Systematic Literature Review: PBL Model Assisted by PhET Simulation to Improve Students' Critical Thinking Ability

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Article Info

ABSTRACT

This study was conducted to demonstrate the effectiveness of implementing a problem-based learning model in enhancing students' critical thinking skills at the high school level or its equivalent. The type of research carried out was a systematic literature review, following seven stages: formulating research questions, establishing selection criteria, developing search strategies, selecting studies based on selection criteria, assessing research quality, synthesizing results for the research questions, and reporting findings. Article searches were conducted using Google Scholar, SINTA, and ProQuest, with the assistance of the Publish or Perish application, utilizing keywords such as "critical thinking skills," "problem-based learning," and "physics." A total of 35 articles were obtained from the study, of which 33 met the inclusion criteria. The quality assessment results indicated that the identified articles were of good quality and were published in SINTA and SCOPUS. The implementation of problem-based learning can be integrated with other media, such as PhET simulations, websites, and Microsoft Teams, to enhance students' critical thinking skills. The review of these articles confirms that the overall application of the problem-based learning model can effectively improve students' critical thinking skills in physics.

INTRODUCTION

Education is one of the most important aspects in preparing students to adapt to developments in the 21st century. Important skills in the 21st century are still relevant to the four pillars of life which include learning to know, learning to do something (learning to do), learning to be something (learning to be) and learning to live together (learning to live together) (Nuriyati & Chanifudin, 2020). Each of the four pillars of life contains special skills that need to be applied in

learning activities, such as critical thinking, problem solving, metacognition, communication, collaboration, innovation and creation, information literacy, and various other skills. Critical thinking ability is a basic ability that students must have to solve various types of problems given by teachers at school. 21st century skills ask teachers, students and the educational environment to carry out learning that supports the development of 21st century skills. According to Ayub et al (2023), 21st century skills are important for students to apply because students have a very important role as social revolutionaries in a developing society, because students have much more enthusiasm, ability, competitiveness, thinking and physically strong and responsive.

According to Ennis, critical thinking is reasonable, reflective thinking focused on deciding what to believe or do (C. & Black, 1947). The ability to think critically is a way of reasoning to determine the appropriate decisions or actions by logically questioning matters related to information (Triandini et al., 2021).

Critical thinking skills are one of the key competencies in 21st-century education; however, students in Indonesia still face significant challenges in mastering these skills, particularly in physics learning. Studies show that many students struggle to deeply understand physics concepts and apply them to solve contextual problems (Milda, D. et al., 2024, p. 97). The importance of students' critical thinking abilities is closely linked to the teaching and learning process between teachers and students. According to Mahadi (2021), the delivery of learning materials or the teaching process is a communication process, which involves transmitting messages or thoughts from one person to another. The use of appropriate methods will enable students to effectively receive the conveyed messages.

In the physics learning process, students are not just memorizing theories and formulas; rather, they are often confronted with phenomena from everyday life. Additionally, physics also trains students to develop reasoning skills in inductive and deductive thinking by using physical concepts and principles to explain various natural events and solve problems, both qualitatively and quantitatively (Sulistiyono, 2022).

The lack of interactive learning methods that actively engage students is one of the reasons for the low levels of critical thinking skills (Putri, N. et al., 2024, p. 69). Therefore, the development of innovative learning approaches has become an urgent necessity. Problem-Based Learning (PBL) has been widely recognized as one of the learning models that can enhance students' critical thinking abilities. PBL encourages students to explore and solve authentic problems, allowing them to build understanding through direct experience (Erlangga et al., 2023). However, the implementation of PBL often faces obstacles due to inadequate learning media that can facilitate the understanding of abstract physics concepts. Therefore, interactive simulation media such as PhET Interactive Simulations can serve as a relevant solution. PhET, designed by the University of Colorado, provides virtual simulations that enable students to understand the relationships between real-life phenomena and scientific theories interactively (Wattimena, H. & Batlolona, J., 2024).

The urgency of this research is increasingly high considering the challenges of learning in the digital era, where technology has become an integral part of the educational process. The research by Mardiyanti & Jatmiko (2022) reveals that the integration of PhET within the PBL model significantly enhances students' critical thinking abilities. The use of media such as PhET has also been shown to improve students' critical thinking skills and bridge the gap between theory and practice (Rani, P., 2019). However, the implementation of this learning model is still uneven across schools in Indonesia, particularly in physics

subjects, which are often perceived as difficult by students.

The main issue that this research aims to address is the low level of students' critical thinking skills in physics learning and the limited innovation in teaching methods. One proposed solution is the integration of PBL supported by PhET Simulation as a learning approach that combines problem exploration with interactive simulations. This research aims to investigate the effectiveness of the PBL model in enhancing students' critical thinking abilities.

A learning model is a systematic conceptual framework that organizes learning experiences to achieve specific goals. This model serves as a guide for designers and educators in planning and implementing learning activities (Abarang & Delviany, 2022). The application of learning models can help address the problems faced by schools. One example of a model that can be applied is the problem-based learning model, also known as Problem-Based Learning (PBL). Problem-Based Learning is an educational model that uses problems as a starting point for learning (Agustina et al., 2022). The problems referred to are those that fulfill real-world contexts found in textbooks or arise from occurrences in the surrounding environment (Hasudungan, 2021). Problem-Based Learning (PBL) presents students with real, open-ended problems (ill-structured) (Gunawan et al., 2021). According to Golightly & Raath (2015), in PBL, the teacher should create a problem based on desired curriculum outcomes, student characteristics, and real-world situations. PBL helps students develop critical thinking to solve problems in their clinical settings and bridges the gap between theory and practice (Aguustina, D.W. & Fitrihidayati, H., 2020).

The use of interactive learning media such as PhET Simulations can also help students understand abstract concepts in science more easily and engagingly. PhET Simulations provide a variety of interactive simulations that allow students to experiment, observe, and analyze various scientific phenomena directly. The application of the PhET-assisted PBL model was selected because it provides a holistic approach to learning physics. This media enables students to visualize abstract concepts directly, enhancing their engagement in the learning process and systematically developing their critical thinking skills. The Physics Education Technology (PhET) simulation media consists of animated designs that can be used to achieve physics learning objectives. PhET Simulations are developed by professionals to facilitate physics teachers in delivering learning materials (Novita et al., 2023). In addition to assisting teachers, PhET Simulations also enhance students' understanding of the material, especially regarding natural phenomena (Rizaldi & Jamaludin, 2020).

Utilizing PhET Simulations in physics learning offers innovative solutions to simplify complex concepts through visualization and interactivity. This media is designed to support the problem-based learning model (Problem-Based Learning/PBL), which encourages students not only to understand the material theoretically but also to apply it in real-world contexts. With simulations resembling laboratory experiments, students can explore physical phenomena such as waves, electricity, and mechanics in a safe, efficient, and enjoyable way (Hidayah, 2022). Based on previous research, PhET Simulations have been proven effective in enhancing students' understanding, developing critical thinking skills, and facilitating teachers in creating meaningful and contextual learning experiences (Rizaldi et al., 2020).

Moreover, PhET Simulations provide flexibility in learning by offering various features that can be customized according to the needs of students and teachers. These simulations allow students to control specific variables, observe changes that occur, and draw conclusions independently, thus supporting exploration-based learning. In

classroom implementation, PhET can also be used as a formative evaluation tool to assess students' conceptual understanding directly through interactive activities. With this approach, students not only learn about theory but also gain a deeper understanding of the scientific process. The use of PhET is also relevant to the demands of 21st-century education (Novita, 2023), as it enhances critical thinking skills, creativity, and problem-solving abilities that are essential in the modern era.

With the results of this research, it is hoped that it can make a tangible contribution to improving physics teaching methods in Indonesia, making them more relevant to the needs of the 21st century. Additionally, this research is expected to serve as a reference for educators and curriculum developers in creating innovative, interactive physics learning experiences that focus on developing students' critical thinking skills.

METHODS

This research employs a systematic literature review (Systematic Literature Review). A systematic literature review is a method used to collect and synthesize scientific evidence to answer specific research questions with a clear and reproducible approach (Larasati, Yusril & Zukri, 2021). This method aims to gather all published evidence regarding the topic and evaluate the quality of that evidence.

The systematic literature review method is applied to identify, analyze, assess, and interpret all existing research related to the interesting phenomenon, focusing on relevant research questions (Utomo, P., Asvio, N., & Prayogi, F., 2024). The process of the systematic literature review in this research follows the steps outlined by Richter et al. (2020) (Sutisna et al., 2022). The stages of this research are illustrated in the following diagram.
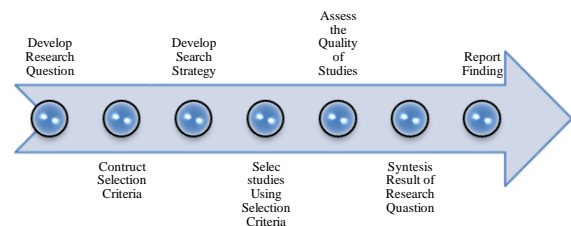

Figure 1. (Diagram of the systematic literature review procedure (Zawacki-Richter et al., 2020))

1. *Develop Research Questions*
   The research questions developed in this study are as follows:

   RQ1 : How can the objectives of Physics learning in high school be achieved based on the results of a review of research articles regarding the Problem Based Learning model?

   RQ2 : Does the Problem Based Learning model influence the achievement of Physics learning objectives in high school?

2. *Selection Criteria*
   The selection criteria for this study are shown in the following table:

Table 1. Inclusion and Exclusion Criteria

Kriteria inclusion	a.	The article is in accordance with the research topic regarding problem-based learning (PMB) or problem-based learning (PBL) in elementary school mathematics subjects.
	b.	Publications (2010-2021).
	c.	Full text
Kriteria exclusion	a.	Research journals or scientific papers outside the research topic.
	b.	Publication before 2010.
	c.	Unfull text

3. *Developing the Search Strategy*
   The search process is carried out using a search engine (using Google Chrome) with the site address http://garuda.ristekdikti.go.id
   Search strings require more specific searches and avoid filtering too large amounts.

   > Search strings for this research: ("Problem-based learning model" or "Problem-based learning model" or "PBM model" or "PBL model") and ("Mathematics" or "Math") and ("Primary School" or "SD " or "Elementary School").

4. *The Study Selection Process*
   The study selection process is a process where the title and abstract of the article are checked first to determine whether the research is relevant or not (Zawacki-richter et al, 2020).

5. *Appraising the Quality of Studies*
   In SLR research, the data found will be evaluated based on the following quality assessment criteria questions:
   QA1 : Has the journal article been indexed?
   QA2 : Does the article write about research problems that are relevant to this research?
   QA3 : Does the article use relevant research methods to improve students' critical thinking skills using the Problem Based Learning model?
   From each journal article, an answer value will be given for each question above with Y (Yes) or T (No).

6. *Synthesis result of research question*
   The synthesis process is not just listing research literature studies. More than that, the synthesis process is an effort to integrate information from findings to answer research questions. The results of the research were analyzed and then conclusions were drawn to answer the research questions that had been set.

7. *Report Findings*
   The final step in SLR research is to create a research results report.

RESULTS AND DISCUSSION

1. Result and Search
   The results of the search process are displayed in Table 2 and grouped by journal type to make it easier to see the type of data or journal type obtained.

Tabel 2. Grouping by Journal

No	Tipe Journal	Number of Articles
1	Education & Learning	2
2	Journal of Studies, Innovation and Applications in Physics Education	1
3	Scientific Journal of Physics Education	2
4	Archipelago Scientific Journal	1
5	Scientific Journal of Mathematics Education	1
6	Educational Professional Scientific Journal	3
7	Journal of Education and the Teaching Profession	1
8	Journal of Education	2
9	Journal of Education: Theory, Research and Development	1
10	Journal of Mathematics and Science Education	2
11	Journal of History & History Education	1
12	Journal of Community Service for the Archipelago	1
13	Indonesian Classroom Action Research Journal	1
14	JOPPAS: *Journal of Public Policy and Administration Silampari*	1
15	Research Journal	1
16	Journal of Information Systems	1
17	Journal on Education	1
18	Pedagogics	1
19	Visipena	1
20	Scholar	1

21	Edycation Journal, Mathematics & Science	2
22	Journal of Education & Social Sciences	1
23	In Annual International Conference on Islamic Education for Students	2
24	Islamic Education For Students	1
25	Journal of Science and Technology Education	1
26	Educational Scientific Journal	1
Total		35

2. Inclusion Selection Results

This process is the process of selecting articles obtained based on previously formulated inclusion criteria. This process left 35 articles published in 25 journals. The journal obtained is accredited by Sinta and Scopus. The results of the selection process based on the inclusion criteria will undergo a Quality Assessment to assess the quality of the study conducted.

3. Hasil *Quality Assessment* (QA)

Table 3 shows the quality assessment results for indicating whether the data was used or not in this study.

No	Writer	Title	Year	QA1	QA2	QA3	results
1	Hayuna Hamdalia Herzon, Budijanto & DwiHari Utomo	Pengaruh Problem-Based Learning (PBL) terhadap Keterampilan Berfikir Kritis	2018	Y	Y	Y	√
2.	Nanda Novita, Intan Tri Aulia S & Nuraini Fatmi	Pengaruh Model Pembelajaran PBL dengan Media PhET Terhadap Hasil Belajara Kognitif	2023	T	Y	Y	√
3	Dedora Milda & Anggreiny	Literature Study of The Application of The Inquiry Learning Model Towards 21st Century Skills in Physics Subjects in High School	2024	Y	Y	Y	√
4	Nadia Istiana Putri, Muhammad Ramadhan Fadillah, Aulya Larasati Putri & Ana Nurhasanah	Analisis Kemampuan Berpikir Kritis Siswa Kelas Xii Ipa 3 Di Sman 7 Kota Serang Pada Mata Pelajaran Sejarah Demokrasi Liberal	2024	Y	T	T	√
5	Sony Yunior Erlangga, Elang Amadeus poort, Puji Hariati Winingsih, Oktaffiarinna Manasikana & Arifian Dimas	Meta-analisis: effect size model pembelajaran berbasis masalah pada kemampuan berpikir tingkat tinggi (HOTS) dan pemahaman konseptual siswa dalam fisika	2023	Y	Y	Y	√
6	Herman	Pelatihan	2024	Y	Y	T	√

No	Author	Title	Year				√
	Samuel Wattimena & John Rafafy Batlolona	Penggunaan PhET Simulation untuk Meningkatkan Konseptual Fisika Siswa Konsep Listrik Searah (DC)					
7	Nur Eka Agusti Mardiyanti & Budi Jatmiko	Keefektifan Pembelajaran Fisika dengan Model Inkuiri Terbimbing Berbantuan PhET Interactive Simulations untuk Meningkatkan Kemampuan Berfikir Kritis Siswa SMA	2022	Y	Y	T	√
8	Peni Puspita Rani	Pengaruh Model Pembelajaran Levels Of Inquiry Menggunakan Phet Simulation Terhadap Kemampuan Berpikir Kritis Siswa Pada Pembelajaran Fisika	2019	Y	Y	T	√
9	Sekar Indah Ret Noing Tiyas, Khusaini & Anita Purwani	Analisis Penerapan Model Pembelajaran Problem Based Learning (Pbl) Berbantuan Media Phet Di Sma Brawijaya Smart School Malang.	2024	Y	Y	Y	√
10	Inggrit Larasati , Azizah Nurfauziah Yusril dan Pajri Al Zukri	Systematic Literature Review Analisis Metode Agile Dalam Pengembangan Aplikasi Mobile. Sistemasi	2021	Y	Y	T	√
11	Prio Utomo, Asvio Baru & Fiki Prayogi	Metode penelitian tindakan kelas (PTK): Panduan praktis untuk guru dan mahasiswa di institusi pendidikan	2024	Y	Y	T	√
12	Sutisna , Novaliyosi & Hendrayana	Systematic Literature Review: Adversity Quotient dan Kemampuan Pemecah	2022	Y	Y	T	√

No	Author	Title	Year				√
		an Masalah pada Pembelajaran Matematika					
13	Tuti Nuriyati & Chanifudin	Pendidik Millenial di Era Globalisasi	2020	Y	T	T	√
14	Syahrial Ayub, Joni Rokhmat & Ahmad Busairi	Implementasi Projek Penguatan Profil Pelajar Pancasila (P5) Sebagai Upaya Menumbuhkan Jiwa Kewirausahaan	2023	Y	T	T	√
15	Widya Triandini, Kosim & I Wayan Gunada	Pengembangan Modul Fisika Berbasis Guided Inquiry Untuk Meningkatkan Kemampuan Berpikir Kritis Peserta Didik.	2021	Y	Y	T	√
16	Sulistiyono	Pengembangan Modul Pembelajaran Fisika Berbasis Scientific Investigation untuk Meningkatkan Kemandirian Belajar	2022	Y	T	T	√
17	Ujang Mahadi	dan Penguasaan Materi Siswa SMA Komunikasi Pendidikan (Urgensi Komunikasi Efektif dalam Proses Pembelajaran)	2021	Y	T	T	√
18	Abarang, & Delviany	Peningkatan Hasil Belajar Peserta Didik Dengan Menggunakan Model Pembelajaran Problem Based Learning (Pbl).	2022	Y	Y	Y	√
19	Heni Agustina, Syahrial A, Susilawati Susilawati, I Wayan Gunada	Pengaruh Penggunaan Modul Fisika Berbasis Problem Based Learning Terhadap Kemampuan Berpikir Kritis Peserta Didik	2022	Y	Y	Y	√
20	Hasudungan	Pengunaan Buku Teks Sejarah Indonesia Pada Satuan Pendidikan Menengah atas	2021	Y	T	T	√

No	Author	Title	Year				
		Dalam Kurikulum 2013					
21	Herzon, & Hayuna	Pengaruh Problem-Based Learning (PBL) terhadap Keterampilan Berpikir Kritis	2018	Y	Y	Y	√
22	Nanda Novita, Intan Tri Aulia S & Nuraini Fatmi	Pengaruh Model Pembelajaran PBL dengan Media PhET Terhadap Hasil Belajar Kognitif Siswa	2023	Y	Y	Y	√
23	Dedi Riyan Rizaldi , A.Wahab Jufri , Jamaluddin Jamaluddin	PhET: Simulasi interaktif dalam proses pembelajaran fisika	2020	Y	Y	T	√
24	indriyani rauf, Irvin Novita Arifin & Rifda Mardian Arif	Pengaruh Model Problem Based Learning Terhadap Kemampuan Berpikir Kritis Siswa	2022	Y	Y	Y	√
25	Hidayah	Pengembangan E-Lkpd Berbantuan Phet Simulation Berbasis Problem Based Learning Pada Materi Pemanasan	2022	Y	Y	Y	√
		Global Untuk Menumbuhkan Keterampilan Berpikir Kritis Peserta Didik Sma					
26	Paulo Roberto, Joel Haroldo & Adelcio Machado	Problem-Based Learning (Pbl) And Interdisciplinarity In Software Engineering Teaching -Learning	2020	Y	Y	Y	√
27	Ike Yanuarti Soima , Miftahus Surur , Yesi Puspitasari	Penerapan Pbl (Problem Based Learning) Berbantuan Media Video Untuk Meningkatkan Kemampuan Berfikir Kritis Peserta Didik Kelas X Di Ma Sarji Ar-Rasyid	2021	Y	Y	T	√
28	Nur Ilmi, Nursalam, Sarifuddin Cn Sida	Pengaruh Penerapan Model Pembelajaran Berbasis Masalah terhadap Peningkatan Berpikir Kritis	2022	Y	Y	Y	√

No	Penulis	Judul	Tahun				
		dan Motivasi Intrinsik Siswa pada Pembelajaran IPS SD Negeri Samata					
29	IGANT Jayantika, Nyoman Parmithi, Desak Nyoman Diah Purwaningsih	Pengaruh Model Pembelajaran Problem Based Learning Terhadap Kecemasan Dan Hasil Belajar Matematika	2020	Y	Y	Y	√
30	Putri Aulias Pratiwi	efektivitas pembelajaran berbasis masalah berbantuan media diorama terhadap hasil belajar materi ipa tentang hubungan antara makhluk hidup dalam ekosistem pada siswa kelas v mi arrosyad bergaslor	2022	Y	Y	Y	√
31	Nurul Muslimah Ritonga, Nirwana Anas, R.Rohani	Pengaruh Model Problem Based Learning (PBL) Terhadap Kemamp	2023	Y	Y	Y	√
32	Saiful Fajar Dwi Ananda, A. Fauziah	Penerapan Model Pembelajaran Problem Based Learning Untuk Meningkatkan Kemampuan Berpikir Kritis Siswa Pada Materi Sistem Peredaran Darah	2022	Y	Y	Y	√
33	Gaspar Melo, AA Lehan, Petrus LB Loy	Penggunaan Model Problem Based Learning Pada Materi Panas Dan Perpindahannya Untuk Meningkatkan Hasil Belajar Siswa Kelas V Sd Gmit Naioni Kota Kupang	2023	Y	Y	T	√
34	Diska Vera Santi, Dewi Handayani, Nana Noviyanti	Penerapan Model Problem Based Learning Berbantuan Multimedia Untuk Meningk	2021	Y	Y	T	√

		atkan Hasil Belajar Dan Aktivitas Belajar Kimia Siswa			
35	Andriyani Mudrikah	Pembelajaran Berbasis Masalah sebagai Bagian dari Pembelajaran yang Berpusat pada Siswa	2021	Y	Y

The research conducted in each journal consisted of true experiments and quasi experiments. The research designs used were pretest-posttest control group design, posttest only control group design, non-equivalent control group design, and one group pretest-posttest. Based on the results of a review of 35 articles regarding the application of PBL to Critical Thinking abilities which are presented in table 3, the results obtained show that the application of PBL to physics learning can improve students' critical thinking abilities in the medium and high categories. This is proven by an increase in students' critical thinking abilities before implementing PBL and after implementing PBL. The increase in critical thinking skills with the PBL model is higher than using the conventional model (Arifin & Arif., 2022; Agustina et al., 2022; Tiyas & Purwantini, 2024.). The application of PBL can also be integrated with media or approaches. The application of PBL can be integrated with the help of media such as PhET (Novita, N., & Fatmi, N. (2023); Hidayah, F. N. (2022). This proves that the application of the PBL model in learning is able to improve students' critical thinking abilities and is also more better than conventional learning. These studies will be a reference for research in

carrying out research using PBL to improve students' critical thinking skills which are still lacking.

CONCLUSION AND SUGGESTION

Based on the results of a literature study, it was found that the application of the Problem Based Learning model was able to facilitate students in solving the problems they faced in several subjects, especially physics. The application of PBL can be integrated with media such as PhET Simulation and so on. These studies can be a relevant reference for researchers in conducting research on the influence of PBL on students' critical thinking abilities.

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