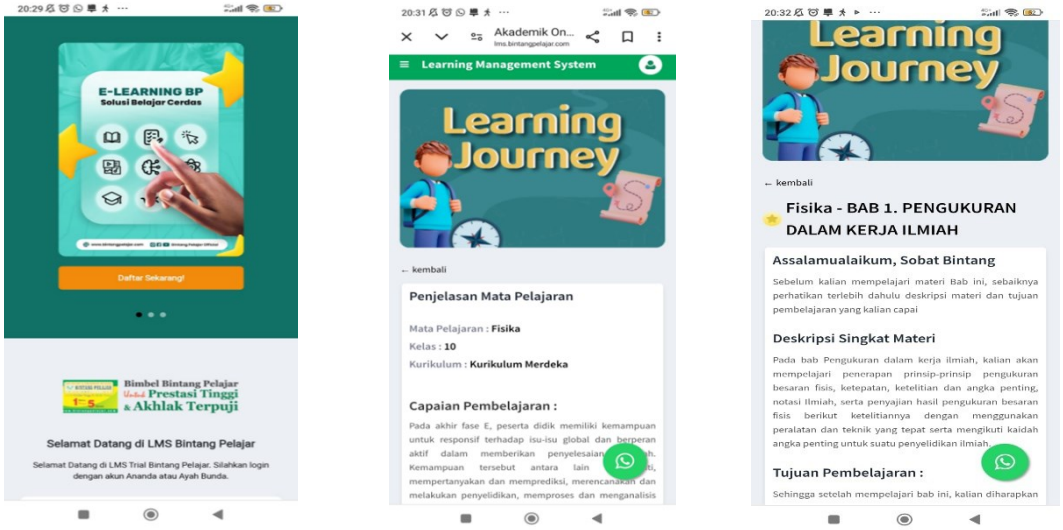

Figure 10. Mobile Version of E-learning Display

Feasibility testing results indicate that the developed e-learning model achieved a "Very Feasible" category across all evaluations. Material expert validation yielded a score of 92%, media expert validation 90.4%, and instructional design expert validation 91.2%. User trials also confirmed feasibility, with scores of 83% (one-to-one), 88.83% (small group), and 83.64% (large group).

Effectiveness Testing Results

The effectiveness of the e-learning model was evaluated using a quasi-experimental design involving an experimental group and a control group. Prerequisite tests indicated homogeneous variances between groups, justifying the use of non-parametric statistical tests. Learning gain analysis showed that the experimental group achieved an N-Gain score of 57.74%, categorized as moderately effective, while the control group achieved 49.68%, categorized as less effective. The Wilcoxon Signed-Ranks Test indicated significant improvement in learning outcomes within both groups ($p = 0.000$), with a higher Z-score observed in the experimental group. The Mann–Whitney U test revealed no statistically significant difference in post-test scores between groups ($p > 0.05$).

Discussion

The findings of this study demonstrate that the development of a multimedia-based e-learning model grounded in the LEARN instructional strategy offers a systematic and theoretically informed response to the instructional challenges identified during the needs analysis stage. As reported in the results section, low student motivation, limited instructional time, and the lack of interactive learning media emerged as dominant factors contributing to suboptimal Physics learning outcomes. These conditions are not unique to the research context but reflect broader challenges commonly reported in Physics and science education, particularly when abstract concepts are taught primarily through conventional lecture-centered instruction. Previous studies have consistently shown that such approaches often fail to adequately support conceptual understanding and active learner engagement in Physics classrooms (Orlich et al., 2009).

The negative student responses related to learning motivation, adequacy of learning time, and instructional methods indicate that existing learning practices did not sufficiently facilitate active participation or independent learning. These findings suggest that students experienced limitations in autonomy and interaction, which are critical components of effective learning in both face-to-face and technology-mediated environments. Research on learner-centered and self-directed learning emphasizes that students are more motivated and engaged when learning environments provide opportunities for exploration, meaningful interaction, and structured guidance (Handayani, 2017; Reigeluth et al., 2017). In this context, the absence of multimedia-supported instruction likely restricted students' ability to visualize abstract Physics concepts, a factor that has been shown to negatively affect conceptual understanding, learning confidence, and retention (Widodo et al., 2020; Putra et al., 2022).

The LEARN instructional strategy embedded in the developed e-learning model provides a structured learning cycle that aligns closely with established instructional design theories. The stages of listening, exploration, application, reflection, and navigation represent a coherent progression from initial knowledge acquisition to active processing and self-evaluation. This sequence reflects the instructional events proposed by Gagné et al. (1992) as well as the systematic design

principles articulated in the Dick and Carey model (Dick & Carey, 2005). The integration of this strategy within an e-learning environment further reflects a design-based research orientation, in which instructional theory is operationalized through iterative development and evaluation of learning systems (Borg & Gall, 1983; Lee & Owens, 2004; Aka, 2019).

The incorporation of diverse multimedia learning objects, including e-modules, instructional videos, and interactive quizzes, supports core principles of multimedia learning. These principles emphasize the integration of visual and verbal information to facilitate deeper understanding and reduce the cognitive burden associated with abstract content. Prior research has demonstrated that multimedia-based learning environments are effective in enhancing comprehension and retention by accommodating different learning preferences and supporting dual-channel processing (Clark & Mayer, 2023; Çeken & Taşkın, 2022). In Physics education, multimedia representations are particularly valuable for visualizing measurement processes and scientific phenomena that are difficult to observe directly, thereby bridging the gap between theoretical concepts and concrete understanding (Herayanti et al., 2017).

The results of expert validation further confirm that the developed e-learning model meets high feasibility standards in terms of content accuracy, media quality, and instructional coherence. High validation scores are consistent with established frameworks for evaluating multimedia learning resources, which emphasize clear learning objectives, alignment between content and instructional strategies, and usability for learners (Clark & Mayer, 2023). Revisions implemented in the second draft of the model, including clearer articulation of learning objectives, improved syllabus transparency, and the application of mastery-based learning cycles, enhanced instructional scaffolding and supported learner autonomy. These characteristics are widely recognized as essential elements of effective e-learning systems.

In terms of learning effectiveness, the higher N-Gain score obtained by the experimental group indicates that the multimedia-based e-learning model contributed to greater learning improvement compared to conventional learning modules. This finding is consistent with previous studies reporting that multimedia-supported e-learning environments can enhance learning gains, even when differences in final achievement scores are not statistically significant (Choiriyah et al., 2022; Himmawan et al., 2024). The absence of a significant difference in post-test scores between the experimental and control groups may be attributed to variations in students' prior knowledge, which has been widely recognized as a strong predictor of learning outcomes in science education (Jurahmin, 2021).

Furthermore, the control group's advantage in direct teacher interaction may have partially compensated for the lack of multimedia support, particularly in explaining complex Physics concepts. Teacher guidance remains a crucial factor in facilitating conceptual understanding, especially in abstract and cognitively demanding subjects such as Physics (Orlich et al., 2009). This finding reinforces the view that multimedia-based e-learning should not be positioned as a replacement for face-to-

face instruction, but rather as a complementary approach that enhances learning flexibility, preparedness, and depth of understanding.

Overall, the findings of this study suggest that the developed multimedia-based e-learning model is most effectively implemented within a blended or flipped classroom framework. In such an approach, students engage independently with multimedia learning materials prior to class and subsequently deepen their understanding through guided discussion, clarification, and problem-solving activities facilitated by teachers. This instructional model aligns with contemporary recommendations for learner-centered design and effective integration of e-learning in formal education contexts (Reigeluth et al., 2017; Khazanchi et al., 2022).

4. Conclusion

This study contributes significantly to the field of educational technology through the design, validation, and empirical testing of a multimedia-based e-learning model that integrates the LEARN instructional strategy (Listen, Explore, Apply, Reflect, and Navigate). Its main contribution lies in the systematic incorporation of guided discovery learning within a structured multimedia environment tailored to address key challenges in Physics learning, particularly limited instructional time and students' difficulties in understanding abstract concepts. Expert validation results and positive student responses across multiple trial stages indicate that the developed model is pedagogically valid, technologically feasible, and instructionally coherent.

In terms of effectiveness, the experimental group achieved a higher N-Gain score than the control group, demonstrating greater learning improvement despite the absence of a statistically significant difference in post-test scores. This finding suggests that the model effectively supports meaningful learning progress, especially in learning contexts with constrained teacher–student interaction. The integration of multimedia elements grounded in learning theory promotes active engagement, encourages self-directed learning, and strengthens conceptual understanding in Physics.Practically, this research offers an applicable instructional alternative for institutions facing limited face-to-face learning time and diverse learner needs. The model can be implemented as a supplementary resource or within blended and flipped learning settings to optimize classroom activities. Moreover, the LEARN strategy provides a replicable framework for developing engaging and outcome-oriented multimedia learning materials. Future studies are encouraged to test this model across different subjects, educational levels, and contexts to examine its broader applicability and long-term impact.

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How to cite this article:

Kusmayadi., Ibrahim, N., & Wibowo, S. (2026). E-Learning Development Based on Multimedia Learning Strategies to Improve Learning Outcomes. *Journal of Educational Sciences*, *10(3)*, 263-280.