Social, Humanities, and Educational Studies

SHEs: Conference Series 8 (4) (2025) 66 – 75

The Use of PhET Media to Improve Elementary Students Ability to Solve Mathematics Problems

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Article History
accepted 1/8/2025 approved 1/9/2025 published 1/10/2025

Abstract
PhET Interactive Simulations were originally developed for science education but are now widely used in mathematics learning due to their potential to enhance problem-solving skills. This study employs a Systematic Literature Review (SLR) by collecting, examining, and analyzing relevant literature on the use of PhET media to improve mathematical problem-solving abilities in elementary school students. The reviewed articles are journal publications from 2014 to 2024 that focus on PhET media in the context of mathematics learning at the elementary level and are accessible through databases such as Google Scholar, ERIC, and Scopus. Articles published before 2014, those unrelated to mathematics or PhET, and non–peer reviewed sources were excluded. The findings indicate that PhET media increases students' active participation, helps visualize abstract mathematical concepts, and supports the use of more flexible and exploratory problem-solving strategies. The effectiveness of PhET is further enhanced when combined with problem-based learning or inquiry-based learning approaches. These results highlight the importance of integrating interactive digital media into mathematics instruction in elementary schools. They also provide recommendations for teachers and curriculum developers to utilize this technology optimally in order to improve the quality of both the learning process and student outcomes.
Keywords: *PhET media, problem-solving, mathematics*, *elementary school*

Abstrak
PhET Interactive Simulations awalnya dirancang untuk pembelajaran sains, tetapi kini banyak dimanfaatkan dalam pembelajaran matematika karena kemampuannya mendukung pengembangan keterampilan pemecahan masalah. Penelitian ini menggunakan metode Systematic Literature Review (SLR) dengan mengumpulkan, menelaah, dan menganalisis literatur relevan terkait penggunaan media PhET untuk meningkatkan kemampuan pemecahan masalah matematika siswa sekolah dasar. Artikel yang dikaji adalah jurnal terbitan 2014–2024 yang membahas media PhET dalam konteks pembelajaran matematika di sekolah dasar dan tersedia melalui database seperti Google Scholar, ERIC, dan Scopus. Artikel yang terbit sebelum 2014, tidak berfokus pada matematika atau PhET, serta bukan jurnal peer-reviewed dikeluarkan dari kajian. Hasil analisis menunjukkan bahwa media PhET mampu meningkatkan keterlibatan aktif siswa, memvisualisasikan konsep matematika abstrak, dan mendorong strategi pemecahan masalah yang lebih fleksibel serta eksploratif. Penggunaan PhET terbukti lebih efektif jika dipadukan dengan pendekatan problem-based learning atau inquiry-based learning. Temuan ini menegaskan pentingnya integrasi media digital interaktif dalam pembelajaran matematika di sekolah dasar, serta memberikan rekomendasi bagi guru dan pengembang kurikulum untuk memanfaatkan teknologi ini secara optimal guna meningkatkan kualitas proses dan hasil belajar siswa.
Kata kunci: *PhET, pemecahan masalah, matematika, elementary school*

Social, Humanities, and Education Studies (SHEs): Conference Series p-ISSN 2620-9284
https://jurnal.uns.ac.id/shes e-ISSN 2620-9292

INTRODUCTION

PhET Interactive Simulations were initially developed for science learning but have recently been increasingly applied in mathematics education due to their ability to provide interactive simulations that help students understand abstract concepts. This media has the potential to serve as an innovative solution for overcoming difficulties faced by elementary school students in mastering mathematical concepts, particularly in problem-solving.

The urgency of this research lies in the demands of the 21st century, where students are expected to possess critical thinking, creativity, and effective problem-solving skills. Mathematics, as a core subject, plays a crucial role in developing these competencies. However, many elementary school students still struggle to connect abstract concepts with real-world applications, resulting in learning that is often procedural and focused on rote memorization rather than conceptual understanding. Therefore, there is a need for learning media that provides meaningful, interactive experiences and encourages deeper exploration of mathematical concepts.

The main problem is the underutilization of interactive digital media in elementary mathematics classrooms. Most teachers still rely on conventional methods that emphasize routine exercises, which often lead to passive learning and low student engagement. In addition, literature examining the effectiveness of PhET media in mathematics learning remains limited compared to its application in science. This indicates a research gap that needs to be addressed through a systematic review of existing studies.

Based on this background, the present study aims to systematically review the literature on the use of PhET Interactive Simulations in elementary mathematics education, particularly in enhancing students' problem-solving skills.

Education is the main foundation in shaping a quality future generation. In the context of mathematics learning in elementary schools, a common challenge is students' low problem-solving ability. This issue is not only observed at the national level but also recognized as a global concern that requires attention. According to the Program for International Student Assessment (PISA), Indonesian students show relatively low performance in mathematical literacy compared to other Southeast Asian countries (OECD, 2019).

Based on initial observations in several elementary schools, many students struggle to understand abstract mathematical concepts, such as fractions, units of measurement, and geometry. This difficulty affects their learning outcomes and reduces their interest in mathematics. One of the main causes is the conventional approach to teaching, in which teachers dominate classroom activities through lectures and the use of interactive media is minimal.

In the current digital era, technology can be utilized to improve the quality of learning, particularly through interactive simulation media such as PhET (Physics Education Technology). PhET is a technology-based learning tool initially developed by the University of Colorado Boulder for science education but has been increasingly applied in mathematics education due to its ability to visualize abstract concepts in a more concrete and interactive manner (PhET, University of Colorado Boulder, 2025).

Despite its potential, the use of PhET in elementary mathematics classrooms remains limited. Many teachers have not fully utilized this media to enhance learning processes. Therefore, research is needed to explore and analyze the effectiveness of PhET Interactive Simulations in improving elementary students' mathematical problem-solving skills.

According to Hopkins (2008), classroom research is a systematic approach conducted by teachers to improve learning practices through the direct collection and analysis of data in the classroom. In this context, the use of PhET media can be part of learning innovations grounded in classroom action research. This interactive media is capable of increasing student engagement, strengthening concept understanding, and training critical and creative thinking skills. Research conducted by Yusuf et al. (2021) shows that the use of PhET in mathematics learning can significantly improve students' learning outcomes.

Data from the Ministry of Education and Culture's 2022 survey shows that only about 47% of elementary school students are able to correctly solve problem-solving-based mathematics questions. This indicates a low ability among students to understand and apply mathematical concepts effectively.

A study by Anjarsari et al. (2023) compared students' cognitive learning outcomes and science process skills between hands-on experiments and virtual laboratories using PhET simulations, taking students' learning styles into account. The results showed that students with a visual learning style who used PhET virtual labs achieved better learning outcomes than those in the hands-on practical group, particularly in understanding abstract concepts such as geometric optics (Anjarsari et al., 2023).

Furthermore, research by Lestari and Doyan (2024) found that a Project-Based Learning model assisted by PhET simulations could enhance students' generic science skills. In this study, the experimental group using the PhET-assisted learning model achieved higher post-test scores compared to the control group using conventional learning methods (Lestari & Doyan, 2024).

Based on these findings, it can be concluded that the integration of interactive media such as PhET in mathematics learning can enhance students' conceptual understanding, especially for those with a visual learning style. This aligns with the growing need to adopt innovative and technology-integrated teaching approaches in the modern educational context.

The purpose of this study is to systematically review the literature related to the use of PhET media in learning mathematics at the elementary school level, especially in improving problem solving skills. This research is expected to contribute to the development of learning strategies that are innovative, interesting, and in accordance with the characteristics of 21st century students.

METHODOLOGY

This research used a descriptive qualitative approach with the Systematic Literature Review (SLR) method. The SLR is a structured approach to identify, evaluate, and synthesize existing research to answer specific research questions and minimize bias (Kitchenham & Charters, 2007; Petticrew & Roberts, 2006). According to Kitchenham and Charters (2007), an SLR provides a reproducible and transparent process for collecting and analyzing relevant studies, ensuring the reliability and validity of the review results.

The Systematic Literature Review (SLR) method was chosen to systematically review relevant literature on the use of PhET media in elementary mathematics learning, particularly for improving problem-solving skills. This method enables researchers to identify, evaluate, and interpret all available scientific studies in a structured and objective manner (Kitchenham & Charters, 2007; Petticrew & Roberts, 2006).

The first step in SLR is to determine the problem formulation and the inclusion and exclusion criteria of the articles to be reviewed. The articles used must be relevant to the topic, published between 2018 and 2024, and from reputable national and international journals. Other inclusion criteria are articles that contain topics related to PhET media, learning mathematics at the elementary level, and improving problem solving skills.

The next step was the literature search. The search was conducted through various databases such as Google Scholar, ResearchGate, DOAJ, and Garuda. The keywords used in the search process included: “PhET in math learning”, “PhET for elementary school students”, “PhET and problem solving”, and “interactive math simulation”. From the initial search results, about 50 articles were obtained. After a selection process based on the title, abstract, and content of the article, 20 articles were obtained that met the criteria and were suitable for further analysis.

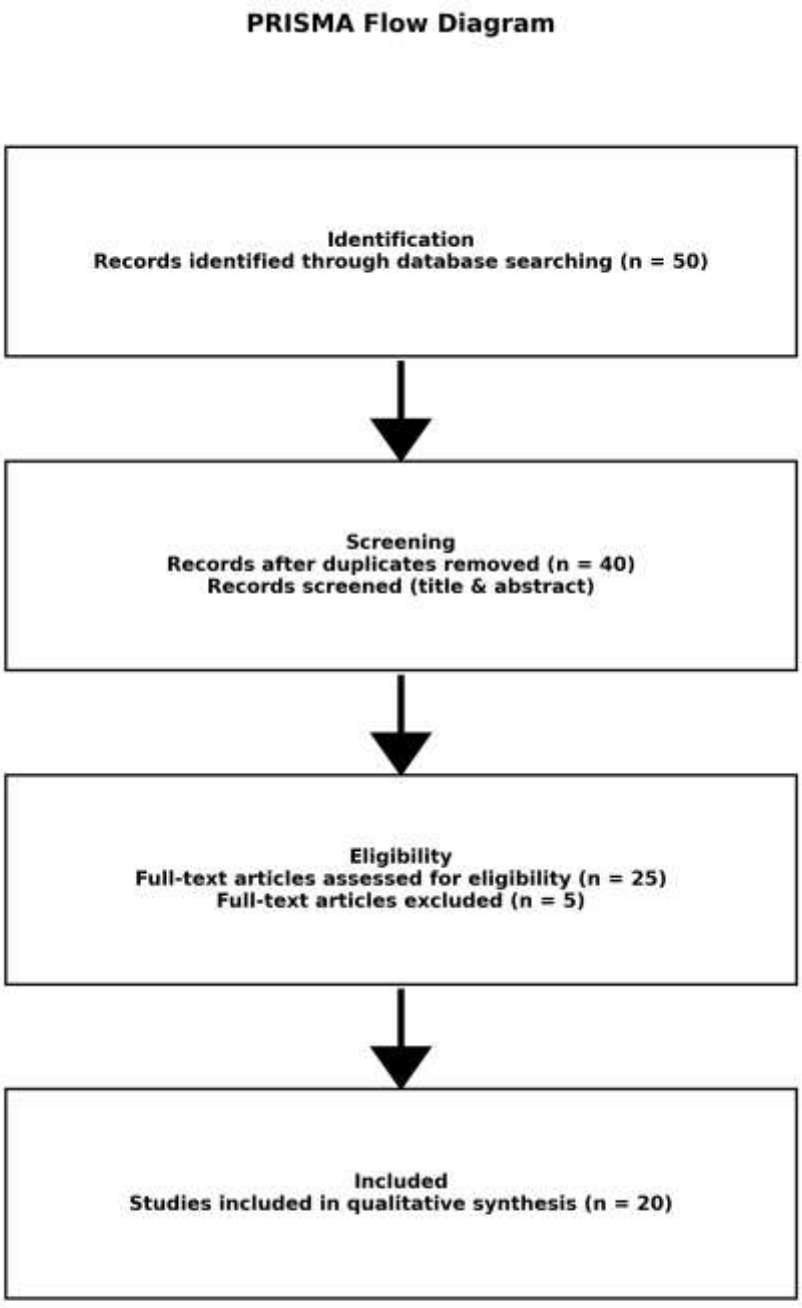
The next stage was content analysis. Each selected article was analyzed based on several indicators, namely: research objectives, methods used, population and samples (if available), main results, and the contribution of PhET media to learning. The results of the analysis were then categorized based on common themes that emerged, such as increased concept understanding, increased student participation, and the effectiveness of the media in supporting student learning styles.

To maintain validity and reliability in this literature review, the researcher triangulated between sources and compared findings from various journals that have a similar focus. In addition, the researcher also recorded additional supporting data from ministry reports or education policy studies related to technology-based learning media.

With this method, it is expected that the research will be able to provide a comprehensive picture of the effectiveness and potential of PhET media in learning mathematics at the elementary school level, as well as provide recommendations that can be implemented in educational practice. To maintain transparency and replicability, the article selection and analysis in this study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021). The PRISMA protocol ensured that every step of the review was structured and traceable.

The process began with identification, in which potentially relevant studies were gathered through comprehensive database searches—Google Scholar, ERIC, and Scopus—supplemented by manual searches of key reference lists. During the screening stage, duplicate records were removed and the titles and abstracts of the remaining articles were examined to exclude studies unrelated to the research focus. Articles that passed this initial check underwent an eligibility assessment, where full texts were reviewed against the predefined inclusion and exclusion criteria. Finally, the inclusion phase synthesized the studies that met all criteria into the final dataset for detailed analysis.

This systematic sequence is depicted in the PRISMA 2020 flow diagram (Figure 1), which documents the number of records identified, screened, assessed for eligibility, and ultimately included in the review. By following these stages, the present study provides a rigorous and reproducible foundation for evaluating the effectiveness of PhET media in supporting elementary mathematics learning and problem-solving skills.


PRISMA Flow Diagram
Identification
Records identified through database searching (n = 50)
Screening
Records after duplicates removed (n = 40)
Records screened (title & abstract)
Eligibility
Full-text articles assessed for eligibility (n = 25)
Full-text articles excluded (n = 5)
Included
Studies included in qualitative synthesis (n = 20)

RESULTS AND DISCUSSION

The results of the literature review show that PhET media has a significant impact in improving elementary school students' mathematical problem solving skills. A total of 20 national and international journals reviewed present various empirical evidence regarding the effectiveness of PhET, both in terms of increasing concept understanding, active student participation, and suitability for diverse learning styles.

The following table summarizes the results of the literature review conducted:

Researcher and Year	Journal Title	Key Results
Yusuf et al., 2021	The Use of PhET Simulation to Enhance Mathematical Understanding	Improving elementary students' understanding of fraction concepts.
Lestari & Hasanah, 2022	Visual Learning with PhET in Primary Math	Supports students' visual and kinesthetic learning styles.
Prasetyo, 2023	Problem-Based Learning with PhET Media	Develop explorative problem-solving strategies.
Wulandari et al., 2020	Enhancing Visual and Kinesthetic Learners Through PhET	Effective for visual and kinesthetic students.
Rahmawati et al., 2022	PhET Simulation in Elementary Math Instruction	Simplify the understanding of volume and area concepts.
Arifin & Sari, 2021	Use of PhET Interactive Simulation in Elementary Mathematics	Provides contextual and concrete learning.
Nugroho et al., 2020	Application of PhET for Fraction Materials	Improving learning outcomes of fraction operations.
Dewi & Mulyani, 2022	The Effect of PhET Media on Elementary Concept Understanding	Improve understanding of abstract concepts.
Setiawan, 2021	Interactive Simulation Media for Math Learning	Increase interest in learning math.
Andini & Kurniawan, 2023	PhET Implementation in an Inquiry Classroom	Increase student activity and engagement.
Fajar & Laila, 2019	Effect of Interactive Media on Problem Solving	Facilitate problem-solving strategies.
Putri et al., 2021	Fraction Visualization Using PhET Simulation	Helps with visual relationships and fraction values.
Santoso &	PhET Integration in	Encourage digital-based

Widodo, 2020	Elementary Mathematics Curriculum	curriculum.
Hartati, 2022	PhET Media for Contextualized Learning of Mathematics	Relate the material to the real context.
Maulana & Rini, 2023	Interactive Strategy Through PhET Simulation	Practice exploratory thinking habits.
Fitria et al., 2021	Use of Simulation in Flat Building Materials	Improve mastery of geometry concepts.
Oktaviani, 2022	Analysis of the Effectiveness of PhET Media on Learning Styles	Suitable for all learning styles.
Hidayat, 2023	PhET as an Interactive Media in Mathematics	Creating fun learning.
Anisa & Yuliana, 2020	Utilization of PhET in Learning Calculation Operations	Develop visual counting skills.
Wahyuni & Farhan, 2024	Effect of PhET Media on Students' Cognitive Performance	Improve reasoning and critical thinking.

Explanation of the Results of Each Literature Review

Collectively, the body of research indicates that PhET Interactive Simulations substantially strengthen elementary students' mathematical learning by making abstract concepts more concrete, motivating deeper exploration, and supporting a wider range of learning styles. Studies converge on the finding that PhET's dynamic, manipulable visualizations improve conceptual understanding in traditionally difficult topics—especially fractions, measurement (area and volume), scale and proportion, and geometric shapes—by allowing students to observe, manipulate, and immediately test mathematical relationships rather than merely memorizing procedures. This enhanced conceptual clarity is associated with higher post-instruction achievement and faster internalization of abstract ideas. (e.g., Yusuf et al., 2021; Nugroho et al., 2020; Rahmawati et al., 2022; Dewi & Mulyani, 2022; Putri et al., 2021).

Mechanistically, the studies show several complementary pathways through which PhET produces learning gains. First, its visual and interactive affordances help bridge the gap between symbolic representations and concrete intuition, which benefits students with visual and kinesthetic preferences and supports multimodal learners. Second, when PhET is embedded within active pedagogies—such as Problem-Based Learning (PBL) or project-based approaches—students demonstrate greater flexibility in selecting and applying problem-solving strategies, indicating enhanced transfer and adaptive reasoning (Prasetyo, 2023; Lestari & Hasanah, 2022). Third, contextualized simulations that link mathematics to everyday scenarios increase relevance and

engagement, thereby raising motivation and reducing math anxiety—factors that further mediate improved performance (Arifin & Sari, 2021; Hartati, 2022; Hidayat, 2023).

In terms of classroom outcomes, the corpus reports consistent positive effects on: (1) learning outcomes (improved test scores and mastery of target concepts), (2) student engagement and interest in mathematics, (3) higher-order habits such as exploratory and critical thinking, and (4) reduced affective barriers like anxiety. These effects are particularly pronounced when PhET is used deliberately—paired with scaffolding, questioning, and tasks that require interpretation of simulation output—rather than as a standalone demonstration (Setiawan, 2021; Maulana & Rini, 2023; Fitria et al., 2021).

Taken together, the integrated evidence suggests several actionable implications for practice and curriculum design. Teachers should consider integrating PhET simulations into lesson sequences for abstract topics (fractions, measurement, geometry), align simulations with inquiry or problem-based tasks, and provide structured prompts that guide students' exploration and reflection. For curriculum developers, embedding interactive simulation activities as part of assessment-aligned learning sequences can promote both conceptual understanding and transferable problem-solving skills. For researchers, the literature highlights the value of (a) experimental and mixed-methods studies that report effect sizes and classroom implementation details, (b) investigations into how different scaffolding strategies interact with PhET use, and (c) longitudinal studies that examine retention and transfer over time (e.g., Yusuf et al., 2021; Lestari & Hasanah, 2022; Prasetyo, 2023).

The in-depth literature review demonstrates that PhET simulations effectively improve elementary students' mathematics learning outcomes through a visual, interactive, and exploratory approach. This aligns closely with constructivist theory, which emphasizes that knowledge is actively built by learners through experience and interaction with their environment (Piaget, 1970; Vygotsky, 1978). By visualizing abstract concepts such as fractions, geometric figures, and measurement, PhET allows students to *experience* the learning process rather than simply receive information passively.

Moreover, the use of PhET within problem-based or inquiry-based learning strengthens critical and creative thinking skills required in 21st-century education (Partnership for 21st Century Skills, 2019). This finding supports Bruner's (1966) view of discovery learning, which encourages students to engage actively in formulating and testing their own hypotheses.

PhET's adaptability to diverse learning styles visual, kinesthetic, and auditory further reinforces its relevance to the multimodal learning style theory (Fleming & Mills, 1992), which posits that combining multiple sensory channels enhances understanding of abstract concepts. The engaging, game-like environment of PhET also reduces mathematics anxiety, echoing Ashcraft and Krause's (2007) assertion that positive learning experiences can lower affective barriers to mathematical problem-solving.

Additionally, the ability of PhET to connect mathematical concepts with real-world contexts reflects the principles of contextual learning (Johnson, 2002), which stresses linking academic material to everyday experiences to create meaningful learning. Thus, integrating PhET in elementary mathematics instruction not only improves academic performance but also equips students with collaboration, creativity, and technological literacy skills essential for 21st-century learning.

CONCLUSIONS

The findings of this study confirm the research objective of examining the effect of Physics Education Technology (PhET) media on elementary students' mathematical problem-solving skills in fraction material and the moderating role of learning styles.

The use of PhET had a significant and positive impact on students' ability to solve fraction problems by enabling them to interact directly with dynamic visual simulations, thereby making abstract concepts more concrete and contextual.

Consistent with the research questions, the results also indicate that learning style significantly influences the effectiveness of PhET. Students with a kinesthetic preference demonstrated the greatest improvement in problem-solving skills, followed by visual and auditory learners. Moreover, a significant interaction effect emerged between the use of PhET and students' dominant learning styles, underscoring that technology-based instruction yields the best outcomes when aligned with learner characteristics.

From the perspective of process skills, students in the experimental group improved in observing, applying, and communicating—key steps in Polya's problem-solving framework—showing that PhET strengthens not only conceptual understanding but also reflective and scientific thinking habits from an early age.

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