Private Social Sciences Journal
E-ISSN 2798-6314
P-ISSN 2798-866X
https://doi.org/10.55942/pssj.v5i12.1073

Volume 5
Issue 12
December Edition 2025

The effect of using PhET simulation media on energy and work materials on improving students' learning outcomes and critical thinking skills: A literature study

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Received 17 November 2025
Revised 31 December 2025
Accepted 31 December 2025

ABSTRACT

Physics education depends on work and energy concepts because they enable students to understand the natural events and technological systems. Students face challenges when learning these concepts because they exist at an abstract level and require a complex understanding while facing restrictions from limited resources and traditional teaching approaches. Students who study energy and work face poor learning results because they lack motivation and critical-thinking abilities. Research from 15 recent academic journals shows that digital education advancements have led to the development of multiple interactive learning tools, including the Physics Education Technology (PhET) Simulation. The implementation of Physics Education Technology (PhET) simulation media has demonstrated successful solutions to overcome learning challenges. The interactive visualizations in PhET media enable students to explore concepts independently, which leads to a better understanding of subjects, improved cognitive, affective, and psychomotor learning results, enhanced critical thinking abilities, and improved scientific literacy. The combination of PhET media with innovative learning approaches, including guided inquiry, problem-based learning, and blended learning, enhances student learning effectiveness for energy and work subjects. The PhET simulation platform functions as an optimal educational resource that enhances physics education quality, specifically for energy and work subjects, to help students reach their best learning potential and develop critical thinking abilities at different educational levels.

Keywords: PhET Simulation, Energy and Work, Learning Outcomes, Critical Thinking, Learning Media

1. INTRODUCTION

The Physics curriculum depends on Work and Energy as fundamental concepts that enable students to understand other scientific subjects. Students face major obstacles when attempting to understand this fundamental concept. Students face their biggest challenge when they attempt to connect abstract physics formulas to actual physical events in the real world (Subiki et al., 2022). Students need to develop their visualization abilities and reasoning skills to understand energy transfer and force work because traditional teaching methods fail to deliver these skills (Salam, 2024). The current educational environment demands investment in learning materials which develop both subject knowledge and practical competencies.

The educational world has experienced major transformations because of information and communication technology advancements which now support digital interactive learning for physics education that includes abstract subjects like energy and work. The traditional teacher-led approach to physics education leads students to become passive learners who struggle with understanding the taught material. The interactive learning platform PhET (Physics Education Technology) simulations helps students overcome their learning barriers (Ridwan et al., 2021). Students can use these interactive simulations to modify physics variables which produce dynamic visual outputs. Research studies have evaluated PhET media effectiveness for enhancing student achievement and critical thinking abilities in energy and work subjects (Fadilah et al., 2024). This review examines all available research about PhET simulation effects on student learning of energy and work concepts.

The use of appropriate media, especially in subjects that rely heavily on visualization such as Natural and Social Sciences (IPAS), is crucial to help students understand the material optimally. Appropriate media can facilitate teachers in delivering material and provide an engaging and enjoyable learning experience for students. Interactive simulation media combines visual, audio, and interactivity elements to create a more engaging teaching and learning experience. In an educational context, learning using interactive simulations allows students to learn through exploration, thereby enhancing their understanding of complex learning content. Research by (Wahidin, 2025) shows that interactive learning can facilitate understanding of concepts and increase student engagement due to its visual and engaging nature.

Based on this description, this study was conducted to determine the effect of using PhET simulation media on student learning outcomes in the IPA lesson with the topic of work and energy which includes basic concepts of energy, various forms of energy (electricity, heat, light), changes in energy forms, kinetic and potential energy, and the use of energy in everyday life. The concept of "work" is generally defined as the ability to perform work or move objects using force. The results of this study are expected to serve as a reference for educators in selecting more innovative and effective learning media in the future.

2. LITERATURE REVIEW

2.1. PhET Simulation as a Learning Medium

PhET (Physics Education Technology) simulation is an interactive learning and teaching medium geared toward assisting learners in grasping and comprehending the intricate and abstract concepts in physics through dynamic visualization and variable real-time manipulation. This technology aids and promotes independent investigation, modeling of physical processes, and visualization, which support the students in strengthening their understanding (Kurniawan et al., 2022; Subiki et al., 2022).

2.2. PhET in Energy and Work Learning

Energy and work PhET simulation it's important to learn about energy and work. Students should relate and integrate mathematical representations to physical phenomena; students need this skill. However, this is a common misconception among many students. This is the gap PhET simulations try to address by presenting an animation depicting the relationship energy changes, while also displaying the

forces, displacements, and graphs illustrating the energy interrelationships (Maharani et al., 2024). Research by Subiki et al., (2022) such a medium significantly increases understanding of energy work and concepts.

2.3. PhET in Developing Critical Thinking Skills

Apart from cognitive learning outcomes, PhET also developed the analytical thinking skills of learners. Using CLIS or PhET assisted curriculum, primary school learners' analytical skills on forms of energy were improved (Khusnandi et al., 2022). Similar results were found by Munif (2022), who noted that PhET facilitates an increase in scientific literacy and critical thinking skills through virtual experimentation. At the secondary school and tertiary level, problem-based learning and virtual lab applications through PhET enhance students' analysis abilities and scientific communication skills (Rasyidi et al., 2024).

3. METHODOLOGY

This study uses a literature review method by collecting and analyzing 15 relevant national scientific journals published between 2022 and 2024. The journals reviewed include quantitative research, quasi-experimental research, and classroom action research using PhET simulation media on energy and work topics, focusing on learning outcomes and critical thinking skills. Data were analyzed descriptively by comparing research results from each journal, which were then interpreted in depth to produce a comprehensive understanding of this topic.

4. RESULTAND DISCUSSION

The number of peer-reviewed scientific publications in journals based on research topics. The review was conducted to identify and analyze the effect of using PhET simulation media on energy and work materials on improving student learning outcomes and critical thinking skills.

Table 1. Results of a review of 15 journals

No	Authors & Year	Type of Research	Subjects	Material Focus	Main Findings	Conclusion
1	(Kurniawan et al., 2022)	R&D Quasi-Experiment	30 high school students	Energy and Work	Improvement in concept mastery, medium N-Gain (56%)	Quite effective
2	(Wahyuningsih & Pramasty, 2024)	Quasi-Experiment	50 elementary students	Energy Sources	Significant improvement in learning outcomes, t-count > t-table	Effective
3	(Suhardiman et al., 2022)	Meta-Analysis	19 articles (elementary to high school)	Various physics topics	Large effect at high school level, very large effect at junior high	Effective
4	(Subiki et al., 2022)	Experiment	29 high school students	Work and Energy	Average pre-post score difference of 9.28	Positive effect
5	(Salam, 2024)	Quasi-Experiment	60 high school students	Elasticity & Hooke's Law	N-Gain 64% (experiment) vs 50% (control)	Significant
6	(Khusnandi et al., 2022)	Collaborative Classroom Action	30 elementary students	Forms of Energy	Improved critical thinking skills	Improved
7	(Munif, 2022)	Qualitative	Elementary students	Energy and Its Changes	Improved critical thinking and scientific literacy	Positive
8	(Fatulloh, 2025)	Quasi-Experiment	20 elementary students	Energy Changes	Post-test scores increased by 39.8, significant	Positive effect

No	Authors & Year	Type of Research	Subjects	Material Focus	Main Findings	Conclusion
9	(Maharani et al., 2024)	Quasi-Experiment	31 high school students	Work and Energy	N-Gain 0.59 (experiment) vs 0.40 (control)	Influential
10	(Fitriyani & Cahyaningsih, 2023)	SLR (Systematic Literature Review)	15 elementary-level articles	General Physics	PhET proven effective at elementary level and higher levels	Feasible to use
11	(Rasyidi et al., 2024)	Quasi-Experiment	25 university students	Law of Conservation of Energy	SCS score 84.74% (experiment) > control	Very good
12	(Ginting & Sidabutar, 2022)	Development Research	32 junior high students	Energy and Its Changes	PhET-assisted worksheet, N-Gain 0.71	High
13	(Amin & Yuneti, 2024)	Quantitative Descriptive	University students	Energy Conversion (Mechanics)	Improved learning outcomes with an average score of 85 and 95% mastery	Positive
14	(Adi et al., 2025)	Quantitative Experiment	21 fourth-grade elementary students	Effect of force on objects (IPAS subject)	Improved learning outcomes: average pretest 45.23 → posttest 84.28; N-Gain 0.71 (high). t-test shows significant effect ($p = 0.000$).	Effective
15	(Putri, 2025)	Experiment	36 high school students	Physics Understanding	N-Gain 0.77, significant improvement in understanding	Positive

The research journals (Table 1) show that PhET creates positive learning outcomes for students who study Work and Energy. The research findings demonstrate that students achieve better results in their understanding of energy and work concepts and their ability to analyze and evaluate information. The research shows that PhET produces positive learning results for students at different educational levels. The educational tool helps students overcome their incorrect beliefs about how potential energy transforms into kinetic energy. Students can observe objects in motion while watching energy graphs through dynamic visual displays which makes it easier to understand than using formulas alone. The research evidence demonstrates that PhET media enhances student learning results and develops their critical thinking abilities (Kurniawan et al., 2022).

The journal also shows that the use of PhET media not only improves cognitive learning outcomes but also encourages students' critical thinking skills. For example, the research by (Maharani et al., 2024) and (Fatulloh, 2025) demonstrates that PhET media integration with Problem-Based Learning and Guided Inquiry active learning models leads to better student performance and enhanced critical analytical abilities. The learning method supported by this platform requires students to actively participate while developing their ability to explore and analyze which are vital for critical thinking. The research conducted by (Munif, 2022) and (Rasyidi et al., 2024), demonstrates that PhET virtual labs enhance critical thinking abilities and scientific communication skills through their interactive and effective learning environment.

Based on research results showing significant improvements in both learning outcomes and critical thinking skills, PhET simulation media delivers superior learning results for energy and work subjects through its innovative teaching approach. The educational platform delivers laboratory experiences through virtual environments which help students learn better while maintaining their interest and motivation levels. The research evidence demonstrates that PhET media delivers successful results for students at all educational levels from elementary to university while enhancing their scientific communication abilities during practical work. The media receives support from experts and positive feedback from teachers and students which confirms its effectiveness for learning purposes. The simulation required additional teacher support because students struggled with basic concept mastery

which included memorization tasks. The research shows that PhET media delivers successful results in enhancing student learning achievements and their critical thinking abilities.

5. CONCLUSION

The use of PhET simulation media on energy and work materials has consistently been proven to have a significant positive influence on improving students' learning outcomes and critical thinking skills through exploration, data analysis, and reflection on scientific phenomena in work and energy materials. This shows that PhET simulations successfully bridge the gap between abstract physics concepts in work and energy materials with concrete visualizations. This media is effective for use at various levels of education from elementary school to college. PhET simulations provide easy visualization of abstract concepts, increase motivation, and strengthen the student-centered learning approach. Therefore, PhET media is recommended as an alternative innovative learning media that can improve the quality of physics learning in work and energy materials.

Ethical Approval
Not Applicable

Informed Consent Statement
Not Applicable

Authors' Contributions
FP contributed to the conceptualization, research design, data analysis, and manuscript writing. AS contributed to the translation process, data collection, and validation testing. SF and RHP contributed to the literature review, data interpretation, and proofreading of the final manuscript.

Disclosure Statement
No potential conflict of interest was reported by the author(s).

Data Availability Statement
The data presented in this study are available on request from the corresponding author due to privacy reasons.

Funding
This research received no external funding.

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