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Literature Study: Application of PhET Simulation-Assisted PBL Learning Modules to Improve Students' Creative Thinking Skills

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Abstract: This study aims to review the effectiveness of the PBL model combined with the simulation of PhET in improving students' creative thinking skills on alternative energy materials. The study was conducted through a review of 19 selected articles from 49 relevant studies, based on the suitability of the research variables, the quality of the journals, and the clarity of the methodologies. The analysis showed that PBL improved students' learning outcomes, concept understanding, and creativity, while the PhET simulation helped visualise abstract concepts interactively. However, few studies have developed specialised PBL-based modules integrated with PhET to train creative thinking on alternative energy topics. Therefore, this study provides novelty by emphasising the importance of the direction of development of PBL-PhET modules as innovative teaching materials that support the learning needs of the 21st century.

Keywords: Problem-based learning; PhET simulation; Creative thinking; Alternative energy

Introduction

21st-century education demands that learners possess high-level thinking skills, especially creative thinking, to solve real problems and navigate rapid technological change. These skills serve as a foundation for students to adapt, innovate, and make sound decisions in complex situations.

One learning model relevant to these demands is problem-based learning (PBL). PBL is considered effective in developing creative thinking skills because it provides opportunities for students to build understanding through active participation in solving contextual problems (Mundilarto & Ismoyo, 2017). PBL also encourages students to submit ideas, evaluate information, and develop original solutions, making it a suitable framework for developing learning tools.

In addition to the learning model, the use of appropriate learning media also helps strengthen students' understanding of concepts. One of the media increasingly used in physics learning is the PhET simulation. PhET simulations are an effective tool for science learning because they visualise abstract concepts in an interactive, engaging way. (Yunzal, Jr. & Casinillo, 2020). The use of PhET makes the exploration of concepts more concrete, thereby supporting students' conceptual understanding and creativity.

In the development of learning tools, modules are among the most important media. Modules are self-paced teaching units designed for students to learn independently (Obidoa, 2014, in Sadiq, 2019). Modules integrated with the PBL approach and PhET simulations are believed to foster active, contextual learning. Modules like this not only facilitate the understanding of concepts but also increase students' interest in learning and involvement in the learning process (Lavonen et al., 2021).

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However, the literature review shows that research on the development of PBL-based modules combined with PhET simulations remains limited. The majority of previous studies have only examined the application of PBL or the use of PhET separately, without integrating them into a single learning tool specifically designed to enhance students' creative thinking skills, especially on alternative energy topics. This gap points to the need for a comprehensive literature review. Therefore, this study was conducted to review and analyse prior studies and identify opportunities to develop PBL-based learning modules, supported by PhET simulations on alternative energy materials, to improve students' creative thinking skills.

Method

This study uses a descriptive research approach, especially a literature review. According to Juliangkary & Pujilestari (2022)The Literature study method is a series of activities for collecting literature data, reading and recording, and processing research materials.Kurniati & Jailani (2023)He also argues that a literature review is the search and research of literature by reading various journals and other publications related to the research topic.

The research method is qualitative, using an analytical-descriptive approach. The data used are secondary, that is, obtained from previous research sources, such as journal articles, rather than from direct field data collection. The selection of articles is carried out using inclusion criteria in the form of: a). articles published in reputable national/international journals. b). Articles discuss module variables, PBL, PhET, or creative thinking. c). The article contains empirical data or development procedures. d). Articles published over the years that are still relevant to the current learning context.

The data analysis technique is carried out in three main steps: data reduction, data presentation, and conclusion. Data reduction is achieved by selecting and summarising the most important information from each article. The presentation of data was carried out by compiling the analysis results into a recapitulation table and a systematic narrative description. Conclusion: Drawing is carried out by identifying patterns in findings, similarities and differences, and research gaps in previous studies.

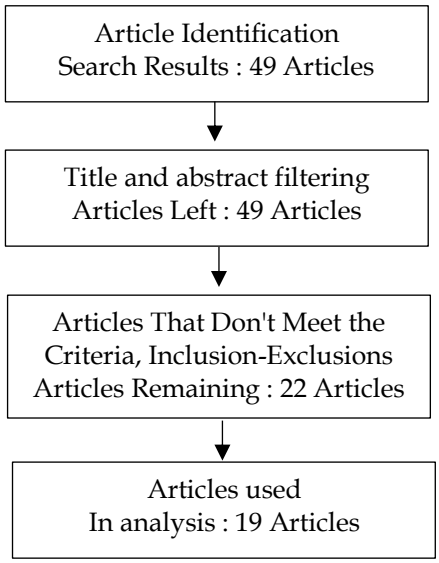

Figure 1. Literature Study Flow

Results and Discussion

The results of this literature review were obtained from the analysis of 19 articles selected from a total of 49 articles collected. These articles are published in national journals indexed by Sinta and other scientific journals. Thus, these 19 selected articles are considered relevant to addressing research questions regarding the urgency of developing PBL-based modules, supported by PhET simulations, to improve creative thinking skills in alternative energy materials.

Table 1: Summary of research results from the article

Not.	Heading	Writer	Result
1.	The effectiveness of the PhET media-assisted PBL model on student learning processes and outcomes	(Marianus et al., 2020)	It was concluded that the PBL model, supported by the PhET simulations, was effective for learning processes and outcomes in physics.
2.	Study of the PBL model in learning in schools	(Meilasari et al., 2020)	From 41 journals, it was found that the PBL model had a positive impact on improving students' learning abilities and interests.
3.	Efforts to improve physics learning	(Parasamya Cut Eka, 2017)	In cycles I to III, it was simulated that

	outcomes through the application of the PBL model.		applying the PBL model could improve learning outcomes.
4.	Application of the PBL learning model to improve physics, temperature, calorie, and material learning outcomes	(Sudiarta, 2019)	The application of the PBL model has been proven to improve physics learning outcomes for grade XI MIPA students.
5.	Development of PBL-based physics learning modules to improve physics problem-solving skills	(Hudha et al., 2017)	The physics module was declared valid, and the students' responses to the modules were 91% and 91.25% for the content and display components, respectively.
6.	The effect of the application of the PBL model through different approaches on student learning outcomes	(Lagarusu et al., 2023)	There is a difference between student learning outcomes on physics concepts when using the PBL learning model.
7.	Development of PBL-based physics modules on static fluid materials	(Nada et al., 2024)	The physics module is based on PBL, which is a feasible, practical, and effective approach to learning.
8.	Development of PBL-based learning modules to improve students' metacognitive understanding of temperature and heat materials	(Al Farizi et al., 2023)	The PBL-based modules developed are valid, practical, and effective for improving metacognitive knowledge.
9.	Development of PBL-based learning modules for understanding physics concepts for grade X students of SMK	(Suswati et al., 2022)	The physics module is suitable for understanding the concept of physics learning.
10.	Meta-analysis of the development of PBL-based physics modules to improve students' skills	(Risma et al., 2020)	The PBL model has a moderate effect on students' overall skills.
11.	Development of HOTS-oriented PBL-based physics modules on static fluid materials	(Sari et al., 2024)	The developed modules are declared valid, practical and effective
12.	Improving students' creative thinking skills through the implementation of PBL	(Rahman, Mariam Ar; Rohaendi, 2020)	There was an increase in creative thinking skills and student learning outcomes in cycles I and II.
13.	The use of PBL to increase students' learning creativity	(Subandi et al., 2023)	The results of the category research are excellent, and the achievement of all indicators of student creativity has increased.
14.	The effect of PBL learning on increasing students' creativity and critical thinking skills	Fajrina hidayati, Adila solida, Andree aulia Rahmat (2024)	There is a difference in students' learning outcomes between those who use conventional methods and those who use PBL.
15.	The effect of virtual simulation-assisted problem-based PBL models on concept use and creativity	(Dewi et al., 2017)	There is a significant influence
16.	Debriefing of creative thinking skills for high school students through	(Liliawati, 2011)	Effective in providing creative thinking skills for high school students

	problem-based physics learning		
17.	Problem-based learning model to enhance students' creativity in science projects	(Wahyudin & Permatasari, 2020)	Help students increase creativity in creating science projects and activities during learning. Problem-solving and his creative attitude
18.	Interactive simulations in the physics learning process	(Rizaldi et al., 2020)	Effective in explaining abstract physics concepts
19.	Application of simulation media using PhET on physics learning outcomes of grade X students of SMA Muhammadiyah	(Ekawati et al., 2015)	The application of media shows an increase in physics students' learning outcomes in class X.

A review of 19 articles found that implementing problem-based learning significantly improved students' learning processes and outcomes. According to Marianus (2020), implementing PBL with the PhET simulation improves *physics learning outcomes,* with an average posttest score of 80.24. These results align with Meliasari's (2019) findings, which stated that PBL encourages active student engagement, increases interest in learning, and helps students connect physics concepts to real-world problems. In addition, the research Parasamya Cut Eka (2017) and Sudiarta (2019)Showed a significant improvement in learning outcomes from 69% to 94%.

The quality of the PBL modules developed is also excellent, with strong validity and practicality. According to al. (2017), PBL-based physics modules are considered very valid, with a validity rate of 94.8% and a practicality rate of 91%. Research by Nada et al. (2024) and Sari et al. (2024) also confirmed that PBL modules across various physics materials have a validity of 88-95% and positive student responses of 91-95.5%. This module is considered easy to apply and relevant for various levels of education because it integrates contextual problems that lead students to discover concepts independently.

The PhET simulation further strengthens the effectiveness of PBL in physics learning. Rizaldi et al (2020), explains that the PhET interactive simulation helps students understand abstract concepts. Integration *of PhET* in the PBL model, as reported by Shinta Mutiara Dewi et al (2017), resulting in a significant improvement in students' mastery of concepts and creativity compared to conventional teaching. Stuttgar Ekawati et al (2015), finding that independent use of Simulation in PhET can improve student learning outcomes and motivation.

Implementing PBL also improves students' creative thinking skills. According to Yanti et al (2019) Problem-based learning encourages students to think differently and generate innovative ideas. Subandi et al (2023), adding that PBL significantly improves all indicators of creativity, such as fluency, flexibility, originality, and elaboration. MoreoverDewi et al (2017)), found that experimental groups that learned through PBL-assisted PhET simulations scored higher on creativity than the control group. This shows that integrating PBL with digital simulation media enhances creative thinking, a key 21st-century skill.

Although most studies show that PBL, PhET simulations, and learning modules can improve students' understanding of concepts and creative thinking skills, the findings are not entirely consistent. Some studies report significant increases in creativity, while others show only improvements in specific indicators, such as fluency or thinking flexibility, differences that may influence learning design, student characteristics, and the duration of application of non-uniform models.

In addition, many articles use simple research methods, such as single-group pretest-posttest designs or limited trials, which limit their ability to control external variables and reduce internal validity. Some of them also do not explain data analysis techniques in depth, so the conclusions are less intense. In addition, few studies explicitly integrate modules, PBLs, and PhET in a single learning kit; most examine these variables separately. This condition highlights an important research gap: the need to develop PhET-assisted PBL modules specifically designed to improve students' creative thinking skills in alternative energy materials.

Conclusion

Based on a study of 19 articles, the application of the problem-based learning model, supported by PhET simulations, is efficacious in improving learning outcomes, conceptual understanding, and creative thinking skills among students. This approach provides a meaningful learning experience by training students to think critically, collaborate, and solve contextual problems through interactive media. The main contribution of this research lies in strengthening the integration of PBL and *PhET* simulations as innovative learning strategies relevant to the demands of the 21st

century. However, this literature review has some limitations. The range of articles reviewed is still limited to specific periods and sources, so it is not fully representative of the entire existing research. The quality of the articles reviewed also varies; some use simple research designs, so the findings are less widely generalizable. In line with these limitations, further research should focus on developing PBL-based learning modules integrated with PhET simulations in more practical ways, especially for alternative energy topics. This effort is important so that the PBL module can be implemented optimally and make a significant contribution to improving students' creative thinking in science learning.

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