

Development of Problem-Based Learning Instructional Media Assisted by the Scratch Application on the Topic of Friction to Enhance Students' Critical Thinking Skills

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Abstract

Critical thinking is essential in physics learning because students are expected not only to understand concepts but also to analyze phenomena, identify problems, examine relationships among variables, and evaluate evidence. Friction is one topic that requires strong conceptual and visual understanding; therefore, interactive learning media are needed to support students in exploring abstract physical phenomena. This study aimed to develop and determine the feasibility of a Problem Based Learning (PBL)-based interactive learning medium assisted by the Scratch application on the topic of friction, designed to support students' critical thinking skills. The study employed a Research and Development (R&D) approach using the 4D model, consisting of define, design, develop, and disseminate stages. The developed product was validated by three final-year prospective physics teachers using a four-point Likert-scale validation questionnaire. The data were analyzed descriptively using mean scores and feasibility percentages. The validation results showed that the visual communication design aspect obtained an average score of 3.75 (94%), the software engineering aspect obtained 3.67 (92%), and the learning media quality aspect obtained 3.93 (98%), all of which were categorized as highly feasible. The developed medium integrates PBL stages with interactive Scratch simulations that allow students to make predictions, manipulate variables, observe friction phenomena, and evaluate simulation results. These features are designed to support active inquiry and critical thinking during physics learning. Therefore, the developed learning medium was considered highly feasible as a supporting tool for learning friction and is recommended for further classroom effectiveness testing to examine its effect on students' critical thinking skills.

Keywords: critical thinking; friction; interactive learning media; Problem Based Learning; Scratch.

1. INTRODUCTION

Physics learning at the senior high school level requires students to do more than memorize formulas; students are also expected to interpret phenomena, analyze relationships among variables, evaluate evidence, and use scientific reasoning to solve problems (Mazidah et al., 2026; Neswary et al., 2023). These competencies are closely related to critical thinking, which is particularly important when students encounter physics problems that require explanation, prediction, analysis, and evaluation rather than routine calculation (Agustina et al., 2025; Jatmiko et al., 2026). Previous studies have shown that students may experience difficulties when physics learning requires deeper reasoning and the application of concepts to real-life situations (Azizah et al., 2025; Bagnoli & Gronchi, 2025; Diya & Putranta, 2025; Kusuma et al., 2024; Shrestha et al., 2023).

One physics topic that presents conceptual challenges is friction. Understanding friction requires students to distinguish between static and kinetic friction, analyze the interaction among applied force, normal force, and coefficient of friction, and explain how these variables influence the motion of an object (Persson & Xu, 2025; Putelat & Dawes, 2015). Previous research has reported that students may have difficulty distinguishing types of friction and applying friction concepts to contextual situations (Fang, 2014; Suárez et al., 2019). These difficulties indicate that learning friction should not rely solely on formulas or verbal explanations but should provide opportunities for students to observe relationships among variables and connect abstract concepts with observable phenomena.

One possible way to address these challenges is through interactive digital learning media. Visual and interactive representations can provide students with opportunities to observe physical phenomena,

manipulate variables, and examine the consequences of changes made during a simulation. This form of representation is particularly relevant for physics concepts that involve relationships among variables that cannot always be directly observed in conventional classroom activities (Fadhilah et al., 2026a; Narulita et al., 2024; Yeni, 2025a). Previous studies have therefore explored the use of digital media to facilitate conceptual understanding and create more interactive physics learning experiences (Akdag et al., 2025; Fadhilah et al., 2026b; Ningrum & Subali, 2025; Yeni, 2025b).

Scratch is a digital platform that can be used to develop interactive learning media. Its block-based programming environment allows developers to combine animation, visual objects, numerical information, and user-controlled interactions within a single learning environment (Maulana et al., 2025; Puteri & Farhurrohman, 2024; Putri et al., 2025). In physics learning, these features can be used to visualize changes in physical quantities and allow students to explore cause-and-effect relationships through simulations (Krisnadi et al., 2023; Ula et al., 2025; Vira et al., 2025). Previous studies cited in this manuscript have demonstrated the use of Scratch in learning contexts such as measurement, elementary science concepts, and physics topics requiring visualization and problem solving (Perdana, Alifa, et al., 2025; Saputra & Perdana, 2024; Weng et al., 2022). However, the educational value of interactive media depends not only on the technology used but also on the pedagogical activities integrated into the media.

Problem-Based Learning (PBL) provides a relevant pedagogical framework because it engages students in identifying problems, investigating possible explanations, analyzing information, and evaluating solutions (Asri et al., 2024; M. Wang, 2025). Previous studies have indicated that PBL-oriented learning materials can support students' problem-solving, scientific process, collaborative, and critical-thinking skills (Dewi et al., 2025; Rehman et al., 2023; Sappaile et al., 2025). More recent research has also explored the combination of PBL and Scratch as a means of supporting critical-thinking processes in science learning (Perdana et al., 2026; Pohan et al., 2026). Therefore, integrating PBL with an interactive Scratch simulation has the potential to provide a learning environment in which students do not merely observe animations but are required to make predictions, explore variables, analyze simulation results, and evaluate their initial reasoning.

Despite these developments, several gaps remain in the literature reviewed in this study. Existing studies cited in the manuscript have examined Scratch-based learning media in contexts such as measurement, projectile motion, and elementary-level science learning (Faradila & Perdana, 2024; Perdana, Saragih, et al., 2025; Sumalia & Listiaji, 2024; Zahro et al., 2025). Studies on friction have also highlighted students' conceptual difficulties, while previous research on PBL has demonstrated its potential to support higher-order thinking skills (Orias et al., 2025; Solehuddin et al., 2025). However, the literature identified in this study provides limited discussion of an interactive Scratch-based learning medium specifically designed for the topic of friction, systematically integrated with the stages of PBL, and structured to facilitate critical-thinking activities such as problem identification, prediction, analysis of simulation data, and evaluation of results.

Accordingly, the novelty of this study lies in the development of an interactive Scratch-based learning medium that combines the visualization of friction phenomena with PBL-oriented learning activities and critical-thinking tasks. The developed medium allows students to interact with simulated variables related to friction while engaging with activities designed to encourage prediction, investigation, analysis, and evaluation. Unlike studies that only examine the use of Scratch as a visualization tool, the present development positions Scratch as part of a structured problem-based learning environment intended to support critical-thinking processes (Afifudin et al., 2025; Nurfadhilah & Listiaji, 2024).

Therefore, this study aims to develop and determine the feasibility of a Problem Based Learning-based interactive learning medium assisted by Scratch on the topic of friction that is designed to support students' critical-thinking skills. The study focuses on the development and feasibility of the product;

therefore, claims regarding its effectiveness in improving students' critical-thinking skills require further classroom testing.

2. METHOD

This study employed a Research and Development (R&D) approach using the 4D development model, which consists of four stages: *Define*, *Design*, *Develop*, and *Disseminate* (Siregar, 2024; Thiagarajan et al., 1974). The model was selected because it provides a systematic procedure for developing, validating, and refining instructional products. In this study, the product developed was an interactive physics learning medium using the Scratch application, integrated with the Problem-Based Learning (PBL) model on the topic of friction and designed to support students' critical thinking skills.

The present study focused primarily on product development and feasibility evaluation. Therefore, the study did not aim to determine the effectiveness of the developed media in improving students' critical thinking skills through an experimental or pretest-posttest design.

2.1 Development Procedure

The development process followed the four stages of the 4D model. At the Define stage, a needs analysis was conducted to identify learning difficulties related to the topic of friction, particularly students' difficulties in understanding the relationships among normal force, coefficient of friction, applied force, and object motion. The analysis also considered the characteristics of the learning content, the need for interactive visualization, and critical-thinking activities required in physics learning. The development framework integrated Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK) through the use of friction concepts, PBL, and Scratch-based interactive simulations.

At the Design stage, the structure, interface, navigation, visual components, and learning activities were designed. The media included interactive objects, friction-related variables, numerical information, animation, and problem-oriented activities. The PBL stages were incorporated into the media through problem prompts, prediction activities, exploration tasks, and opportunities for students to compare their predictions with the simulation results. At the Develop stage, the initial design was transformed into an interactive Scratch-based learning medium. The development process included the construction of sprites, friction simulations, interactive buttons, numerical displays, and learning instructions. After the prototype was completed, the product was evaluated and revised based on validator feedback.

At the Disseminate stage, the revised product was shared on a limited basis through the Scratch platform and reviewed by prospective physics teachers as potential users. The purpose of this stage was to obtain additional feedback regarding accessibility, clarity of instructions, interface design, and functionality before wider classroom implementation.

2.2 Participants

The feasibility evaluation involved three final-year prospective physics teachers. The validators had completed relevant courses in physics learning strategies, physics instructional development, and Technological Pedagogical and Content Knowledge (TPACK). Their academic background was considered relevant for providing initial judgments regarding the content, pedagogical design, and technological aspects of the developed media. To avoid overstating their expertise, the participants in this study are referred to as validators or prospective physics teacher validators, rather than expert validators.

2.3 Research Instrument

Data were collected using a media validation questionnaire with a four-point Likert scale. Each item was scored as follows:

1 = Very Infeasible / Very Unclear / Very Inconsistent

2 = Infeasible / Unclear / Inconsistent

3 = Feasible / Clear / Consistent

4 = Very Feasible / Very Clear / Very Consistent

The validation instrument evaluated several aspects of the developed media, including: visual communication design; software functionality and accessibility; accuracy and clarity of physics content; learning-media quality; alignment with the stages of Problem-Based Learning; integration of content, pedagogy, and technology; and learning activities designed to facilitate analysis, prediction, evaluation, and other critical-thinking processes.

The questionnaire also provided an open-response section for validators to give suggestions and recommendations for product improvement.

2.4 Data Collection Procedure

The developed Scratch-based learning medium was provided to the validators together with the validation questionnaire. The validators explored the learning media, examined its content and functions, and then evaluated each indicator using the four-point rating scale. Qualitative suggestions from the validators were also collected and used as the basis for revising the product.

The revision process focused on improving aspects such as interface layout, visual clarity, navigation, interactivity, instructional instructions, and the alignment of activities with the PBL stages.

2.5 Data Analysis

The quantitative validation data were analyzed descriptively using the mean score and feasibility percentage. The mean score for each aspect was calculated by dividing the total score obtained by the number of ratings.

The feasibility percentage was calculated using the following formula:

$$\text{Feasibility Percentage} = \frac{\text{Obtained Score}}{\text{Maximum Possible Score}} \times 100\%$$

The resulting percentages were interpreted using the following criteria:

Table 1. Feasibility Criteria for the Developed Learning Media

Percentage	Category
≥ 85%	Very Feasible
70–84%	Feasible
55–69%	Fairly Feasible
≤ 55%	Not Feasible

These categories were used to determine the feasibility of the Scratch-based learning media prior to further classroom effectiveness testing. We analyzed validators' qualitative comments and suggestions descriptively and used them to identify aspects of the product that required revision.

3. RESULTS AND DISCUSSION

Present the research findings using tables or figures where appropriate; every table and figure must be discussed in the text, not merely displayed. The discussion must interpret the findings in relation to relevant theory and previous research — not merely restate the data. The discussion should: (1) answer

the research questions; (2) explain how the findings were obtained; (3) interpret the findings; (4) relate the findings to established knowledge; and (5) propose new theoretical insights where relevant.

3.1 Define Stage

The define stage was conducted to identify the learning needs underlying the development of the Scratch-based interactive learning media. The analysis focused on the characteristics of the friction topic, students' learning difficulties, the need for interactive visualization, and the critical-thinking processes expected during physics learning.

The topic of friction requires students to understand the relationships among several variables, including normal force, applied force, coefficient of friction, and object motion. Previous studies cited in this study indicate that students may experience difficulties distinguishing types of friction and applying friction concepts to contextual situations (Slesarenko & Pastewka, 2024; B. Wang, 2025; Yi et al., 2023). These difficulties suggest that students need learning experiences that enable them to observe and manipulate variables rather than relying solely on verbal explanation and mathematical formulas.

Based on the needs analysis, Scratch was selected as the technological platform because it allows the development of interactive animations and simulations in which students can manipulate variables and directly observe changes in object motion. The learning design was integrated with Problem-Based Learning (PBL) so that the media did not function merely as a visualization tool but also provided learning activities involving problem identification, prediction, exploration, analysis, and evaluation.

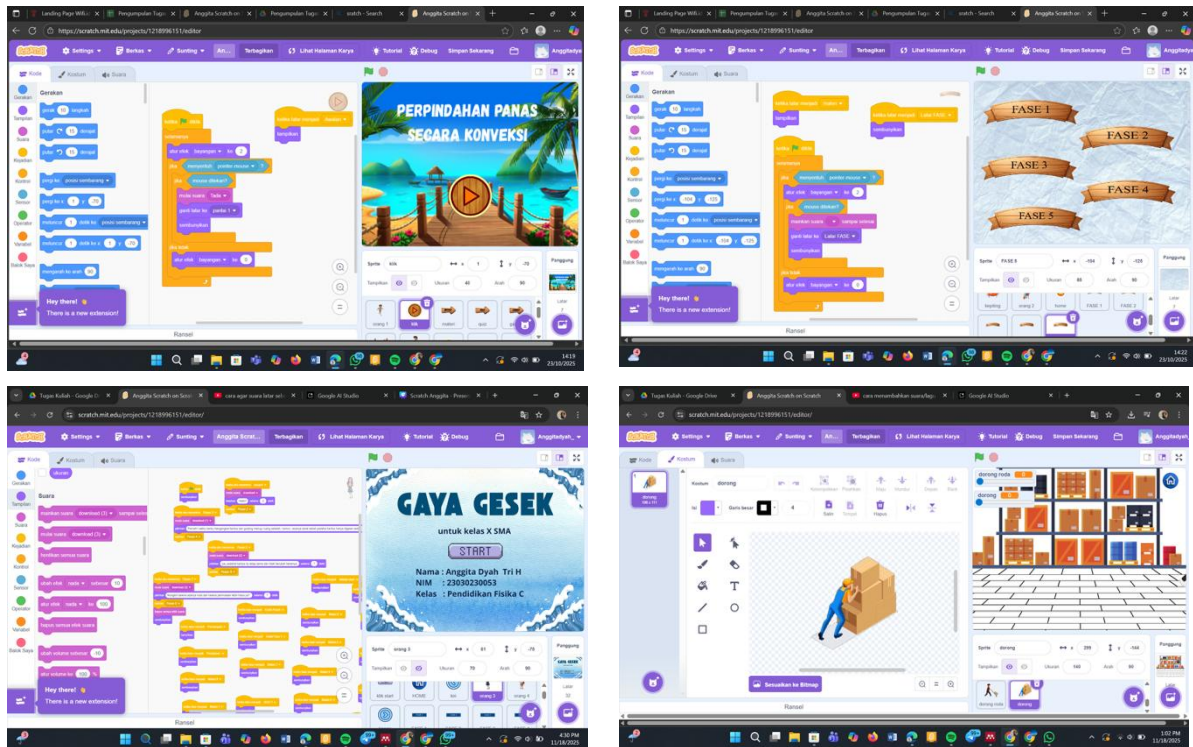
The development process was also guided by the integration of content, pedagogy, and technology. The Content Knowledge (CK) component focused on static and kinetic friction and the relationships among friction-related variables. The Pedagogical Knowledge (PK) component was represented through the stages of PBL, while the Technological Knowledge (TK) component involved the use of Scratch to create interactive simulations.

The outcome of the define stage was therefore a set of development requirements for an interactive learning medium that could visualize friction phenomena while providing structured activities intended to facilitate students' critical-thinking processes.

3.2 Design Stage

The design stage translated the results of the needs analysis into the initial structure of the learning media. The design process included determining the learning objectives, organizing the friction content, constructing the PBL learning flow, designing the interface and navigation, and preparing interactive simulation features. The initial media design included visual objects representing a moving block and contact surface, numerical information related to friction variables, navigation buttons, and interactive elements that allowed users to explore changes in the simulation. Activities were structured so that students could first encounter a problem, make predictions, manipulate selected variables, observe simulation results, and subsequently compare the observed outcomes with their initial reasoning.

The PBL stages were incorporated into the media through problem-oriented prompts and exploration activities. This design was intended to encourage students to engage with the simulation analytically instead of simply observing an animation. The Scratch environment therefore served as both a visualization tool and an interactive environment supporting the learning sequence. A storyboard was also developed to organize the sequence of screens, animations, instructions, and student activities. During this stage, the initial development concept was revised before the final prototype was produced.

Figure 1. Initial Design of the Scratch-Based Learning Media

3.3 Develop Stage

During the develop stage, the initial design was transformed into a functional Scratch-based interactive learning medium. The visual components, animation, instructional content, interaction buttons, numerical displays, and friction simulation were developed according to the storyboard. The simulation was designed to allow users to observe physical relationships related to friction and object motion. Interactive elements were incorporated to provide opportunities for students to explore the simulation and examine how changes in selected variables affected the displayed phenomena. The learning activities were arranged according to the PBL sequence so that the use of technology remained connected to the pedagogical objectives. After the prototype was completed, the product underwent a feasibility evaluation involving three final-year prospective physics teachers who had completed relevant courses in physics learning strategies, instructional development, and TPACK. The evaluation focused on the quality and feasibility of the developed media rather than on its effectiveness in improving students' learning outcomes.

3.3.1 Media Feasibility

The validation results indicated that all evaluated aspects were categorized as highly feasible. The visual communication design aspect obtained an average score of 3.75, equivalent to 94%. The software engineering aspect obtained an average score of 3.67, equivalent to 92%, while the learning media quality aspect obtained the highest score of 3.93, equivalent to 98%.

Table 2. Results of the Learning Media Feasibility Evaluation

Aspect	Mean Score	Percentage	Category
Visual Communication Design	3.75	94%	Very Feasible
Software Engineering	3.67	92%	Very Feasible
Learning Media Quality	3.93	98%	Very Feasible

The high score obtained for visual communication design indicates that the validators generally considered the interface, layout, typography, and visual presentation appropriate for use as learning media. Nevertheless, the qualitative feedback showed that some visual components still required improvement, particularly regarding layout consistency and the visibility of certain interactive elements. The software engineering aspect obtained a slightly lower score than the other aspects.

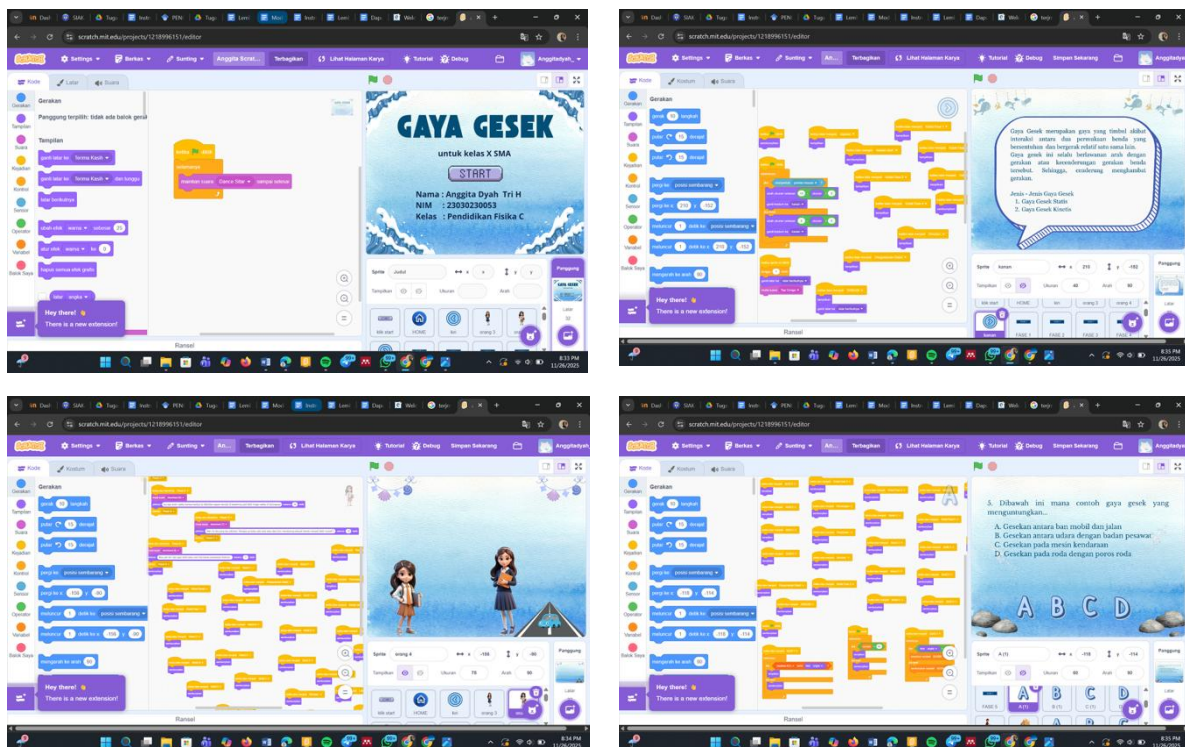
This finding is consistent with the qualitative feedback indicating that navigation and several interactive functions needed refinement. One validator specifically identified confusion in the transition between learning phases, while another recommended increasing direct student interaction by providing spaces for students to respond to questions within the media. The learning media quality aspect obtained the highest feasibility score. This result suggests that the overall structure, language, and instructional presentation were judged positively by the validators. However, these results should be interpreted specifically as evidence of product feasibility based on validator judgment, rather than evidence that the media has already improved students' critical-thinking skills.

3.3.2 Validator Feedback and Product Revision

In addition to numerical ratings, the validators provided qualitative suggestions for improving the product. The first validator considered the product generally appropriate, whereas the second suggested increasing interactivity by providing opportunities for students to directly respond to questions within the media. The third validator identified several issues related to interface layout, audio, learning-phase organization, and navigation.

These comments were used as the basis for product revision. The revision focused particularly on improving navigation clarity, strengthening interaction between the learner and the media, refining visual layout, and ensuring that the sequence of activities corresponded consistently to the intended PBL stages. The revision process is an important component of development research because a high feasibility score does not necessarily indicate that every component of the product is already optimal. Qualitative feedback provides complementary information that may not be fully captured through numerical ratings alone.

Figure 2. Revised Scratch-Based Learning Media Following Validator Feedback



3.4 Integration of PBL, Scratch, and Critical-Thinking Activities

An important characteristic of the developed media is the integration of technological features with the learning process. Scratch was not used solely to display animated physics content. Instead, interactive simulations were combined with learning activities structured around the PBL process. Within the media, students are expected to encounter contextual problems, formulate initial predictions, explore the simulation, observe changes in physical variables, and evaluate the relationship between their predictions and the simulation results. These activities were designed to correspond with critical-thinking processes such as identifying problems, analyzing relationships among variables, interpreting evidence, and evaluating conclusions.

This design is consistent with previous studies cited in the manuscript indicating that PBL can provide opportunities for students to engage in problem-solving and higher-order thinking activities (Goshu & Ridwan, 2024; Marini et al., 2026). Previous studies have also explored the combination of Scratch and PBL for supporting critical-thinking-oriented learning activities (Akhmad et al., 2025; Negoro et al., 2023; Yuliana & Kurnianto, 2026). Nevertheless, the present findings should be interpreted carefully. The validation results demonstrate that the design of the media was judged feasible and relevant to critical-thinking-oriented learning, but they do not demonstrate an actual increase in students' critical-thinking scores. Determining whether the media significantly improves critical thinking requires subsequent classroom testing using an appropriate effectiveness design.

3.5 Disseminate Stage

The disseminate stage was conducted on a limited scale after the product had undergone validation and revision. The developed media was shared through the Scratch platform so that prospective users could access and explore its features. Limited dissemination was intended to obtain additional information regarding accessibility, clarity of instructions, interface functionality, and the overall usability of the product before broader classroom implementation.

This stage should not be interpreted as an effectiveness test. Although users were able to access and explore the developed media, the study did not measure changes in students' critical-thinking ability, conceptual understanding, motivation, or learning outcomes through a controlled classroom evaluation. Therefore, the primary outcome of the present study remains the development and feasibility of the product.

The limited dissemination nevertheless provided an important basis for preparing the media for subsequent implementation. The resulting Scratch-based learning medium combines interactive visualization of friction with a problem-oriented instructional sequence and provides opportunities for further investigation in actual classroom settings.

Overall, the development process resulted in an interactive Scratch-based learning medium integrating friction content with PBL-oriented activities. The feasibility evaluation showed percentages ranging from 92% to 98%, indicating that the validators considered the product highly feasible in terms of visual communication design, software engineering, and learning media quality.

The results also demonstrate that the quality of instructional media should not be evaluated only from its visual appearance. The validator feedback concerning navigation, interaction, and organization of PBL activities shows that technological functionality must remain aligned with pedagogical objectives. A visually attractive simulation may have limited instructional value if students only observe the animation without engaging in prediction, exploration, analysis, or evaluation.

The integration of PBL into the Scratch environment therefore represents an important aspect of the developed product. Rather than presenting friction as a static concept, the media provides an environment in which variables and phenomena can be explored through interactive simulations. This feature has the potential to support a more active learning process and provide opportunities for critical-thinking activities.

However, feasibility and effectiveness represent different levels of evidence. The present validation results demonstrate that the media is considered appropriate for learning use and sufficiently developed to proceed to classroom testing. They cannot yet demonstrate that the media improves students' critical-thinking ability. Therefore, the next stage of research should examine its effectiveness using actual student participants and direct measures of critical thinking, preferably through a pretest–posttest or comparative design.

4. CONCLUSION

This study developed a Problem-Based Learning (PBL)-based interactive learning medium using the Scratch application on the topic of friction. The development followed the 4D model through the define, design, develop, and limited dissemination stages. The feasibility evaluation showed that the developed media was categorized as very feasible, with scores of 3.75 (94%) for visual communication design, 3.67 (92%) for software engineering, and 3.93 (98%) for learning media quality. These results indicate that the media is appropriate for further classroom implementation.

However, the findings of this study represent product feasibility rather than effectiveness. Although the media was designed to support students' critical-thinking processes through problem identification, prediction, exploration, analysis, and evaluation, this study did not directly measure changes in students' critical-thinking skills. Therefore, further research is needed to examine the effectiveness of the developed media using actual student participants and direct measures of critical thinking.

AI USAGE STATEMENT

During the preparation of this manuscript, the authors used ChatGPT to assist with language editing, improving sentence clarity, and refining the academic presentation of the manuscript. The authors reviewed, verified, and revised all AI-assisted content and take full responsibility for the accuracy, originality, interpretation, and final content of the publication.

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