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Integrating Scratch-Based Educational Games with Problem-Based Learning to Enhance Students' Conceptual Understanding

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Abstract

The urgency of this research lies in the increasing need for innovative instructional approaches that effectively enhance students' conceptual understanding through the integration of Scratch-based educational games and Problem-Based Learning. This study aimed to describe the implementation of Scratch-based Archery Game media integrated with the Problem Based Learning (PBL) model in teaching momentum and collision concepts in physics. The study employed a one-shot case study design involving 28 students of class XII B at SMAN 14 Gowa, while response data were obtained from 26 students. Data were collected through observation, documentation, and student response questionnaires using a Likert scale, then analyzed descriptively using quantitative and qualitative approaches. The results showed that most PBL syntax stages were successfully implemented through discussion activities, simulation exploration, and game-based problem solving. The learning implementation also indicated the emergence of computational thinking activities, including pattern recognition, abstraction, and algorithmic thinking while students explored momentum and collision simulations. Questionnaire results showed that student responses were in the Good category with a percentage of 78.06%, indicating positive responses toward learning engagement, participation, and the perceived ease of understanding concepts through interactive simulations. The novelty of this study lies in the integration of Scratch-based Archery Game media with the PBL model to support exploratory activities and computational thinking in physics learning. The findings suggest that coding-based media and interactive simulations have the potential to become alternative learning tools for abstract physics concepts that are more contextual, interactive, and relevant to 21st-century learning needs.

Keywords: *Scratch, Archery Game, Problem Based Learning, Computational Thinking, Physics Learning*

Introduction

Physics learning plays an important role in helping students understand natural phenomena through systematic scientific concepts (Wilujeng & Hidayatullah, 2021). However, many physics concepts are still perceived as difficult to understand because they are abstract and require strong visual representation and conceptual reasoning skills (Wulandari et al., 2021). One topic that frequently presents learning difficulties is momentum and collisions, as students must understand the relationships among mass, velocity, impulse, and the law of conservation of momentum in various real-world situations (Defrianti et al., 2021).

The students continue to experience conceptual difficulties in understanding momentum and impulse (Adianto & Rusli, 2021; Sakinah et al., 2023). Furthermore, physics instruction is often dominated by conventional teaching methods, causing students to become passive learners and making it difficult for them to visualize abstract concepts in a concrete manner (Budiarti, 2018). From a constructivist perspective, learning becomes more meaningful when students actively construct knowledge through learning experiences. Mayer's Multimedia Learning Theory also suggests that the integration of visuals, text, animation, and interaction can help students develop mental models of abstract concepts. In line with the digital transformation of education and the implementation of the Merdeka Curriculum, the use of technology-based interactive learning media has become increasingly relevant for creating active, student-centered learning environments (Tampubolon & Megalina, 2025).

One educational technology that can be utilized is Scratch, a block-based visual programming platform that enables users to create interactive animations, simulations, and educational games (Ma'rifah et al., 2024). Previous studies have found that the use of Scratch in physics learning helps students understand abstract concepts through more concrete visual representations (Choi & Kim, 2022). In addition, game-based learning has been recognized as an effective approach for increasing student engagement and learning motivation, as students learn through challenges and exploration (Putra et al., 2025; Hwang & Chien, 2022; Annisa & Perdana, 2024). Game-based learning media can improve the effectiveness of the teaching and learning process (Putra et al., 2025; Aina & Wulandari, 2026).

Beyond the use of interactive media, the integration of the Problem-Based Learning (PBL) model is also highly recommended in physics education (Kanyesigye et al., 2022). PBL places contextual problems at the center of the learning process, encouraging students to think critically, conduct investigations, and actively construct knowledge (Hidayat & Maulida, 2022; Firmansyah et al., 2022). Previous studie showed that the implementation of PBL can improve students' learning outcomes and critical thinking skills (Adawiyah et al., 2022; Suindhia, 2023).

The use of Scratch is also closely associated with the development of computational thinking (CT), including pattern recognition, abstraction, and logical reasoning. Computational thinking enables students to solve problems systematically, thereby supporting the development of conceptual reasoning in physics learning. Nevertheless, most previous studies have focused on the use of Scratch for introductory coding instruction and have rarely integrated Scratch-based educational games with PBL syntax in teaching momentum and collisions.

Therefore, this study developed a Scratch-based Archery Game that integrates the concepts of momentum and collisions into an archery simulation. The motion of the arrow represents momentum, the release of the arrow illustrates impulse, and the interaction between the arrow and the target represents collision phenomena and the conservation of momentum. Through this approach, the study contributes to the development of coding-based physics learning by connecting computational thinking and conceptual understanding through an interactive, contextual, and student-centered learning experience.

This study aims to investigate the effectiveness of integrating Scratch-based educational games with the Problem-Based Learning (PBL) approach in enhancing students' conceptual understanding. Specifically, it seeks to examine how the combination of game-based programming activities and authentic problem-solving experiences facilitates active learning, promotes meaningful knowledge construction, and improves students' ability to comprehend, apply, and retain key concepts. Furthermore, the study explores the potential of this integrated instructional model to foster higher levels of engagement, critical thinking, and collaborative learning compared with conventional teaching approaches.

The novelty of this research lies in the integration of Scratch-based educational game development with the Problem-Based Learning (PBL) framework as a unified instructional strategy to improve conceptual understanding. While previous studies have independently examined the effectiveness of Scratch programming, educational games, or PBL, limited research has explored the synergistic effects of combining these approaches into a single pedagogical model. This study introduces an innovative learning design in which students actively create and utilize Scratch-based educational games to solve authentic problems, thereby simultaneously developing computational thinking, problem-solving skills, and conceptual understanding. The findings are expected to contribute a novel instructional framework that bridges game-based learning and inquiry-driven pedagogy, offering practical implications for 21st-century STEM and computer science education.

Method

This study employed a pre-experimental research design using a one-shot case study approach. A one-shot case study involves a single group receiving an intervention, after which observations are conducted to examine participants' responses (Sugiyono, 2022). This design does not involve a control group or pretest measurement. The research design is illustrated as follows:

$$X \rightarrow O$$

Description:

X = Implementation of Scratch-based learning integrated with Problem-Based Learning (PBL)

O = Observation and students’ responses following the learning implementation

This design was employed to describe the implementation of Scratch-based learning integrated with PBL and to investigate students’ responses to the use of the Archery Game learning media on the topic of momentum and collisions.

The study was conducted in the Computer Laboratory of SMAN 14 Gowa, Gowa Regency, South Sulawesi, Indonesia, on April 21, 2026. The participants consisted of 32 students from Class XII-B selected through purposive sampling based on the availability of computer laboratory facilities, students’ basic technological skills, and their active participation in digital-based learning activities. The independent variable was the implementation of Scratch-based learning integrated with PBL, while the dependent variable was students’ responses to the learning process, including learning interest, student engagement, ease of media use, perceptions of conceptual understanding of momentum and collisions, and the perceived benefits of the learning media.

The research procedure consisted of three stages: preparation, implementation, and evaluation. During the preparation stage, the researchers developed the learning materials, the Scratch-based Archery Game, an implementation observation sheet, and a student response questionnaire. The questionnaire consisted of 15 items distributed across five indicators: (1) interest in learning (3 items), (2) ease of media use (3 items), (3) student engagement (3 items), (4) perceptions of understanding momentum and collision concepts (3 items), and (5) perceived benefits of the learning media (3 items). Prior to implementation, the instrument was validated by two experts, consisting of a physics education lecturer and a senior high school physics teacher. The validation focused on content relevance, language clarity, statement readability, and indicator alignment.

The results indicated that the instrument was suitable for use with minor revisions based on the validators' recommendations. Statistical reliability testing was not conducted because this study represents an initial implementation-oriented descriptive investigation. The implementation stage involved a single learning session lasting 2 × 45 minutes. Students were organized into eight groups, each consisting of four members. Learning activities were conducted following the PBL syntax: (1) problem orientation through momentum and collision phenomena in an archery context, (2) organization of students into collaborative groups, (3) investigation and exploration using the Scratch-based Archery Game, (4) development and discussion of solutions, and (5) presentation and reflection on learning outcomes.

Throughout the learning process, students explored the relationships among momentum, impulse, and collisions through simulations involving arrows and targets. The teacher acted as a facilitator, guiding students during investigation, discussion, and conceptual reflection activities. The implementation process was observed using a non-participant observation technique conducted by a physics teacher serving as an observer. The observer utilized a checklist-based observation sheet accompanied by descriptive field notes to monitor student activities throughout the lesson. Observation indicators included participation in group discussions, engagement with the Scratch media, teamwork, presentation participation, problem-solving activities, and students' abilities to identify patterns, formulate solution strategies, and relate game simulations to the concepts of momentum and collisions as part of computational thinking practices. In addition, documentation in the form of classroom photographs and screenshots of the Scratch media was collected as supporting evidence and for implementation triangulation purposes.

The evaluation stage was conducted through the administration of a student response questionnaire after the learning activities were completed. The questionnaire was distributed via Google Forms to facilitate data collection and automatic data compilation. The instrument employed a four-point Likert scale consisting of: 1 = strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree. An example questionnaire item was: "The Scratch-based Archery Game helped me understand the concepts of momentum and collisions more easily." The collected data were analyzed using descriptive quantitative techniques. Questionnaire scores were calculated to determine the percentage of students' responses using the following formula:

$$P = \frac{Total\ Score}{Maksimume\ Score} \times 100\%$$

The percentage scores were subsequently interpreted using the following criteria adapted from the previous studied: 81–100% = very good, 61–80% = good, 41–60% = fair, 21–40% = poor, and 0–20% = very poor (Sugiyono, 2022). Data analysis was also conducted for each indicator to identify trends in students' responses toward the implementation of Scratch-based learning integrated with Problem-Based Learning. In addition to quantitative analysis, observation and documentation data were analyzed descriptively as supporting evidence to provide a comprehensive description of the learning implementation and student activities during the use of the Scratch-based media.

This study received official permission from the school administration prior to implementation. All student data were collected solely for research purposes, and the confidentiality of participants' identities was maintained throughout the study. The scope of this research was limited to examining students' responses to the learning implementation. Therefore, the findings cannot be generalized to determine the effectiveness of the media in improving learning outcomes or conceptual understanding on a broader scale.

Result

Results of Learning Implementation

The implementation of Scratch-based physics learning integrated with the Problem-Based Learning (PBL) model was conducted at SMAN 14 Gowa on May 6, 2026. The activity involved 28 students from Class XII-B; however, only 26 students completed the response questionnaire because several students did not have mobile devices required to access the Google Form used for data collection.

The lesson utilized a Scratch-based Archery Game on the topic of momentum and collisions. Based on non-participant observations using an implementation checklist and descriptive field notes, most of the key stages of the PBL model were successfully implemented. Students actively participated in discussions, explored the game simulation, and attempted to relate the motion of the arrow to the concepts of momentum and impulse. These activities provided opportunities for students to engage in computational thinking practices, such as pattern recognition, abstraction, and algorithmic thinking during the exploration of the game simulation.

The observer also noted that students demonstrated a high level of enthusiasm throughout the learning process. Most students actively asked questions and experimented with different scenarios in the Scratch simulation to achieve desired outcomes. However, several students experienced difficulties in understanding the functions of Scratch code blocks and therefore required additional guidance from the teacher and their peers.

Overall, students responded positively to the implementation of Scratch-based learning integrated with PBL. The questionnaire analysis revealed an average response percentage of 78.06%, which falls within the "Good" category. These findings indicate that students perceived the Scratch-based interactive media as beneficial for learning momentum and collisions, although some stages of the PBL model could not be implemented optimally due to time constraints.

Key Findings from the Learning Implementation

Student Engagement with Interactive Media

Students demonstrated considerable enthusiasm toward the Scratch-based learning activities. The use of simulations and interactive game elements helped students visualize momentum concepts that were previously perceived as abstract. The visual representation of arrow motion and target interaction provided learning experiences that were more concrete and engaging. This finding is consistent with Mayer's Multimedia Learning Theory, which emphasizes that the integration of visual and interactive elements can facilitate meaningful learning experiences by supporting learners in constructing mental models of abstract concepts.

Learning Experiences in Student-Centered Activities

Students reported that exploratory and collaborative activities were more engaging than conventional teacher-centered instruction. Through the Archery Game simulation, students were encouraged to investigate, discuss, and test various possibilities related to momentum and collisions. This finding aligns with the principles of Problem-Based Learning, which emphasize active participation, collaborative inquiry, and knowledge construction through contextual problem-solving activities.

Technical Challenges During Implementation

Despite the positive responses, several technical challenges were identified during implementation. Some students experienced difficulties accessing Scratch online because of unstable internet connections, while others did not have personal devices to access the questionnaire. These findings highlight the importance of adequate technological infrastructure and institutional support to ensure the effective implementation of digital learning media in schools.

Results of Problem-Based Learning Implementation

The implementation of the PBL model followed the instructional stages that had been planned prior to the lesson. Observation results indicated that most PBL phases were successfully conducted, although the presentation phase could not be completed because of limited instructional time.

Table 1. *Implementation of PBL Phases*

PBL Phase	Evidence from Observation	Status
Problem Orientation	Students discussed momentum phenomena through archery-related situations	Implemented
Organizing Students	Students were grouped and guided in using Scratch	Implemented
Investigation	Students explored and tested the Archery Game simulation	Implemented
Developing Solutions	Students analyzed simulation outcomes and discussed findings	Implemented
Presentation	Not conducted because of time constraints	Not Implemented
Evaluation	Students completed response questionnaires	Implemented

As shown in Table 1. five out of the six primary PBL phases were successfully implemented. Although the presentation stage could not be completed, the essential characteristics of PBL were maintained through investigation, simulation exploration, collaborative discussions, and reflection activities. Students actively discussed ideas, tested different problem-solving strategies, and related game simulations to the concepts of momentum and collisions.

Student Response Questionnaire Analysis

The student response questionnaire consisted of 27 items organized into five indicators: (1) ease of using Scratch, (2) learning interest, (3) student engagement, (4) perceived conceptual understanding, and (5) perceived benefits of the media and effectiveness of the PBL model.

Table 2. *Student Response Summary*

Indicator	Percentage (%)	Category
Ease of Using Scratch	75.4	Good
Learning Interest	81.7	Very Good
Student Engagement	79.3	Good
Perceived Conceptual Understanding	78.4	Good
Media Benefits and PBL Effectiveness	80.1	Good
Overall Response	78.06	Good

Table 2 shows that students' responses to the Scratch-based learning media integrated with the Problem-Based Learning (PBL) model were generally positive, with an overall response score of 78.06%, categorized as Good. Among all indicators, Learning Interest obtained the highest percentage (81.7%), indicating that the media successfully enhanced students' motivation and enthusiasm for learning. Meanwhile, Ease of Using Scratch received the lowest score (75.4%), although it remained within the Good category, suggesting that students were generally able to operate the media with only minor difficulties. Overall, the findings indicate that the developed learning media is well accepted by students and effectively supports engagement, conceptual understanding, and the implementation of PBL in elementary science learning.

Ease of Using Scratch

Students generally reported that Scratch was easy to operate and that its basic features could be used without major difficulties. However, several students experienced challenges in understanding the logic of block-based programming. This finding suggests that introductory guidance may be necessary when implementing Scratch-based learning activities, particularly for students with limited prior programming experience.

Learning Interest and Student Engagement

The highest response scores were found in the learning interest indicator. Students reported that the Scratch-based learning activities were more enjoyable and engaging than conventional instruction. This finding supports previous studies on game-based learning, which suggest that interactive challenges and immediate feedback can enhance learner motivation and engagement.

Perceived Conceptual Understanding

Students reported that the Archery Game simulation helped them relate abstract physics concepts to more concrete visual experiences. The movement of arrows and targets provided representations that enabled students to connect momentum and collision concepts with observable phenomena. According to Multimedia Learning Theory, such visual representations can support the construction of meaningful conceptual understanding.

Media Benefits and PBL Effectiveness

Students also perceived that group discussions, investigations, and simulation exploration contributed positively to the learning process. The highest score within this indicator was obtained for collaborative discussion activities. This result reflects the effectiveness of PBL in promoting active participation and collaborative learning during physics instruction.

Summary of Findings

Based on the questionnaire results, most indicators were categorized as Good, while learning interest achieved the Very Good category. Observation notes and classroom documentation further indicated that students were highly enthusiastic when interacting with the Scratch-based media. Several students experimented with modifying simulation parameters to observe changes in arrow trajectories and collision outcomes, demonstrating exploratory behavior and simple problem-solving activities. Overall, the implementation of Scratch-based learning integrated with Problem-Based Learning received positive responses from students. The interactive Archery Game created opportunities for active exploration, collaborative discussion, and engagement with momentum and collision concepts through visual simulations. Although the present study did not directly measure learning outcomes, the findings suggest that Scratch-based educational games have the potential to support student-centered physics learning and provide meaningful learning experiences in physics classrooms

Discussion

The findings indicate that the integration of the Scratch-based Archery Game with the Problem-Based Learning (PBL) model provided a more interactive, contextual, and student-centered learning experience in physics. The game simulation enabled learners to visualize momentum and collision phenomena that are often perceived as abstract, thereby allowing them to relate concepts such as motion, velocity, and collisions to observable representations. Participants reported that the visual and interactive features of the simulation helped them understand these concepts more easily. This finding is consistent with previous studied, which highlighted the important role of interactive media and visual representations in supporting physics learning (Andani et al., 2023; Budiarti, 2018).

While previous studies have primarily utilized Scratch for introductory programming instruction, coding activities, or science simulations, the present study integrated a Scratch-based educational game with Problem-Based Learning within a single instructional framework for teaching momentum and collisions. In this implementation, Scratch functioned not only as a visualization tool but also as a medium for exploration, collaborative inquiry, and problem-solving. This integration represents the primary contribution of the study and extends previous findings reported, which demonstrated the potential of Scratch-based interactive simulations to enhance student engagement during learning activities (Annisa & Perdana, 2024; Ma'rifah et al, 2024).

The implementation of PBL encouraged active participation in group discussions, exploration of simulation scenarios, and collaborative development of problem-solving strategies. Similar findings have been reported in previous studies, where problem-based and game-based learning environments promoted higher levels of student participation and engagement. During the implementation, learners analyzed relationships among mass, velocity, direction of motion, and collision outcomes while exploring the game simulation. These activities provided opportunities for students to engage in computational thinking practices, such as pattern recognition, abstraction, and algorithmic thinking. This observation is consistent with the findings of previous studied, which suggested that coding-based learning environments can support logical reasoning and the development of twenty-first-century skills (Darmayanti et al., 2024).

Nevertheless, the present study did not directly assess computational thinking skills using a standardized instrument; therefore, conclusions regarding the development of computational thinking should be interpreted cautiously. The questionnaire results revealed an overall response percentage of 78.06%, categorized as Good. Although students generally responded positively to the learning implementation, the results did not reach the Very Good category. Several factors may explain this outcome, including difficulties in understanding Scratch code blocks, limited access to digital devices and internet connectivity, and students' limited prior experience with coding-based learning environments. Similar challenges have been reported in previous technology-integrated learning studies, particularly during the initial stages of implementation. In addition, the possibility of a novelty effect should be considered, as students' initial enthusiasm toward a new learning medium may have contributed to their positive responses.

Students also reported that the Archery Game simulation helped them relate momentum concepts to more concrete visual experiences. This finding can be explained through Mayer's Cognitive Theory of Multimedia Learning, which proposes that meaningful learning occurs when learners actively process information through verbal and visual channels. The visual, animated, and interactive elements embedded in the Archery Game may have supported students in constructing mental representations of momentum and collision concepts. However, it is important to note that the present study examined students' perceptions regarding conceptual understanding rather than actual learning gains. Consequently, no conclusions can be drawn regarding improvements in conceptual understanding without additional evidence from achievement tests or conceptual assessments.

Several implementation challenges were identified throughout the study. Some students experienced difficulties in understanding the functions of Scratch code blocks, while others encountered limitations related to digital facilities and internet access. Furthermore, the presentation phase of the PBL model could not be conducted optimally because of time constraints. As a result, opportunities for scientific communication, peer feedback, and conceptual reflection were limited. These findings suggest that successful implementation of Scratch-based learning requires effective time management, adequate scaffolding in the use of digital media, and sufficient technological infrastructure.

Limitations of the Study

Several limitations should be acknowledged. First, the study employed a one-shot case study design without a control group or pretest-posttest measurements. Second, the findings were primarily based on students' responses and classroom observations rather than direct assessments of conceptual understanding. Third, computational thinking skills were not measured using a validated assessment instrument. Therefore, future studies should incorporate conceptual tests, standardized computational thinking assessments, and more rigorous experimental or quasi-experimental designs to provide stronger empirical evidence regarding the effectiveness of Scratch-based educational games integrated with Problem-Based Learning.

Overall, the findings suggest that the integration of a Scratch-based Archery Game with Problem-Based Learning may provide meaningful opportunities for active participation, collaborative problem-solving, and engagement with physics concepts in secondary school classrooms. The implementation not only encouraged student involvement in learning activities but also offered opportunities for exploration and interaction within a coding-based learning environment. As such, Scratch-based educational games integrated with PBL show promise as an alternative approach for creating engaging and student-centered physics learning experiences.

Conclusion

This study demonstrated that the implementation of a Scratch-based Archery Game integrated with the Problem-Based Learning (PBL) model generated positive student responses in learning momentum and collisions. The interactive coding-based game, momentum simulations, and problem-solving activities promoted an engaging, contextual, and student-centered learning environment while encouraging students to practice computational thinking skills, including pattern recognition, abstraction, and algorithmic thinking. The questionnaire results showed an overall response score of 78.06%, categorized as Good, indicating that the learning media effectively supported student engagement and provided meaningful learning experiences in understanding abstract physics concepts. Although some challenges were identified, particularly in understanding Scratch code blocks and the availability of digital facilities and internet access, these limitations did not diminish students' overall positive perceptions of the learning experience.

The main contribution of this study is the integration of a Scratch-based educational game with the Problem-Based Learning model to support interactive physics learning while fostering computational thinking and digital literacy skills relevant to twenty-first-century education and Society 5.0. These findings suggest that coding-based learning media can serve as an effective alternative for teaching abstract physics concepts through exploration and collaborative problem-solving. However, because this study focused primarily on students' responses rather than measuring conceptual understanding or learning outcomes, future studies should employ experimental or quasi-experimental designs, assess conceptual understanding and higher-order thinking skills, and examine the application of Scratch-based learning in other physics topics to provide stronger evidence of its educational effectiveness.

Acknowledgement

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