

DEVELOPMENT OF INQUIRY-BASED SCRATCH SIMULATION LEARNING MEDIA FOR HIGH SCHOOL KINEMATICS COGNITIVE OUTCOMES

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Abstract :

Low cognitive learning outcomes in kinematics are often caused by the limitations of conventional learning media in visualizing abstract physics concepts. The objectives of this study are to describe the feasibility of the media, student responses, and improvements in students' cognitive learning outcomes. The study employed a Research and Development (R&D) approach using the ADDIE model, consisting of analysis, design, development, implementation, and evaluation stages. A One-Group Pretest-Posttest design was applied during the implementation phase involving 30 students of class X at State High School 10 Bengkulu.. Research instruments included an expert validation questionnaire, a learning outcome test, and a questionnaire for student responses. The results of the study indicate that the Scratch-based learning media with dynamic simulations received an expert validation score of 94.44%, a student response rate of 91.60%, and an N-Gain score of 0.85. It is determined from the discussion and overall research findings that the Scratch-based learning media with dynamic simulations is suitable for use. The use of this media in the learning process can improve students' cognitive learning outcomes and receives an excellent response from students. Practically, this study implies that Scratch-based learning media can be used by teachers as an interactive and effective instructional tool to facilitate students' understanding of abstract physics concepts, particularly in kinematics.

Keywords: Cognitive Learning Outcomes, Learning Media, Scratch, Kinematics, Inquiry-Based Learning

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INTRODUCTION

Physics, as one of the core subjects in the Mathematics and Natural Sciences (MIPA) cluster, involves many abstract concepts that require visual representations and contextual learning experiences (Arrafi et al., 2025). One topic that consistently poses a challenge to understanding is kinematics, which covers Uniform Linear Motion (ULM), Uniformly Accelerated Linear Motion (UALM), vertical motion, parabolic motion, and circular motion. Students' difficulties arise not only in understanding formulas and calculation procedures but also in interpreting motion graphs such as velocity versus time ($v-t$), position versus time ($x-t$).

t), and acceleration versus time ($a-t$). Students also frequently struggle to develop a conceptual understanding of the relationships between physical quantities such as position, velocity, and acceleration (Madani et al., 2023). Therefore, a teaching approach is needed that can help students develop a more concrete conceptual understanding of kinematic concepts.

Low cognitive learning outcomes in physics, particularly in kinematics, are often caused by students' difficulties in visualizing the abstract concepts of motion in kinematics. Students' lack of understanding of the physical processes involved leads them to rely solely on memorizing mathematical formulas, which hinders their ability to analyze and master concepts optimally (Saputra et al., 2024). This situation calls for educational innovations capable of increasing student engagement. Innovative approaches, such as tutoring programs, have been shown to positively contribute to improved physics learning outcomes (Tianita et al., 2025). Therefore, there is a need for educational innovations that emphasize not only mathematical aspects but also a comprehensive conceptual understanding.

This phenomenon is exacerbated by the use of conventional teaching materials, which cannot be used to visualize changes in position, velocity, and acceleration continuously. In kinematics, the use of dynamic simulations is essential for students to understand the relationships between variables. The use of dynamic simulations enables two-way communication between teachers and students, allowing students to actively explore by independently adjusting variables and observing the results through the simulation. Thus, the use of dynamic simulations as an interactive learning media can strengthen students' understanding and significantly improve their cognitive learning outcomes in kinematics (Ma'rifah et al., 2023). Therefore, the use of dynamic simulations is a promising alternative solution for improving the quality of kinematics instruction.

The development of ICT has transformed educational paradigms toward a more open, flexible, and data-driven digital era. As digital natives, students heavily rely on technology throughout the process of learning, making the integration of interactive learning media an essential requirement for supporting the understanding of physics concepts in schools. These changes demand a transformation in instructional design toward approaches that are more interactive, adaptive, and technology-based (Maharani et al., 2025). Therefore, the integration of ICT in education is now a strategic need to satisfy the objectives of 21st-century learning rather than an alternative, which emphasizes digital literacy, collaboration, and problem-solving (Selwyn, 2022). Therefore, the use of technology in physics education needs to be optimized to support a more effective and relevant learning process.

In line with the digital transformation, the Ministry of Education, Culture, Research, and Technology (Kemendikbudristek) is actively promoting the digitization of education through various platforms such as Merdeka Mengajar and Rapor Pendidikan as part of the Merdeka Belajar policy (Kemendikbudristek, 2023). This challenge is particularly evident in science subjects, especially physics, which demands conceptual understanding at the cognitive level. Based on interview results conducted on Monday, September 1, 2025, at State High School 10 in Bengkulu City, it was found that the physics learning process is still dominated by conventional media such as printed materials and static presentations. The limited use of interactive media has led to low student engagement, feelings of boredom, and difficulties in understanding abstract concepts. Although interactive media like PhET have begun to be used, visual programming platforms such as Scratch have never been implemented. Learning conditions are further affected by infrastructure limitations, such as Wi-Fi access available only to educators, physics laboratories repurposed as classrooms, and unstable electricity. Additionally, the availability of learning media accessible offline remains a challenge.

The constructivist theory proposed by Piaget and Vygotsky emphasizes that learning involving active interaction, exploration, and visual representation can effectively build an *Development of Inquiry-Based.... (Niket et al.) pp:195-208*

accurate understanding of abstract concepts (Triana et al., 2025). The principles of multimedia learning developed by Mayer (2009) also underscore the importance of integrating words and images in forming a comprehensive mental representation. Recent research indicates that visual-verbal digital media can significantly enhance understanding of physics concepts (Rosydiana et al., 2023). Furthermore, learning media that integrate simulations with dynamic graphics have been demonstrated to improve pupils' comprehension of abstract ideas (Koilmo et al., 2025). Therefore, the development of instructional materials must be based on a solid theoretical foundation in order to optimally support the learning process.

Dynamic simulation is defined as the imitation of a real-world system that changes over time using a computer model (Stermann, 2000). In the context of physics education, dynamic simulation allows students to explore relationships between physical quantities in real-time through the manipulation of variables and the observation of graphs (University of Colorado Boulder, 2025). Recent research indicates that the development of Scratch-based learning media has proven to be valid and effective in improving student learning outcomes on the subject matter (Ma'rifah et al., 2023). This study developed Scratch-based media that integrates dynamic simulations with kinematic visualizations, enabling students to build a deeper conceptual understanding. Thus, the integration of dynamic simulations into Scratch-based learning media has the potential to improve students' conceptual understanding.

Scratch, as a visual programming-based learning platform, aligns with the principles of multimedia learning and supports inquiry-based learning (Ropi et al., 2019). Scratch allows for real-time manipulation of motion and graphical parameters, enabling students to directly explore relationships between physical variables (Nuraini et al., 2026). The learning media created with Scratch in this study is designed to support active and exploratory learning, particularly in kinematics. Through interactive simulations, students can observe, connect, and apply concepts independently, making learning more meaningful (Turnip, 2025). This design is based on the principles of constructivism and multimedia learning and supports cognitive learning outcomes based regarding the updated Bloom's Taxonomy (Bloom, 1956; Anderson & Krathwohl, 2001). Therefore, the use of Scratch as an interactive learning tool is considered relevant for supporting more meaningful physics learning.

In this context, the implementation of the Inquiry-Based Learning (IBL) model is highly relevant. IBL emphasizes inquiry-based learning, exploration, and independent discovery of concepts, enabling Students should actively create their own knowledge through investigation and experimentation. Several studies indicate that the implementation of IBL in physics education has been shown to significantly improve students' cognitive learning outcomes, as they are actively engaged in analyzing data, drawing conclusions from data, interpreting observational results, and developing a deeper conceptual understanding (Fatikasari et al., 2020; Saputri et al., 2020; Apriliandita et al., 2025). Thus, the implementation of IBL can serve as an effective learning strategy to enhance student engagement and understanding.

Although various Research has looked at the application of interactive learning media in physics education, most of these studies still focus on simulations based on specific platforms such as Scratch, which are generally used as general-purpose multimedia tools and do not yet provide sufficient flexibility for students to independently explore variables (Ma'rifah et al., 2023). Furthermore, the developed media often rely on internet connectivity, limiting their applicability in schools with constrained technological infrastructure (Irawan et al., 2023). In addition, research on the use of Scratch in physics education is still predominantly oriented toward game-based learning approaches or simple simulations and has not specifically integrated dynamic simulations with real-time kinematic graph visualizations (Ganish & Subali, 2025). Moreover, studies investigating the effectiveness of Scratch-based media in improving higher-order cognitive learning outcomes, such as analysis and evaluation, remain limited (Ma'rifah et al., 2024; Dwiyanti & Perdana, 2024). Therefore, a significant research gap exists

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in the development of comprehensive learning media that integrate dynamic simulations, real-time graphical visualization, and offline accessibility to support deeper conceptual understanding.

Given these limitations, this study addresses the research gaps by developing Scratch-based learning media that integrate dynamic simulations with real-time kinematic graph visualization within a single interactive learning environment. Unlike previous studies, which generally used simple or game-based simulations, the media developed in this study allows students to independently manipulate motion variables and directly observe the relationships between physical quantities. Additionally, this medium is designed to be accessible offline, making it more adaptable to school infrastructure limitations. Thus, the primary novelty of this study lies in the integration of Scratch-based dynamic simulations, real-time graphical visualization, offline access, and the application of Inquiry-Based Learning (IBL), all simultaneously aimed at enhancing cognitive learning outcomes at higher-order thinking levels (C2–C5). This indicates that this study makes a significant contribution to the development of innovative physics teaching materials. Based on this rationale, this study aims to develop and evaluate the feasibility, student responses, and effectiveness of inquiry-based learning media using Scratch-based dynamic simulations in improving students' cognitive learning outcomes in kinematics.

RESEARCH METHOD

Research Design

The goal of this research and development (R&D) study is to develop Scratch-based interactive learning media to support students' understanding of kinematics concepts. The R&D approach was selected because the study focuses not only on testing theories but also on developing products, validating their feasibility, and conducting limited trials to evaluate improvements in students' cognitive learning outcomes.

During the product implementation phase, a one-group pretest-posttest design was employed. This design was chosen because it is suitable for measuring improvements in learning outcomes before and after the use of the developed media, rather than comparing different instructional methods. The pretest was used to assess students' initial abilities, while the posttest measured learning improvements after the intervention. Objective test instruments were used as they align with the cognitive domains (C2–C5) in kinematics material, are practical for classroom implementation, and allow for the analysis of learning improvements using N-Gain scores.

The development model used in this study is the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation. The ADDIE model is widely recognized as a systematic instructional design framework developed and popularized in educational research (Branch, 2009), as it offers a methodical foundation for analyzing the needs for the design, creation, execution, and assessment of instructional media (Irawan et al., 2023). This model aligns with the nature of R&D research, which emphasizes a gradual and structured product development process.

Research Target/Subject

The population of this study consisted of all 10th-grade students at State High School 10 in Bengkulu City. The sample was Class XH, comprising 30 students. The sampling technique used was purposive sampling, which involves selecting samples based on specific considerations relevant to the research objectives (Sugiyono, 2020). The selection of Class XH was based on several criteria, including the suitability of the learning material (kinematics), a representative number of students, heterogeneous student abilities, and the willingness of the physics teacher to collaborate in the implementation of the study.

Research Procedure

This study employed a Research and Development (R&D) approach using the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation.

Analyze

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The analysis phase aims to identify learning needs, student characteristics, and the direction for developing instructional media that align with the learning objectives for physics in the kinematics unit. The analysis phase was conducted using two approaches: field research and a literature review.

Field studies were conducted through structured online and face-to-face interviews with high school students, as well as direct observation of the process of learning in the classroom. Interviews were used to obtain information regarding learning difficulties, student needs, and the use of learning media that had been implemented thus far. Meanwhile, observations were conducted to obtain a realistic picture of learning conditions, student activities, and interactions in the physics method of learning in the classroom.

The literature review was conducted by examining several literary sources, including as physics textbooks, journal articles, and previous research relevant to the development of simulation-based learning media.

Design

The design phase is the second phase in the ADDIE model, which aims to design instructional materials based on previously analyzed needs. Activities in this stage include selecting the material to be developed, determining the instructional media, designing a Scratch-based simulation, and preparing supporting learning media such as modules, worksheets based on inquiry-based learning (IBL), and presentation media (PowerPoint). This design was developed by considering the principles of instructional design and the needs of high school students.

Development

This stage aims to transform the initial design into a learning media product ready to aid in the process of learning. During this development stage, the researcher developed an interactive simulation based on Scratch, designed to improve students' cognitive learning outcomes in kinematics across several stages. The prepared product design was refined during this stage to produce an initial product consistent with the design.

The resulting initial product was then validated by three validators two physics education professors and one physics instructor to evaluate the media's suitability in terms of content, appearance, language, and interactivity. Following the validation process, revisions were made based on the validators' suggestions and feedback, such as improvements to the interface, clarity of instructions, and enhancements to the simulation features to make them easier for students to use.

Implementation

The implementation stage involved limited trials of the developed learning media with 30 tenth-grade students at State High School 10 Bengkulu City during kinematics learning activities. This stage employed a One-Group Pretest-Posttest design to examine the potential effectiveness of the developed media in improving students' cognitive learning outcomes.

The learning process was conducted over 2-3 sessions using the IBL model. The Inquiry-Based Learning (IBL) model was chosen because it aligns with the nature of Scratch-based media, which enables students to independently explore concepts through dynamic simulations. IBL emphasizes the processes of investigation, analysis, and conceptual discovery, thereby supporting the achievement of cognitive domains C2-C5. Additionally, prior research indicates that the application of IBL in physics instruction can enhance student engagement and cognitive learning outcomes.

The learning process was conducted by dividing students into several groups and using IBL-based worksheets as activity guides. Students explored concepts through Scratch simulations, observed changes in variables, analyzed data, and drew conclusions based on their observations. The improvement in cognitive learning outcomes was evaluated using a pretest administered before the lesson and a posttest administered after the lesson.

Evaluation

The evaluation phase aims to assess the quality and suitability of the developed learning media and to examine improvements in students' learning outcomes following the use of the media. The evaluation was conducted through an analysis of pretest and posttest results to determine improvements in the cognitive learning outcomes of pupils, as well as an analysis of student questionnaires regarding their responses to Using Scratch-based educational resources. The results of this evaluation were used as the basis for making improvements and refinements to the final product.

Instruments, and Data Collection Techniques

The research instruments consisted of an expert validation questionnaire, a learning outcome test, and a student response questionnaire. The cognitive learning outcome test consisted of 16 multiple-choice questions designed to measure students' understanding of kinematics concepts. The test covered cognitive levels C2 (understanding), C3 (applying), C4 (analyzing), and C5 (evaluating) based on the revised Bloom's Taxonomy. The test included sub-topics of Uniform Linear Motion and Uniformly Accelerated Linear Motion, as well as the interpretation of position-time, velocity-time, and acceleration-time graphs.

Prior to implementation, the test instrument underwent content validation through expert judgment by three validators, consisting of two physics education lecturers and one high school physics teacher. The validators assessed the relevance of content, the appropriateness of construct, and the clarity of language. Based on the validation results, all items were declared valid and suitable for use in this study. The instrument was validated through expert judgment to ensure content relevance, construct appropriateness, and language clarity. However, empirical reliability testing was not conducted because the study primarily focused on the development and limited implementation of the instructional media. Therefore, this limitation should be considered when interpreting the findings.

The expert validation questionnaire consisted of 12 items assessed using a five-point Likert scale. The instrument evaluated four aspects of the developed media: (1) content feasibility, (2) language clarity, (3) media design and visual appearance, and (4) interactivity and functionality.

The student response questionnaire consisted of 15 items using a five-point Likert scale. This instrument was used to measure students' perceptions of the Scratch-based learning media. The aspects assessed included: (1) media appearance, (2) ease of use, (3) level of engagement, and (4) perceived benefits in supporting students' understanding of kinematics concepts.

Data analysis technique

Expert validation and student responses were analyzed using a five-point Likert scale. The expert validation and student response data were analyzed using a five-point Likert scale, in which a score of 5 indicated "Very Good," 4 indicated "Good," 3 indicated "Fair," 2 indicated "Poor," and 1 indicated "Very Poor." The percentage score for both expert validation and student responses was calculated using the following formula:

$$\text{Validation} = \frac{\text{Total score}}{\text{Total ideal score}} \times 100 \quad 1)$$

The interpretation criteria were adjusted according to the minimum score of the Likert scale. Since the lowest possible score in the instrument was 1 out of 5, the minimum percentage score began at 20% rather than 0%. Therefore, the percentage intervals were categorized into five levels ranging from "Very Poor" to "Very Good" to facilitate more representative interpretation of the data.

Table 1. Percentage Interpretation Criteria

Percentage (%)	Category
84% - 100%	Very Good
68% - <84%	Good
52% - <68%	Fairly Good
36% - <52%	Not Good
20% - <36%	Very Not Good

Table 1 shows the categories of educational media suitability based on the percentage of validation results. The higher the percentage obtained, the higher the suitability level of the developed media.

The N-Gain test was used to measure the improvement in students' cognitive learning outcomes after the implementation of Scratch-based learning media with dynamic simulations on kinematics content. The calculation was based on pretest and posttest scores obtained from 30 tenth-grade students. The interpretation of N-Gain scores is presented in Table 2 were used as a reference for determining the level of improvement in students' learning outcomes.

Table 2. N-Gain Interpretation Criteria

N-Gain Score	Criteria
$g > 0,7$	High
$0,3 \leq g \leq 0,7$	Moderate
$g < 0,3$	Low

RESULTS AND DISCUSSION

This section presents the main findings of the study, which focuses on expert validation, student responses, and improvements in students' cognitive learning outcomes. This study produced Scratch-based learning media equipped with dynamic simulation features for kinematics material. The developed media were evaluated in terms of validity, practicality, and effectiveness. The interface of the media is shown in Figures 2 and 3, which include dynamic simulations for Uniform Linear Motion (ULM) and Uniformly Accelerated Linear Motion (UALM). Through this media, students can manipulate motion variables such as velocity, acceleration, and time, and then observe the changes that occur on the graph in real time.



Figure 1. Screenshot of the Scratch-Based Learning Media for the GLB Topic

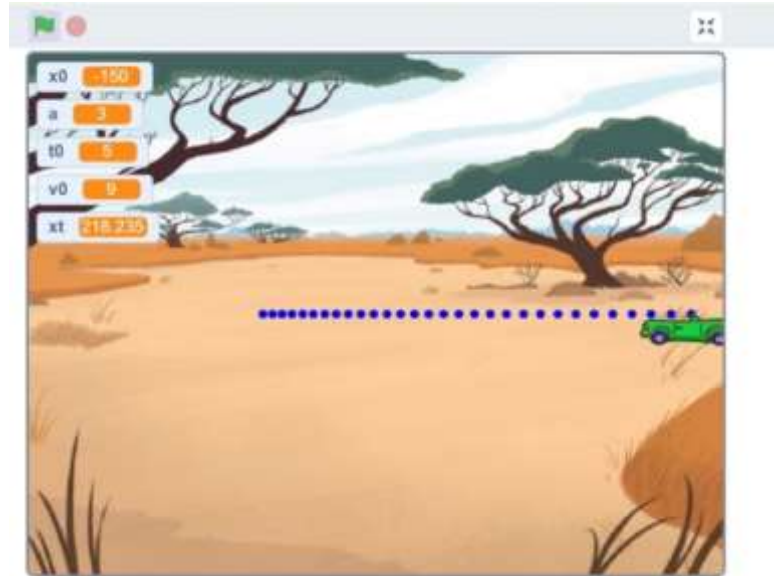


Figure 2. Screenshot of the Scratch-Based Learning Media for the GLBB Topic

Before implementation, the developed instructional materials were validated by three validators—two physics education lecturers and one physics teacher from State High School 10 in Bengkulu City—using a 12-item validation instrument. The Design and Technical aspects received the highest score of 97.80%. Why did this aspect receive the highest score? The validators stated that the simple interface, intuitive navigation system, and offline access were the main strengths of the media. One validator commented, “Students do not need much time to learn how to use this media. They can immediately focus on physics concepts.” This finding aligns with Mayer’s multimedia learning theory, which states that the effective integration of text, graphics, and animation can enhance students’ mental representations and conceptual understanding (Mayer, 2009). Offline access is also a significant advantage because the research location has limited internet access, allowing the media to be used optimally without relying on a network connection (Irawan et al., 2023). The validation results are presented in Table 3.

Table 3. Validation Results of the Developed Learning Media

Aspect	Score	Category
Learning Content	95.56%	Very good
Accuracy of Simulation	93.3%	Very good
Design and Technical Aspects	97.8%	Very good
Education	91.11%	Very good
Average	94.44%	Very good

The Instructional Content aspect received a score of 95.56%. The validator emphasized that the material aligns with the learning outcomes of the Merdeka Curriculum for kinematics. The simulation successfully represented the relationship between position, velocity, acceleration, and time through dynamic visual changes. This finding supports constructivist theory, which emphasizes that students actively construct knowledge through interaction and observation (Triana et al., 2025). The validator also suggested adding contextual examples related to everyday phenomena, such as the movement of vehicles on the highway. These suggestions were subsequently integrated into the worksheets and simulation.

The Simulation Accuracy aspect received a score of 93.30%. Although this falls into the “highly satisfactory” category, the validator identified several important revisions regarding the visualization of acceleration direction in the uniform accelerated motion (GLBB) simulation. In the early stages, students could observe changes in velocity but still struggled to visually distinguish between positive and negative acceleration. After the revisions were made, directional arrows, color indicators, and motion cues were added to improve the clarity of the representation. These findings indicate that precision in

representing physical quantities is crucial in simulation-based learning because misconceptions can arise when visual representations are incomplete.

The Education aspect received the lowest score of 91.11%. The validators noted that although the principles of Inquiry-Based Learning had been integrated into the worksheets, the simulations initially provided limited guidance during the inquiry process. As a follow-up, prompts were added to encourage prediction, hypothesis testing, and reflection at each stage of the simulation. This revision strengthens the media's alignment with the Inquiry-Based Learning model. These results indicate that interactive technology alone is insufficient to improve learning outcomes without appropriate pedagogical support. The effectiveness of digital media is determined not only by visual quality but also by the media's ability to facilitate meaningful cognitive engagement. Similar findings were also reported by Mas'ulah and Perdana (2024), who found that Scratch-based interactive animation media on uniformly accelerated motion improved students' conceptual understanding through dynamic visualization and direct interaction with motion variables.

Previous research has shown that Scratch-based learning media can support students' conceptual understanding through interactive visualization and active exploration. Nurmaulidina et al. (2022) developed 3D Scratch-based physics learning media and found that interactive visual representations helped students understand abstract concepts more effectively. Similar findings were also reported by Wakidawantama and Perdana (2024), who showed that Scratch-assisted physics learning media can improve student learning outcomes on the topic of vibrations and waves through simulation-based activities. Additionally, Ningrum et al. (2023) found that Scratch-assisted learning activities can improve students' problem-solving skills because students are encouraged to actively explore concepts during the learning process. Compared to previous studies, this research offers a different approach by integrating simultaneous visualization of position, velocity, and acceleration graphs, offline access, and inquiry-based activities within a single integrated learning environment.

Student responses were measured using a 15-item questionnaire administered to 30 students. Student responses to the developed media also showed excellent results, with an average score of 91.60% in the "excellent" category. The "Media Presentation" aspect received the highest score, at 92.40%. The students stated that the media interface was visually appealing, easy to understand, and helped them follow the learning process systematically. The layout of the buttons, instructions, and simulation controls allowed students to use the media independently without always needing assistance from the teacher.

Table 4. Students' Responses to Scratch-Based Learning Media

Aspect	Score	Category
Media Presentation	92.4%	Very Good
Media Design	90.4%	Very Good
Media Benefits	92%	Very Good
Average	91.60%	Very Good

The "Benefits of Media" aspect received a score of 92.00%. Observations during the lesson showed that students were highly engaged when given the opportunity to directly manipulate variables through simulation activities. One student explained that before using the media, physics formulas tended to be memorized without truly understanding their meaning. After using the simulation, students could observe how changes in acceleration affected the motion graph, making the concept easier to understand. This finding indicates that direct interaction with variables in the simulation plays a crucial role in enhancing student engagement during the learning process. Similar findings were also reported by Ningrum et al. (2023), who found that Scratch-assisted learning activities encouraged students to explore concepts more actively and supported problem-solving skills. Wakidawantama and Perdana (2024) also reported that Scratch-based simulations can improve student learning outcomes because students can observe physical phenomena through interactive exploration. Furthermore, Hermansyah et al. (2022) explain that interactive multimedia can support conceptual understanding through a combination of visualization and active student interaction during learning. Similar results were also reported by Putri and Festiyed (2023), who found that interactive multimedia can increase student engagement and support conceptual understanding in learning.

The “Media Design” aspect received the lowest score of 90.40%, although it still falls within the “very good” category. Some students reported that the buttons were relatively small on older computers and that the media performed slightly slower when run on devices with lower specifications. These findings indicate that device compatibility and interface optimization remain important factors in the development of digital learning media, particularly in schools with varying levels of technological infrastructure (Selwyn, 2022).

The effectiveness of the developed media was evaluated using pretest and posttest scores obtained from a 16-item cognitive test covering levels C2–C5 based on the revised Bloom’s taxonomy (Anderson & Krathwohl, 2001). The detailed results are presented in Table 5.

Table 5. Pretest and Posttest Score Data

Indicator	Average Pretest Score	Average Posttest Score	N-Gain Score
Understanding (C2)	32.5	91.67	0.87
Applying (C3)	23.33	90.83	0.88
Analyzing (C4)	26.92	85	0.79
Evaluating (C5)	41.67	85.83	0.75

The pretest and posttest scores for each cognitive level were converted into percentages before the N-Gain calculation. The N-Gain scores for each cognitive level were calculated separately based on the distribution of test items in each category, whereas the overall N-Gain score was calculated using the total pretest and posttest scores. The results showed an overall pretest score of 27.50% and an overall posttest score of 88.33%, resulting in an overall N-Gain score of 0.85 in the high category. These findings indicate that the developed Scratch-based learning media with dynamic simulations effectively improved students’ cognitive learning outcomes in kinematics learning

The application level (C3) achieved the highest N-Gain score of 0.88, followed by the comprehension level (C2) at 0.87. This improvement appears to be related to the learning activities conducted during the simulation process. Students repeatedly applied the relationships between motion variables by changing the acceleration values and directly observing the changes in the velocity graph. Through these activities, students not only memorized formulas but also applied concepts within the simulation context. These findings suggest that direct interaction with dynamic visualizations can strengthen students’ conceptual understanding and application skills. Similar results were also reported by Banda and Nzabahimana (2021), who explained that simulation-based learning environments can support conceptual understanding in physics education. Putri and Festiyed (2023) also found that interactive multimedia can increase student engagement and facilitate conceptual understanding through active interaction and visualization. Similar findings were reported by Sabilla et al. (2024), who found that Scratch-based game learning increased students’ engagement and conceptual understanding in physics learning activities

The Analyzing level (C4) achieved an N-Gain score of 0.79, which is lower than that of levels C2 and C3. The analysis task required students to interpret several graphical representations simultaneously, including graphs of position, velocity, and acceleration. Some students still struggled to establish connections between these representations. Meanwhile, the Evaluating level (C5) achieved the lowest N-Gain score of 0.75, indicating that higher-order thinking skills require a longer learning process and more intensive practice. Similar findings were also reported by Manurung and Panggabean (2020), who explained that interactive multimedia learning is generally more effective in improving conceptual understanding and problem-solving skills than evaluative skills.

Compared to previous research, the results of this study are consistent with various studies on the use of interactive simulations in physics education. Fatikasari et al. (2020) reported that inquiry-based learning supported by PhET simulations was able to improve students’ cognitive learning outcomes. Ma’rifah et al. (2023) also found that Scratch-based interactive multimedia could improve learning outcomes through enhanced visualization and interactivity during learning. Furthermore, Rosydiana et al. (2023) explained that Scratch-based digital learning media can improve students’ problem-solving skills through active exploration. Yuliananto and Subali (2024) also reported that Scratch-based learning media improved students’ conceptual understanding in momentum and collision topics through interactive simulations. Compared to previous research, this study offers a distinct

approach by integrating simultaneous visualization of position, velocity, and acceleration graphs, offline access, and inquiry-based learning activities within a single learning environment.

The improvement in student learning outcomes may be attributed to the combination of dynamic visualization features and inquiry-based learning activities integrated into the developed media. Dynamic visualization helps students transform abstract kinematic concepts into more observable representations, while inquiry activities encourage students to build understanding through observation, prediction, experimentation, and reflection. These findings support the constructivist perspective, which emphasizes that knowledge is actively constructed through interaction and learning experiences. Similar results were also reported by Apriliandita et al. (2025), who found that inquiry-based learning can improve students' cognitive learning outcomes through active exploration and conceptual investigation.

The pedagogical implications of this study suggest that simulation-based learning media should not only provide engaging visual representations but also facilitate students' thinking processes during learning activities. The developed media can serve as an alternative instructional tool for physics learning, particularly in schools with limited internet access, since the simulations can be operated offline. Nugroho et al. (2025) also emphasized that Scratch-assisted learning environments can strengthen students' physics identity and increase their participation during learning activities. In addition, Selwyn (2022) highlighted that accessible educational technology plays an important role in supporting equitable learning opportunities across different educational contexts.

Despite producing positive results, this study still has several limitations. The use of a one-group pretest-posttest design without a control group limits stronger causal interpretation regarding the effectiveness of the developed media. In addition, the sample was limited to 30 students from a single school, reducing the generalizability of the findings. The implementation period was also relatively short, consisting of only three learning sessions. Therefore, future studies are recommended to employ quasi-experimental designs involving larger and more diverse samples across different educational contexts. Further development may also expand Scratch-based simulations to other physics topics as suggested by Ganish and Subali (2025), such as dynamics, energy, and fluid mechanics,

CONCLUSION

This study demonstrates that Scratch-based learning media with dynamic simulations is highly feasible and effective for supporting kinematics learning in physics education. The developed media enabled students to visualize the relationships among position, velocity, and acceleration more clearly through interactive simulations and graphical representations. The results showed a significant improvement in students' cognitive learning outcomes, with an overall N-Gain score in the high category, indicating that visual exploration and direct interaction can support conceptual understanding in physics learning. Student responses also indicated that the media was engaging, easy to use, and supportive of active learning activities.

In addition, the developed media has practical advantages because it can operate offline, making it suitable for schools with limited internet access and technological facilities. However, this study was limited by the use of a one-group pretest-posttest design, a relatively small sample from a single school, and the absence of empirical reliability testing for the research instruments. Therefore, future studies are recommended to employ quasi-experimental designs involving larger and more diverse samples, as well as empirical instrument testing, to strengthen the validity and generalizability of the findings..

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