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Technology-Based Parabolic Motion in Physics Education: A Systematic Literature Review

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Abstract:

Parabolic motion based on technology is a major concern in physics education because this concept is fundamental but requires the integration of complex mathematical, visual, and conceptual representations. Although various learning technologies have been used, research that systematically examines the relationship between the type of technology, pedagogical approach, and learning outcomes on the topic of parabolic motion is still limited and fragmented. This systematic literature review follows the PRISMA 2020 guidelines to analyze 26 peer-reviewed studies published between 2016 and 2025, selected from the Scopus and ERIC databases. The analysis focused on three main aspects, namely learning technology categories, related pedagogical methods, and reported learning outcomes, including conceptual understanding, higher-order thinking skills (HOTS), and the possibility of computational integration. The synthesis results show that the effectiveness of technology in teaching parabolic motion does not depend on the platform used, but is largely determined by the underlying pedagogical design. Interactive simulations and computational modeling combined with inquiry, problem-solving, or project-based approaches typically have a positive effect on conceptual understanding and HOTS development, while the use of passive visual technology has a more minimal impact. In addition, several studies show the potential for developing computational skills related to artificial intelligence preparation, although these results have not been clearly implemented in many studies. This research contributes by designing a pedagogical-technological classification framework for parabolic motion learning that can serve as a conceptual map for educators and researchers in adjusting technology choices to conceptual, cognitive, and computational learning objectives in physics education.

1. Introduction

Parabolic motion is a fundamental topic in physics education that plays an important role in building students' understanding of kinematics and two-dimensional motion dynamics. However, various studies report that this concept is consistently difficult for students at various levels of education to understand. Supriyanto (2021) explains that physics learning in schools is still dominated by a teacher-centered approach and an excessive emphasis on mathematical and procedural aspects, leading students to memorize formulas without understanding the physical meaning behind the equations. As a result, students have difficulty relating mathematical representations to the physical phenomena that actually occur. This difficulty is persistent and has become a widespread concern in physics education research, especially at the secondary school level, because students often experience conceptual barriers in understanding the relationship between horizontal and vertical motion components, which are actually independent (Azhar et al., 2021; Celestino-Salcedo et al., 2024; Fitri et al., 2019; la Aca et al., 2020). The problem becomes even more complex when teaching parabolic motion is still dominated by conventional approaches that lack visualization and the exploration of real phenomena. In fact, science learning requires clear and diverse visual representations so that abstract concepts can be understood meaningfully. Multimedia learning theory asserts that conceptual understanding is optimal when information is presented through a combination of complementary visual and verbal representations (Celestino-Salcedo et al., 2024), so that students have difficulty understanding concepts.

In the context of technology-based physics learning (Azhar et al., 2021; Fitri et al., 2019; la Aca et al., 2020), it is emphasized that a contextual approach is essential to help students understand the concept of parabolic motion more meaningfully. Learning technology enables the dynamic presentation of parabolic motion phenomena through simulations, animations, video analysis, and computational modeling, allowing students to directly observe the effects of physical variables on motion trajectories. Although various learning technologies have been used, research findings are still scattered and have not been systematically mapped to show how the characteristics of technology, learning design, and learning outcomes are interrelated in learning parabolic motion. According to the literature, the use of technology in physics education can be a solution to overcoming these problems (Lestari & Mansyur 2021; Nasbey et al., 2024; Siswanto et al., 2025; Supriyanto, 2021). Educational technology, such as digital media, animation, and simulation, allows students to observe physical phenomena in a more concrete and interactive way.

The integration of technology in physics education has a significant impact on improving students' conceptual understanding. Various interactive simulations, such as PhET, Algodo, and GeoGebra, have been proven to strengthen the understanding of basic concepts of parabolic motion through dynamic visualization of motion trajectories, interrelationships between variables, and interactive parameter exploration (Aslan & Buyuk, 2021; Celestino-Salcedo et al., 2024; Chinaka, 2021; Delubom & Tatira, 2025; Lestari & Mansyur, 2021; Liu et al., 2025; Siswanto et al., 2025). In addition, the Video Tracker effectively improves the ability to analyze real motion by connecting real-world phenomena and physics concepts through direct measurement of position, velocity, and trajectory (Azhar et al., 2021; Handayani et al., 2016; Lestari & Mansyur, 2021; Supriyanto, 2021; Wijayanti et al., 2025). Interactive and production-based digital technologies such as programming, digital media, mobile applications, virtual reality (VR), and Arduino require active student involvement in building models, media, or digital artifacts. This approach supports contextual, project-based, and problem-solving learning, while integrating visual, numerical, and conceptual representations in a meaningful way (Anggraini et al., 2018; Astra & Kartini, 2023; Bachtiar et al., 2021; Celestino-Salcedo et al., 2024; Chin et al., 2016; Dewi et al., 2023; Raras & Kuswanto, 2019; Saputra & Kuswanto, 2018; Taufiq et al., 2024; Villada Castillo et al., 2025; Wijayanti et al., 2025).

This study aims to synthesize research on the use of learning technology in teaching parabolic motion to overcome students' conceptual difficulties, improve conceptual understanding, strengthen multiple representations, foster Higher-Order Thinking Skills (HOTS), and reduce misconceptions in kinematics. In the conceptual realm, this study analyzes how learning technology is not merely a visualization tool, but an epistemic instrument that enables students to build causal understanding, integrate visual, numerical, and conceptual representations, and reconstruct the concept of parabolic motion through virtual experimental experiences (Liu et al., 2025). Thus, parabolic motion is positioned as a phenomenon that can be explored conceptually, not just calculated mathematically.

In the methodological realm, this study presents a transparent and replicable Systematic Literature Review (SLR) procedure to map technology-based parabolic motion learning (Bachtiar et al., 2021). The study protocol includes strategies for searching literature across scientific databases, establishing inclusion and exclusion criteria that emphasize peer-reviewed publications, and a gradual screening process and study quality assessment. In addition, a data extraction codebook was developed to capture the characteristics of learning technology, learning design, educational context, and learning outcomes, including concept understanding, multiple representations, HOTS, and misconceptions. The reporting of the study results follows the latest SLR guidelines to ensure transparency, traceability, and replicability of the synthesis process. The synthesis results are presented in the form of a thematic descriptive analysis and a mapping of the relationships among types of technology, learning approaches, and learning outcomes, which can serve as a methodological basis for the development of learning designs, further research, and the formulation of technology-based physics learning policies.

Although various studies have examined the use of technology in teaching parabolic motion, most still focus on media development or on measuring learning outcomes separately (Abdillah et al., 2021; Astra & Kartini, 2023; Dramae et al., 2017; Raras & Kuswanto, 2019; Saputra & Kuswanto, 2018). To date, there have been few studies that systematically map the relationships among the type of technology, the pedagogical approach used, and the reported learning outcomes in physics education on the topic of parabolic motion. Furthermore, there is no synthesis framework available to help educators understand how the pedagogical functions of technology contribute to conceptual understanding and HOTS. Therefore, this systematic literature review was conducted to fill this gap by providing a comprehensive mapping of technology-based research on parabolic motion learning.

To focus the study and maintain consistency in the analysis, the following research questions were formulated as the main guidelines for this study.

RQ1. What are the trends in learning technologies used in technology-based parabolic motion learning in physics education?

RQ2. What are the characteristics of the learning approaches (core, contextual, and other/emerging approaches) applied in technology-based parabolic motion learning?

RQ3. What are the learning outcomes reported in studies of technology-based parabolic motion learning, particularly in relation to conceptual understanding, HOTS, and 21st-century competencies?

2. Theoretical Framework

2.1. Basic concept: Learning Parabolic Motion as a Cognitive Problem

Theoretically, parabolic motion is understood as a kinematic concept that requires simultaneous integration between mathematical, visual, and conceptual representations. Students' difficulties in learning parabolic motion stem not only from the complexity of the mathematical equations but also from the cognitive demands of understanding the independence of motion on the horizontal and vertical axes. Therefore, learning parabolic motion is often categorized as a high cognitive demand topic in physics education (Siswanto et al., 2025; Supriyanto, 2021). This condition indicates the need for a learning approach that can help visualize and interpret the concept of parabolic motion more concretely.

The role of technology in theoretical perspective within the framework of constructivism and multiple representations theory, learning technology is viewed as a cognitive tool that helps learners build conceptual understanding through visualization, interactivity, and independent exploration. Technology enables abstract parabolic motion phenomena to be presented through dynamic simulations, animations, and multimedia, so that the learning process focuses not only on manipulating mathematical symbols but also on interpreting relationships among physical variables (Nasbey et al., 2024).

Unlike previous studies, which generally view learning technology as merely a means of visualization, this study views technology as cognitive and epistemic tools that shape how students construct, manipulate, and represent the concept of parabolic motion. Thus, the grouping of technologies in this study is not based solely on the type of platform used, but rather on the pedagogical functions and level of cognitive engagement facilitated by the technology.

Conceptual classification of learning technologies based on a theoretical review of the pedagogical functions of technology in physics learning. Learning technologies for parabolic motion material are classified into three main conceptual approaches: core, contextual, and other/emerging.

a. Core approaches refer to technologies that directly support understanding of the core concepts of parabolic motion. These approaches emphasize dynamic, interactive representations to visualize relationships among physical variables, such as position, velocity, angle of elevation, and time. Theoretically, these approaches serve to reduce cognitive load while strengthening students' basic conceptual understanding.
b. Contextual approaches place the learning of parabolic motion within a broader context, such as problem-solving, integration with specific learning models, or linking to real-world situations. Conceptually, this approach aims to strengthen knowledge transfer and help students relate physics concepts to meaningful learning experiences.
c. Other/Emerging Approaches. Other or emerging approaches are not yet established in learning practices but show potential to support parabolic motion learning, including the integration of new technologies or interdisciplinary approaches. These approaches help open space for innovation and indicate the direction of future research in physics learning.

The relationship between the theoretical framework and HOTS and conceptual understanding is that learning technology is not only positioned as a medium for visualization but also as a means to support the development of HOTS. Through exploration, variable manipulation, and analysis of parabolic motion phenomena, students are encouraged to engage in reasoning, evaluation, and the synthesis of concepts, which are the main components of HOTS. Therefore, improving conceptual understanding and developing HOTS are seen as interrelated theoretical outcomes.

This theoretical framework serves as a conceptual basis for analyzing empirical findings in this SLR, particularly for identifying patterns in learning approaches, the types of technology used, and their implications for students' understanding of concepts and HOTS.

2.2. Learning Approaches for Technology-based Parabolic Motion Learning

This section presents the learning approaches used in technology-based parabolic motion learning studies analyzed in this review. The discussion focuses on pedagogical implementation patterns that appear consistently in the literature, rather than on theoretical foundations.

Core approaches. The core approach is a learning strategy that uses technology as the primary means of exploring the concept of parabolic motion.

a. Simulation-Based Inquiry, most studies use interactive simulations to allow students to manipulate motion variables (initial velocity, elevation angle, and gravity) and observe changes in trajectory in real time. This approach is generally combined with guiding questions or exploratory worksheets.
b. Technology-Supported Problem Solving: Several studies have presented parabolic motion as open-ended problems solved with simulation software or digital modeling. Technology serves as an analytical tool to compare mathematical predictions with visual or numerical results.

c. Digital Project Development: This approach involves the development of simple digital products, such as trajectory simulations, animations, or computational models, as a means of integrating concepts, representations, and reflections on learning outcomes.

Overall, this core approach has been consistently reported to increase active engagement, conceptual understanding, and analytical skills among students.

Contextual Approaches. The contextual approach links technology-based parabolic motion learning to authentic or interdisciplinary contexts relevant to students.

a. STEM/STEAM-Integrated Contexts, Parabolic motion is studied in interdisciplinary project contexts, such as sports, simple engineering, or ballistic applications, with technology support for visualization and analysis.
b. Multimedia and Visualization-Oriented Learning, studies in this category emphasize the use of animation, simulation-based videos, and dynamic graphic representations to help students connect mathematical equations with physical phenomena.
c. Everyday-Context Physics Learning: this approach places parabolic motion within everyday phenomena, so that technology serves as a bridge between real experiences and scientific models.

Other/Emerging Approaches.

Other approaches that are still limited in number but show potential include:

- Computational Modeling Approaches, which emphasize the formulation of mathematical models in algorithmic form;
- Virtual and Remote Laboratory, which allows parabolic motion experiments to be conducted without the limitations of physical equipment;
- Hybrid Learning Environments, which combine simple physical activities with simulation-based digital analysis.

These approaches indicate the direction of development for technology-based parabolic motion learning, though their implementation remains experimental.

3. Method

3.1. Design and Guidelines

This study uses an SLR approach with reporting following the PRISMA 2020 guidelines (Page et al., 2021). The study protocol was developed at the initial stage to determine the study's scope, research questions, inclusion and exclusion criteria, literature search strategy, and step-by-step screening procedures, including title and abstract selection and full-text review. Data extraction was performed using a structured codebook that mapped the types of learning technologies, pedagogical approaches, educational contexts, and learning outcomes related to parabolic motion. The synthesis of findings was presented descriptively and narratively to identify patterns, trends, and research gaps. The methodological framework referred to the principles of SLR in the Cochrane Handbook (Aslan & Buyuk, 2021; Delubom & Tatira, 2025; Siswanto et al., 2025). Articles that were questionable at the initial stage were not immediately eliminated but were reevaluated at the full review stage to minimize selection bias. All inclusion and exclusion decisions were based on explicit relevance to the topic of technology-based parabolic motion learning in the context of physics education.

3.2. Search Strategy

The search strategy was designed in parallel across the Scopus and ERIC databases using core terms for parabolic motion, learning technology, and physics education. The term learning approach was not included in the initial search stage to minimize bias and maintain search sensitivity; noise control was performed at the title/abstract screening and full-text review stages. Facets and filters were applied in accordance with pre-determined policies on time range, document type, language, and access. All search results from both databases were combined and deduplicated prior to screening.

a. Scopus

   Initial query:

   ```
   TITLE-ABS-KEY (projectile OR "projectile motion" OR "parabolic motion") AND TITLE-ABS-KEY (technolog* OR simulation OR digital OR "virtual lab*" OR software)
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   Initial results: n = 1,113 after applying facets (article/proceedings document type, English language, open access, and year according to policy): n = 195.

b. ERIC

   Initial query:

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   (projectile motion OR parabolic motion) AND (technology OR simulation OR digital OR "virtual laboratory" OR software) AND (physics education OR physics learning OR science education)
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   Initial results: n = 510.

Before screening, 12 duplicate articles were removed, leaving 228 articles to be screened. Screening was conducted by reviewing the titles and abstracts, and 192 irrelevant articles were excluded, leaving 36 articles. Of these, 9 articles were not available in full text, so 27 articles were assessed for eligibility by reading the full text. At this stage, 1 article was excluded, leaving 26 articles included in the systematic review. A total of 26 articles that met the inclusion criteria were then further analyzed at the data extraction stage, as shown in Figure 1.

3.3. Inclusion and Exclusion Criteria

a. Inclusion criteria:
   1) Explicitly discussing the topic of parabolic motion or projectile motion.
   2) Involving the use of learning technology (e.g., simulations, modeling software, or virtual laboratories).
   3) Be within the context of formal physics education.
   4) Present empirical data or analysis of learning implementation.
   5) Be published as a journal article or proceedings in accordance with the specified time frame and access policy.
b. Exclusion criteria:
   1) Only discusses parabolic motion theoretically without any learning context.
   2) Uses technology solely as a presentation tool without any learning interaction.
   3) Is outside the context of physics education.
   4) Is in the form of an editorial, non-systematic review, or publication that does not provide the full text.

The screening of abstract titles and the full-text review were conducted in stages, using predetermined inclusion and exclusion criteria. To minimize subjective bias, inclusion decisions for questionable articles were made at the full-text review stage by assessing their explicit relevance to the topic of parabolic motion and technology-based learning activities.

3.4. Data Extraction & Codebook

The search results from Scopus and ERIC were combined, deduplicated, and then selected in two stages according to PRISMA 2020: screening of abstract titles followed by full-text review to verify the presence of student programming activities and learning outcomes. Doubtful decisions in the initial stage were deferred to the full-text stage. The scope of extraction was limited to the following four core variables; all decisions were coded consistently using this codebook.

a. Types of learning technology
   Includes interactive simulations (PhET, GeoGebra), video analysis (Tracker), physics engines (Algodoo), as well as interactive and production-based digital technologies such as programming, VR, Arduino, and digital media.
b. Learning approach
   1) Core: Project-Based Learning (PjBL), Problem-Based Learning (PBL), Inquiry-Based Learning (IBL).
   2) Contextual: STEM/STEAM, Game-Based Learning, Domain-Specific Applications
   3) Other/Emerging: Creative Coding dan Maker Education.
c. Creative learning outcomes are coded into four dimensions, namely process, domain, nature, and product, based on the description of learning outcomes reported in each study.

3.5. Synthesis & Analysis Strategy

Data synthesis was conducted using a descriptive-narrative approach with individual studies as the unit of analysis. The analysis focused on four main variables relevant to technology-based parabolic motion learning in physics education: the type of learning technology, the learning approach category, the reported learning outcomes, and the strength of computational integration. Learning technologies were grouped into interactive simulations (e.g., PhET and GeoGebra), video-based motion analysis (Tracker), physics engines (e.g., Algodoo), and production-based digital technologies (such as programming, Arduino, and VR). Learning approaches were classified into core categories (Project-Based Learning, Problem-Based Learning, and Inquiry-Based Learning), contextual categories (STEM/STEAM, game-based learning, and domain-specific applications), and other/emerging categories (creative coding and maker education).

The frequency and proportion of each category's appearance were analyzed to identify dominant trends in the literature. To examine the interrelationships between components, a cross-tabulation was compiled between technology categories and learning approaches using a presence-based multi-label scheme, allowing a single study to contribute to more than one category. The strength of computational integration was analyzed as an overlay, assigning strong or weak labels based on the extent to which the technology was used for variable manipulation, modeling, and active exploration by learners, or only for passive visualization. The synthesis results are presented in tables and concise visualizations, such as bar charts and cross-tabulations, to facilitate pattern reading. The reporting of results follows the PRISMA 2020 guidelines to ensure the transparency and replicability of the study (Page et al., 2021).

3.6. *PRISMA Reporting*

Reporting follows the PRISMA 2020 structure, covering the stages of identification, screening, and inclusion. Records from Scopus and ERIC were combined, deduplicated, and then screened for titles and abstracts before full-text review. Key figures are reported in Figure 1.

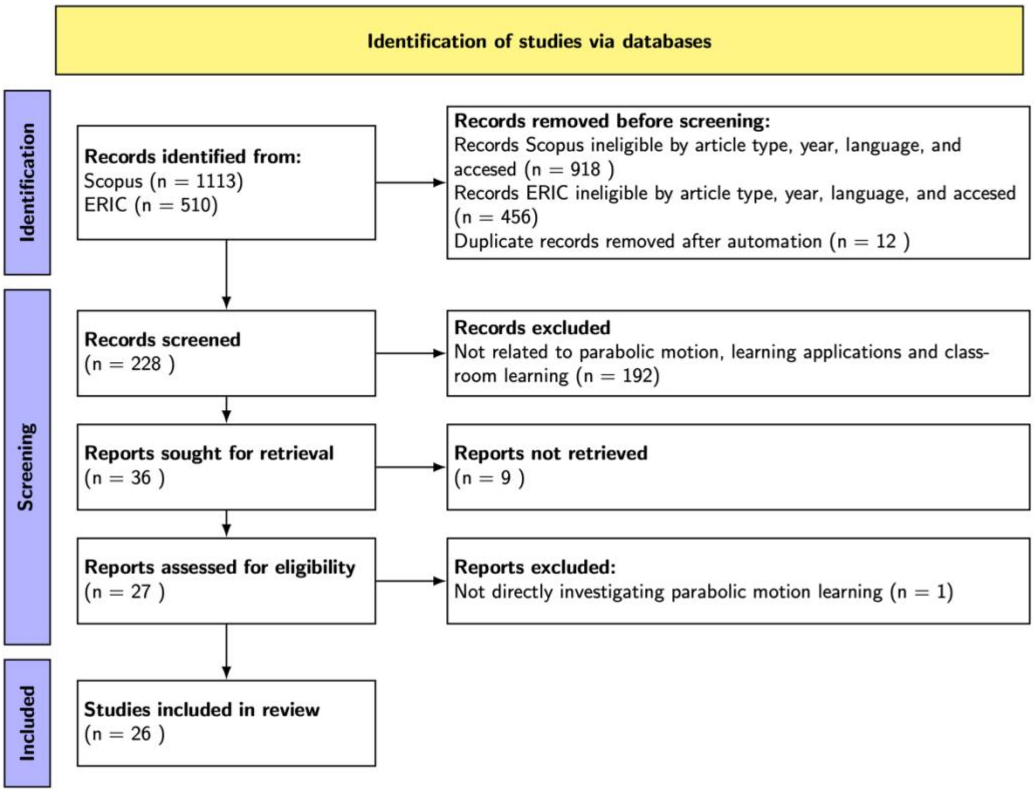

Figure 1. *PRISMA statement*

4. Result

A total of 26 studies that passed inclusion formed the basis of the synthesis. The findings are presented according to the predefined categories. All synthesized data were shown in the Appendix.

4.1. *RQ1 Parabolic Motion Learning Trends Technology*

The results of the literature analysis show that the learning technology used in parabolic motion learning is predominantly video-based multimedia, particularly platforms such as YouTube. This type of technology is used more than simulations, virtual laboratories, or other more technical technologies. These findings indicate that parabolic motion learning tends to use visual media that are easily accessible and familiar to students

Figure 2 shows that in instructional videos, the concept of parabolic motion is generally presented through visualizations of object trajectories, two-dimensional animations, and real-world examples such as the motion of a thrown ball or a launched bullet. Some videos compare trajectories with different launch angles, accompanied by narrative explanations of how angle, initial velocity, and gravity affect the trajectory's shape. This presentation helps students intuitively understand the characteristics of parabolic motion, especially for abstract concepts (Aslan & Buyuk, 2021; Halim & Hamid, 2021; Siswanto et al., 2025).

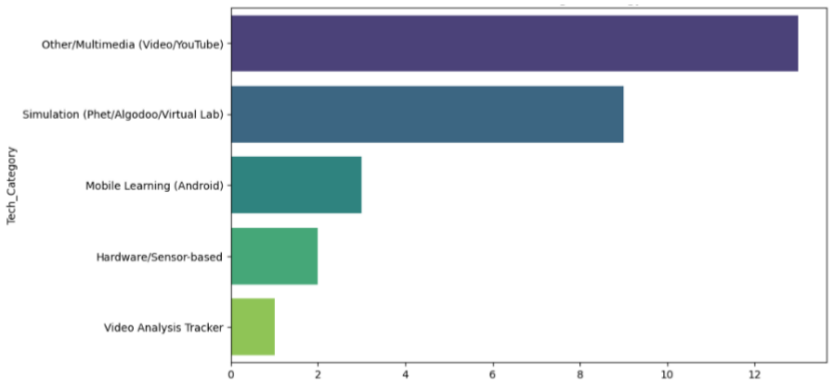

Figure 2. *Trends in learning technology*

Simulation technologies and virtual laboratories, such as PhET and Algodoo, rank second in terms of usage. These simulations allow students to observe parabolic motion dynamically by adjusting parameters and seeing the effects immediately. Through simulations, students can explore concepts and inquiry-based learning without the limitations of real laboratory equipment (Azhar et al., 2021; Handayani et al., 2016; Supriyanto, 2021).

Meanwhile, Android-based mobile learning shows moderate usage levels. This indicates that learning through mobile devices is beginning to develop, but its application is still limited compared to video and simulation. These limitations are likely due to the need for specialized application development and the readiness of teachers and supporting infrastructure. The use of hardware- or sensor-based technology and video analysis trackers remains relatively low. Although this technology has great potential for quantitative analysis of parabolic motion, its application is still limited because it requires technical skills and more in-depth data analysis.

Overall, these findings indicate that the trend in parabolic learning technology remains dominated by easily accessible visual media, while analytical and experimental technologies have not been fully utilized. This situation opens up opportunities for learning that place greater emphasis on strengthening students' analytical skills and conceptual understanding.

4.2. RQ2 Technology-Based Learning Approach to Parabolic Motion

The results of the literature analysis show that learning approaches in technology-based parabolic motion learning can be grouped into three main characteristics, namely the core approach, the contextual approach, and other/emerging approaches. These three approaches are distinguished by their focus on learning, the role of technology, and how students build understanding.

Figure 3 shows that the contextual approach, with a percentage of 69.2%, is dominant, indicating that most studies relate the concept of parabolic motion to real-life situations close to students' experiences. In this approach, context is not only used as an illustration but also as the basis for designing learning activities, programming tasks, and exploring the concept of parabolic motion. In its application, the contextual approach usually presents parabolic motion through real-world problems, such as the trajectory of a ball in sports, projectile motion in digital games, or programming-based simulations that represent everyday physical phenomena. In this context, students not only learn mathematical equations but also understand the physical meaning of each variable and the relationships between concepts. This approach is considered effective because it helps students connect theory with phenomena that they can observe and imagine directly (Chen et al., 2023).

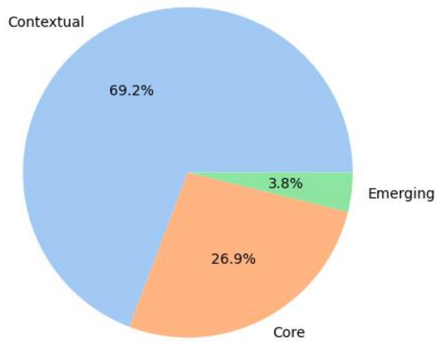

Figure 3. *Dimensions of creativity according to learning approach categories.*

The core approach ranks second, with a 26.9% share. This approach includes project-based, problem-based, and inquiry-based learning that focuses on mastering basic concepts and key principles before linking them to a broader context. The dominance of this approach shows that many studies still emphasize the importance of strong conceptual understanding as the foundation of learning. Meanwhile, emerging approaches are still rarely applied, with a percentage of only 3.8%. These approaches, such as creative coding and maker education, generally require technological readiness, creativity in learning design, and specific skills from educators. The limited use of these approaches indicates that their application remains limited, either due to a lack of references or empirical evidence supporting their effectiveness.

Overall, these findings indicate that technology-based parabolic motion learning relies more on a contextual approach, followed by a core approach, while innovative approaches still have ample room for development. This condition opens up opportunities for further research into new learning approaches that can complement established ones and improve the quality of learning.

4.3. RQ3 Learning Outcomes of Technology-Based Parabolic Motion Learning

This subsection synthesizes learning outcomes to answer RQ3, including conceptual understanding, HOTS, and misconceptions. The results show that conceptual understanding is the most dominant outcome reported, followed by HOTS in limited numbers, while misconceptions are rarely discussed, and the potential of computational skills has not been explicitly reported as a major learning outcome in most studies. The strength of the findings is examined through the dimensions of creativity, namely process, product, trait, and domain-specific.

Figure 4 shows that, to strengthen the analysis, learning outcomes were further reviewed along the dimension of creativity, which includes process, product, individual characteristics (traits), and knowledge domain. The distribution of these four dimensions shows that learning outcomes do not only focus on the final output but also emphasize the process of developing student competencies. The process dimension emerged as the most dominant, indicating that most studies emphasized the development of 21st-century competencies, such as collaboration, communication, and iterative problem-solving. In practice, this dimension is reflected in students' work traces, from the planning stage and gradual project development to critical reflection on the solutions produced. This shows that technology in parabolic motion learning is widely used to facilitate creative thinking and dynamic problem solving.

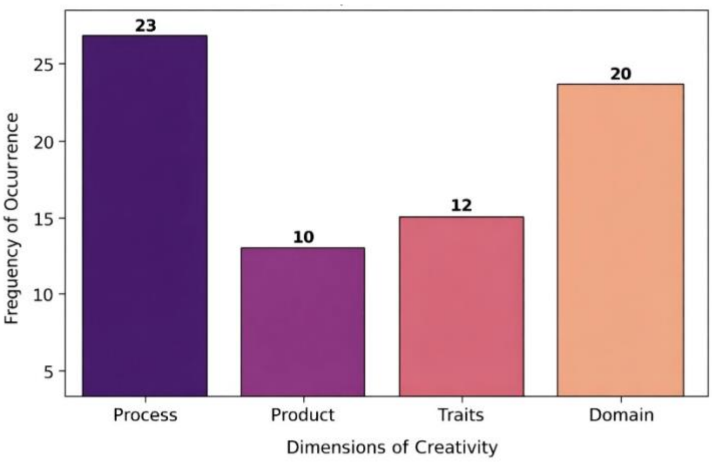

Figure 4. *Learning outcome distribution*

The domain dimension ranks second and reflects a strong command of concepts specific to a particular field of study. In this dimension, learning outcomes often manifest as creative mathematical reasoning and the application of distinctive initial strategies in programming or STEM practices. For example, the use of STEM software or educational robotics encourages students to test trajectory strategies, make predictions, and modify system behavior in accordance with the principles of parabolic motion. Thus, the domain dimension acts as a bridge between academic mastery and practical creative application.

Conversely, the dimensions of individual and product characteristics showed lower frequencies. The low findings on the individual characteristics dimension reflect the challenge of quantitatively measuring creativity as a personal trait, although some studies have begun to develop more concrete assessment indicators (Chen et al., 2023). As for the product dimension, which ranked lowest, it shows that achievements in the form of functional artifacts, such as program code or parabolic motion solutions using GeoGebra, are still viewed as complementary to the depth of the exploration and problem-solving process (Aslan & Buyuk, 2021).

Overall, the distribution of learning outcomes confirms that technology-based parabolic motion learning emphasizes the dynamics of the learning process and mastery of knowledge domains rather than simply assessing final products or individual characteristics separately.

5. Discussion

5.1. Interpretation of Findings

A literature synthesis indicates that technology-based parabolic motion learning in physics education has developed through three main approaches, namely the core approach, the contextual approach, and other approaches that are still developing. These three approaches demonstrate that technology plays a role that goes beyond visualization; it is also a tool for developing conceptual understanding, critical thinking skills, and the relationship between physics concepts and real-world events.

The core approach has become a widely recognized method, mainly through the use of interactive simulations and computational modeling such as PhET, GeoGebra, Algodoo, Scratch, and worksheets. The power of this technology is evident, as simulations provide dynamic representations that support students in systematically investigating relationships among parabolic motion variables. These results are consistent with previous research showing that dynamic visualization and parameter adjustment are effective in addressing misconceptions and improving students' conceptual understanding and representation skills in two-dimensional motion (Aslan & Buyuk, 2021; Astra & Kartini, 2023; Liu et al., 2025).

The contextual approach demonstrates the role of technology as a bridge between abstract ideas of parabolic motion and students' real-world experiences. The integration of real-world contexts and local culture, such as analyzing basketball throws, activities using video trackers, and specific cultural phenomena, enables students to develop a deeper understanding. These findings reinforce the view that context-based learning not only influences cognitive aspects but also increases student participation and motivation to learn. In this way, these SLR findings expand on previous research that has typically emphasized the cognitive effectiveness of technology, highlighting the significance of affective and contextual dimensions in physics learning (Azhar et al., 2021; Nasbey et al., 2024; Supriyanto, 2021).

Other emerging approaches, such as virtual reality, serious games, interactive motion graphics, and simulation-based vodcasts, still have relatively few studies. However, research shows that these approaches have great potential to create an exciting learning atmosphere and encourage active student participation. This indicates a shift in the role of technology from a mere auxiliary medium to a learning environment that supports more intensive exploration and interaction. These findings enrich the existing literature, which generally continues to view technology as a supporting tool in physics education (Taufiq et al., 2024; Villada Castillo et al., 2025).

Overall, this systematic literature review demonstrates its strength in describing the main patterns of technology use, learning approaches, and learning outcomes in parabolic motion learning. By classifying the findings into core, contextual, and emerging approaches, this study not only summarizes existing trends but also provides a conceptual framework for further learning and research. The consistent correlation between visual and simulation technologies, contextual approaches, and the reinforcement of creative and conceptual thinking processes indicates that technology-based parabolic motion learning has evolved into a more meaningful practice relevant to the demands of 21st-century learning.

5.2. Practical Implications and Research Development Directions

The results of this literature synthesis have important implications for physics education practice, particularly for technology-based learning of parabolic motion. The findings show that the effectiveness of technology use is not determined by its technical sophistication, but rather by the suitability of the technology, learning objectives, and pedagogical approach. Therefore, educators need to prioritize the pedagogical function of technology, especially in supporting students' conceptual understanding and reasoning processes. Various studies show that simulations and modeling are most effective when used in inquiry-based learning or problem-solving that requires active student involvement (Chin et al., 2016; Liu et al., 2025).

In addition, the dominance of the contextual approach emphasizes that physics learning can be more meaningful when technology is integrated with everyday phenomena and familiar cultural contexts for students. In the context of parabolic motion, the practical implication is the need to strengthen the use of visual media, especially videos, in the development of teaching materials. Videos allow for the representation of parabolic motion, which is easily observed in everyday activities such as throwing a ball or moving objects, thereby helping students connect abstract concepts with real experiences. The integration of this real-world context has been shown to increase student motivation and engagement in learning (Azhar et al., 2021; Nasbey et al., 2024).

Furthermore, the study's results show that student creativity develops more in the process and domain dimensions, while creative products are still relatively rarely reported as learning outcomes. In fact, the characteristics of parabolic motion, which are easy to visualize and commonly found in everyday life, offer great opportunities for developing creative products, such as target-throwing games, basketball-throwing simulations, or simple design-based projects. These findings indicate a gap in research and practice that warrants further development, given that the literature explicitly exploring creative products in parabolic motion learning remains limited (Taufiq et al., 2024; Wijayanti et al., 2025).

From a research perspective, this study also reveals that HOTS and computational competence have not been widely formulated as explicit learning objectives, even though the technology used has great potential to support modeling, data analysis, and computational reasoning. Therefore, further research is needed to design technology-based parabolic motion learning that consciously targets the development of these skills, and to examine its long-term impact on concept transfer and problem-solving across physics topics. The integration of new technologies, such as virtual reality and serious games, also needs to be tested on a larger scale in the classroom to strengthen their contribution to meaningful physics learning relevant to the demands of the 21st century.

5.3. Research Limitations

This systematic literature review has several limitations. The scope of the study is limited to articles that explicitly discuss technology-based parabolic motion learning in physics education, thereby excluding relevant studies discussed in the context of more general kinematics or mechanics. Furthermore, this study used only the Scopus and ERIC databases, restricted to English-language articles, and limited to full-text access and a specific time frame, potentially limiting the completeness of the literature reviewed. The diversity of research designs, educational contexts, and learning outcome indicators in the reviewed studies also limited the possibility of conducting a meta-quantitative analysis, so that the synthesis of findings was carried out descriptively and interpretively. Finally, this study relied entirely on the results reported by the original authors, making it impossible to directly evaluate learning effectiveness and potentially subject to publication bias.

6. Conclusion

This systematic literature review aims to map and synthesize the latest research findings on the use of technology and learning approaches in teaching parabolic motion in physics education. Based on an analysis of 26 studies, the most dominant technologies were visual and simulation media, particularly instructional videos and interactive simulations. These findings indicate that the effectiveness of technology-based parabolic motion learning is not determined by a particular technology, but rather by how it is integrated into the learning design.

The study's results also show that the learning approaches used can be grouped into three main trends: core, contextual, and emerging. The core approach relies on simulations and modeling to strengthen conceptual understanding and mathematical representation. The contextual approach has emerged as a strong trend by linking technology to everyday phenomena and cultural contexts, thereby helping students build a more meaningful understanding. Meanwhile, emerging approaches, such as virtual reality and serious games, are still relatively limited in the number of studies but show potential to increase student engagement in learning.

In terms of learning outcomes, the dominant findings show that conceptual understanding and creativity in the process dimension and domain are most frequently reported, while creative product development and computational skills are still relatively rarely the main focus. This indicates an opportunity to develop parabolic motion learning towards more productive activities oriented towards creating artifacts or creative projects, given the material's characteristics, which are close to everyday life and easy to visualize.

Overall, this conclusion confirms that effective technology-based parabolic motion learning is characterized by alignment between learning objectives, pedagogical approaches, and technological functions. These findings provide a conceptual basis for educators and researchers to design more focused, contextual, and relevant parabolic motion learning that meets the demands of 21st-century physics education, as well as opening up space for further research related to the development of computational skills and creative products in physics education.

Authors Contribution

Diyah Ayu Kuntari: Conceptualization, Methodology, Analysis, Writing – original draft, Writing – review & editing. **Sigit Ristanto:** Conceptualization, Methodology, Data curation, Writing – review & editing. **Joko Siswanto:** Validation, Supervision, Writing – review & editing. **Wawan Kurniawan:** Conceptualization, Supervision, Writing – review & editing. All authors have read and approved the final version of the manuscript and the order of authorship.

Ethical statement

This study is a systematic literature review using secondary data from published scientific articles, thus not directly involving human or animal participants. Therefore, approval from an ethics committee is not required. The entire review process was conducted in accordance with the principles of academic honesty, scientific integrity, and compliance with the rules of scientific publication ethics.

Declaration of AI use

The authors used ChatGPT for language editing purposes, including improving clarity, readability, and overall writing quality. The use of these tools was limited to linguistic support and did not involve data analysis, interpretation of results, or generation of scientific content. All AI-assisted outputs were carefully reviewed and revised by the authors, who remain fully responsible for the accuracy, originality, and integrity of the final manuscript

Conflict of Interest

The authors declare that there are no conflicts of interest, either financial or non-financial, that could influence the writing, assessment, or interpretation of the results of this study. All authors have reviewed and approved this statement.

Supplementary Materials and Data Availability

The data used in this study were obtained from scientific articles that were published openly and accessible through relevant journal databases. The list of articles analyzed and the study selection flow

(PRISMA diagram) are presented in the article. There is no additional raw data beyond what is included in this article.

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Appendix

Table 1. *Data extraction.*

Author	Educational Level	Technology Type	Research Design	Learning Approach	Creativity Dimensions C1	C2	C3	C4
Bachtiar et al., (2021)	High School Students	Perangkat Lunak Animasi Stop-Motion	Qualitative Case Study	LA1	1	1	1	1
(Anggraini et al., 2018)	High School Students	Multimedia-based digital learning tools	R&D (4-D)	LA3	1	0	1	1
Aslan & Buyuk, 2021	Higher Education Institution	Geogebra, Animasi Simulasi Phet	Quantitative Semi-Experimental Design	LA2	1	1	0	1
Astra & Kartini, 2023.	High School Students	Simulasi Phet	R&D (4-D)	LA2	0	0	1	1
(Azhar et al., 2021)	High School Students	Video-based motion analysis tools)	Descriptive Experimental Research	LA2	0	0	0	0
(Celestino-Salcedo et al., 2024)	High School Students	Simulation-based digital learning tools	Development Research Design	LA2	1	0	0	1
(Chin et al., 2016)	High School Students	Simulasi Phet	Quasi-Experimental	LA1	1	1	0	1
Chinaka, 2021	Higher Education Institution	Simulasi Phet	Quasi-Experimental, Mixed Methods	LA1	1	0	0	1
Delubom & Tatira, 2025	High School Students	Simulasi Phet	Qualitative with Phenomenological Design	LA1	1	0	1	1
(Dewi et al., 2023)	Perguruan Tinggi	Web-based digital learning tools	R&D (4-D)	LA1	1	1	0	0
(Dramae et al., 2017)	High School Students	Gambar Dan Film	Learning Method Through Movie Scenes	LA2	1	0	0	1
(Fitri et al., 2019)	High School Students	Digital practicum tools	R&D (4-D)	LA1	1	0	1	
Halim & Hamid, 2021	Higher Education Institution	Geogebra, Animasi Simulasi Phet	Reference Analysis	LA2	1	1	0	1
(Handayani et al., 2016)	Higher Education Institution	Perangkat Lunak Analisis Video	Quasi-Experimental	LA2	1	0	0	0
(Abdillah et al., 2021)	High School Students	Computer-Based Assessment (Formative)	Mixed Methods with Embedded Experimental Design	LA2	1	0	0	1
(la Aca et al., 2020)	High School Students	Video-based learning (Lightboard)	R&D (4-D)	LA2	1	1	1	0
Lestari & Mansyur, 2021	High School Students	Simulasi Phet	Quasi-Experimental Research with Pre-Post-Test Control Group Design	LA2	0	0	1	1
(Liu et al., 2025)	Higher Education Institution	Simulasi Phet	Qualitative With Phenomenological Design	LA2	1	0	0	1
(Nasbey et al., 2024)	High School Students	Video-based and digital learning tools	R&D (4-D)	LA2	1	1	1	1
Raras & Kuswanto, 2019	High School Students	Media Pembelajaran Berbantuan Android	R&D (4-D)	LA2	0	0	1	1
Saputra & Kuswanto, 2018	High School Students	Aplikasi Pembelajaran Seluler Android, Adobe Animate, Coreldraw X7	R&D (4-D)	LA2	1	1	1	0
(Siswanto et al., 2025)	Higher Education Institution	Simulasi Algodo	One-Group Pre-Test and Post-Test Pre-Experimental Design	LA2	1	1	0	0
Supriyanto, 2021	High School Students	Pelacak Video	One Group Pretest Posttest Design	LA2	1	0	0	1
(Taufiq et al., 2024)	Higher Education Institution	Program Scratch	Design-Based Research (Modified Waterfall Model)	LA2	1	1	1	1
(Villada Castillo et al., 2025)	Higher Education Institution	Realitas Virtual Immersif (Ivr	Single Case Experimental Design	LA2	1	0	1	1
(Wijayanti et al., 2025)	General Students	Computational and data analysis tools	Qualitative description with an ethnographic approach	LA1	1	0	0	1

Dimensions of creativity consist of four aspects: process (C1), product (C2), characteristics (C3), and domain (C4).