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Trends and Effectiveness of Problem-Based Learning in Enhancing Critical Thinking: A Systematic Literature Review of The Last 10 Years

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ABSTRACT

This study aims to analyze the trends and effectiveness of Problem-Based Learning (PBL) in improving students' critical thinking skills over the last ten years. This study employed a systematic literature review approach using the PRISMA method, which included identification, screening, eligibility, and inclusion stages. A total of 51 articles were selected from the Dimensions database using keywords related to PBL, critical thinking, and science education. The findings showed that PBL consistently had a positive effect on students' critical thinking skills, particularly in analysis, problem-solving, and conceptual understanding. Most studies were conducted at the senior high school level, while research at the junior high school and higher education levels remained limited. In terms of learning media, the majority of studies still implemented PBL without technology integration, although several studies utilized videos, simulations, e-modules, and multimedia, which produced more optimal results. In addition, research topics were predominantly focused on dynamics, whereas other physics topics remained underexplored. This study highlights gaps in technology integration and research distribution. Therefore, future studies are recommended to develop technology-based PBL and expand its implementation across various educational levels and learning materials.

Keywords : Problem-Based Learning; critical thinking skills; systematic literature review; science education; technology integration.

I. INTRODUCTION

Education plays a crucial role in shaping individuals who are capable of facing future life challenges [1], [2]. As the primary foundation for human resource development, education not only functions to transfer knowledge but also develops skills, values, and character that support individual and societal progress [3], [4]. In the modern era, which is characterized by rapid change and global complexity, education is expected to produce individuals who are critical, creative, and adaptive. Therefore, the development of higher-order thinking skills has become one of the main focuses of current educational systems. One of the most important skills to be developed is critical thinking, as it enables individuals to analyze information, evaluate arguments, and make rational and evidence-based decisions [5].

In recent years, the importance of critical thinking has been further emphasized by global educational frameworks that highlight essential competencies for the 21st century. International organizations emphasize that education should not only focus on content mastery but also on the development of transferable skills such as critical thinking, collaboration, and problem-solving. These competencies are essential for preparing students to face complex real-world challenges [6]. Therefore, instructional approaches that actively engage students in the learning process are increasingly prioritized.

In the context of science education, particularly physics, critical thinking skills play an essential role. Physics learning requires not only conceptual understanding but also the ability to solve problems and relate concepts to real-life phenomena. However, in practice, physics instruction is still often teacher-centered and provides limited opportunities for students to optimally develop critical thinking skills. As a result, students tend to be passive and focus primarily on memorizing concepts. Therefore, learning approaches that encourage active student engagement are needed. One approach considered effective is Problem-Based Learning (PBL), which places contextual problems as the starting point of learning and encourages students to think critically and independently identify solutions [7].

Problem-Based Learning is a learning model that focuses on solving real-world problems as a means of developing students' knowledge and skills. In its implementation, PBL encourages students to engage in exploration, discussion, and reflection on the problems provided. Through this process, students not only gain conceptual understanding but also develop critical thinking, collaboration, and communication skills. PBL is also considered relevant to the demands of 21st-century learning, which emphasizes higher-order thinking skills [4]. Therefore, PBL has become one of the most widely studied approaches in science education .

Furthermore, the integration of technology in education has transformed the way learning is delivered and experienced. Digital tools such as simulations, virtual laboratories, and interactive multimedia provide opportunities for students to visualize abstract concepts and engage in inquiry-based learning. In physics education, where many concepts are difficult to observe directly, technology-enhanced learning environments are particularly valuable [8]. When combined with student-centered approaches such as PBL, these tools have the potential to significantly enhance critical thinking and conceptual understanding [9].

Previous studies have shown that PBL has a positive effect on students' critical thinking skills. At the secondary education level, PBL has been found to improve students' analytical and problem-solving abilities in physics learning. At the higher education level, this approach has also supported students in developing reflective thinking and scientific argumentation skills [10]. Furthermore, instructional media integrated with PBL, such as simulations and e-modules, have contributed to improving critical thinking skills [8]. Nevertheless, existing studies remain fragmented and show variations in their implementation. Therefore, a more systematic review is needed to obtain a comprehensive understanding.

Despite these advancements, challenges remain in the effective implementation of innovative learning approaches. Many educators still face limitations related to technological access, pedagogical knowledge, and classroom management when applying PBL and integrating instructional media [11]. As a result, the adoption of PBL varies widely across different educational contexts. This variation highlights the importance of examining not only the effectiveness of PBL but also the conditions under which it is most successfully implemented.

In addition, the diversity of physics topics presents unique challenges and opportunities for the application of PBL. Certain topics, such as mechanics and dynamics, are more frequently explored due to their strong connection to real-life phenomena. However, other areas, including modern physics and abstract theoretical concepts, require different instructional strategies and supporting media to facilitate understanding. This diversity suggests that the effectiveness of PBL may depend on the characteristics of the subject matter being taught.

Although many studies have been conducted, gaps still exist in the literature regarding trends and characteristics of PBL implementation in improving critical thinking skills. Several studies focus only on effectiveness without examining distributions across educational levels, instructional media, and physics topics. In addition, limited studies systematically investigate research trends over a specific period. These limitations indicate the need for a systematic literature review.

In addition, a systematic synthesis of existing studies is essential to provide evidence-based insights for both educators and researchers. By identifying patterns, strengths, and limitations in previous research, a systematic review can offer a clearer direction for the development of more effective instructional strategies. Such synthesis also helps bridge the gap between theory and practice by translating research findings into practical implications for classroom implementation. Moreover, understanding these patterns enables stakeholders to make informed decisions regarding the integration of pedagogical approaches and instructional technologies in physics education. Therefore, a comprehensive and structured analysis of the literature is necessary to support the advancement of critical thinking-oriented learning.

Therefore, this study aims to analyze research trends and characteristics related to the implementation of PBL in improving critical thinking skills. Based on this background, this study employs a Systematic Literature Review (SLR) approach to identify and analyze relevant studies. By examining research trends, educational levels, instructional media, and physics topics simultaneously, this study is expected to provide a more comprehensive understanding of PBL implementation and its future research directions.

The research questions proposed in this study are as follows:

1. How are the research trends of Problem-Based Learning in improving critical thinking skills?
2. How is the distribution of studies based on educational levels?
3. How are instructional media used in the implementation of PBL?

4. How are physics topics distributed across the selected studies?

II. METHOD

This study employed a Systematic Literature Review (SLR) method using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach to identify, screen, and select articles for analysis. The literature review process consisted of four main stages: identification, screening, eligibility, and inclusion. This approach was used to ensure that the article selection process was conducted systematically and transparently. The study focused on analyzing trends in the implementation of Problem-Based Learning in improving students' critical thinking skills. In total, 51 articles that met the criteria were analyzed. These articles were obtained through a step-by-step selection process based on the initial search results.

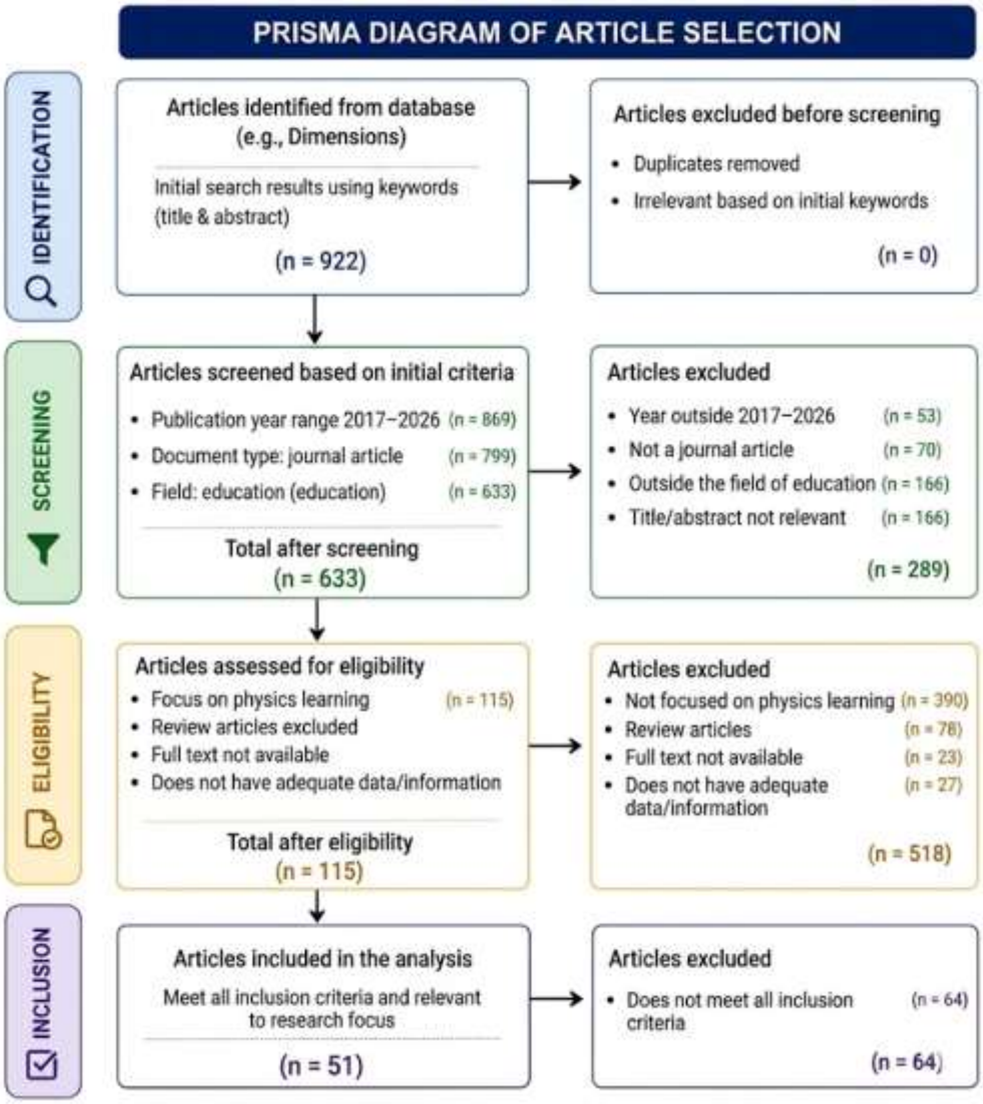

Fig 1. PRISMA Flow Diagram

Identification

The identification stage was conducted by searching articles in the Dimensions database. The search was performed in the title and abstract sections to ensure relevance to the research topic. The keywords used included Problem-Based Learning, Critical Thinking, Effectiveness, as well as educational and physics contexts. Keyword combinations were arranged using Boolean operators such as AND and OR to broaden the search results. The search string consisted of combinations of learning terms, critical thinking skills, and science education contexts. A total of 922 articles were obtained from the identification stage.

Screening

The screening stage was conducted to filter articles based on predetermined initial criteria. This process included limiting the publication years to 2017–2026, resulting in 869 articles. Furthermore, the document type was restricted to journal articles only, reducing the number to 799 articles. The articles were then limited to the field of education, leaving 633 articles. Screening was also conducted by examining the relevance of titles and abstracts to the research topic. This stage aimed to ensure that the selected articles were relevant to the research focus.

Eligibility

In the eligibility stage, a more in-depth evaluation of the article content was conducted. Selected articles were required to have direct relevance to physics learning, resulting in 115 articles. In addition, review articles were excluded from the analysis. Articles lacking sufficient data or information were also excluded. This process was carried out through a more detailed reading of the article contents to ensure alignment with the research variables. This stage was essential for improving the quality of the data to be analyzed.

Inclusion

The final stage was inclusion, in which articles that fully met all research criteria were selected. After completing all selection stages, 51 articles were considered eligible for analysis. These articles were then used as the primary data sources in this study. The data were analyzed descriptively by grouping them based on educational level, learning media, publication year, and physics topics. The analysis results were used to identify research trends and research gaps. Therefore, this study provides a comprehensive overview of research developments related to Problem-Based Learning and critical thinking skills.

III. RESULTS AND DISCUSSION

The findings of this study were organized based on the analysis of 51 articles that met the inclusion criteria. The analysis focused on several main aspects, namely educational levels, the use of learning media, and key findings related to the effectiveness of Problem-Based Learning in improving critical thinking skills. This classification aimed to provide a more systematic overview of the characteristics of the studies that have been conducted. In addition, the analysis was carried out to identify general patterns and trends in the implementation of PBL in physics learning.

Overall, the results indicated variations in the implementation of PBL, both in terms of educational level and the integration of learning media. Several studies implemented PBL conventionally without media support, while others integrated various educational technologies, such as videos, simulations, and interactive multimedia. These differences in approach contributed differently to the improvement of students' critical thinking skills. A summary of these findings is presented systematically in Table 1.

The table shows the distribution of articles based on predetermined categories and summarizes the main findings from each research group. Through this presentation, trends in the dominance of studies at specific educational levels, as well as patterns in the use of learning media in PBL implementation, can be identified. In addition, the table provides an overview of the effectiveness of various approaches used to improve critical thinking skills. Therefore, these findings serve as the basis for further analysis in the discussion section.

Table 1. Summary of PBL Implementation Based on Educational Level, Learning Media, and Main Findings

Author (Code)	Educational Level	Learning Media	Main Findings
[12]	Junior High School	Without Media	PBL improved critical thinking skills; however, its implementation remained limited to simple contexts and basic levels.
[6], [13], [22]–[26], [14]–[21]	Senior High School	Without Media	PBL significantly improved students' critical thinking, analytical skills, and problem-solving abilities across various physics topics.
[5], [27]–[34]	Senior High School	Without Media	PBL supported students' conceptual understanding in physics through contextual problem-solving approaches and improved learning outcomes.
[35]–[37]	Higher Education	Without Media	PBL promoted reflective thinking, scientific argumentation, and complex problem-solving skills among university students.
[38]–[40]	Senior High School	Video-Based Learning	The integration of video into PBL enhanced student engagement and visual conceptual understanding.
[41]–[44]	Senior High School	Simulation (PhET/Virtual)	Interactive simulations strengthened understanding of abstract concepts and improved critical thinking skills.

Author (Code)	Educational Level	Learning Media	Main Findings
[8], [45]–[47]	Senior High School	E-Module / E-Book	Digital learning materials supported independent learning and improved students' critical thinking skills and literacy.
[11], [48]–[50]	Senior High School & Higher Education	Interactive Multimedia	Interactive multimedia enhanced learning interaction, conceptual understanding, and critical thinking skills.
[51]	Senior High School	Game-Based Learning	Educational games increased student motivation, engagement, and critical thinking skills.
[52], [53]	Senior High School	Virtual Lab / AR/VR	Immersive technologies supported the visualization of complex concepts and improved students' conceptual understanding.
[54], [55]	Senior High School	Blended Learning	The combination of online and offline learning strengthened the effectiveness of PBL in improving critical thinking skills.
[56]–[58]	Senior High School	Without Media	The integration of PBL with other approaches (e.g., STEM/inquiry) strengthened critical thinking skills and conceptual understanding.

Publication Trends

The distribution of publications showed an increasing number of studies over time. In the early period, the number of studies discussing Problem-Based Learning and critical thinking skills was relatively limited. This condition began to change in the following periods, with a gradual increase in the number of publications. A significant increase was observed after 2022. This trend is supported by the data distribution presented in Table 2, which shows a sharp rise in the number of publications during the 2023–2024 period. In addition, the number of studies remained high during 2025–2026. These findings indicate that the topic of PBL has continued to develop and has become an important focus in educational research.

Table 2. Publication Year Distribution

Year Range	Frequency	Percentage
2017–2018	3	6%
2019–2020	4	8%
2021–2022	4	8%
2023–2024	22	43%
2025–2026	18	35%
Total	**51**	**100%**

Distribution by Educational Level

The analysis of educational levels revealed an imbalance in research distribution. Most studies were concentrated at the senior high school level. This finding indicates that the implementation of Problem-Based Learning has been more frequently focused on senior high school students compared to other educational levels. The number of studies conducted at the junior high school level remained very limited, as did those conducted at the higher education level. This condition can be seen in the data distribution presented in Table 3, which shows a strong dominance of studies at the senior high school level. This dominance may be attributed to the alignment between the characteristics of physics materials and students' cognitive abilities at this educational stage. Therefore, further studies at other educational levels are still needed to provide a more comprehensive understanding.

Table 3. Distribution by Educational Level

Educational Level	Frequency	Percentage
Junior High School	1	2%
Senior High School	45	88%
Higher Education	4	8%
Total	**51**	**100%**

Distribution by Learning Media

The use of learning media in the implementation of Problem-Based Learning showed considerable variation. Most studies still used PBL without learning media. This finding indicates that PBL has often been implemented conventionally without technological support. However, several studies have begun integrating technology-based media such as simulations, e-modules, and interactive multimedia. This pattern can be observed in the data distribution shown in Table 4, which highlights the dominance of implementation without media compared to other categories. The use of videos, virtual laboratories, and blended learning remained relatively low. These findings suggest that technology integration in PBL has not yet been optimal and still offers substantial opportunities for further development.

Table 4. Distribution by Learning Media

Kategori Media	Frequency	Percentage
Without Media	30	59%
Video	3	6%
Simulation	4	8%
E-Module / E-Book	4	8%
Interactive Multimedia	4	8%
Game-Based Learning	1	2%
Virtual Lab / AR	2	4%
Blended Learning	2	4%
Total	**51**	**100%**

Distribution by Physics Topics

The physics learning materials used in previous studies showed concentration on specific topics. Most studies focused on dynamics, including concepts related to force, Newton’s laws, and energy. This finding suggests that these topics are considered the most suitable for problem-based approaches. In addition, wave and electromagnetism topics were also relatively common in the reviewed studies. This distribution is clearly presented in Table 5, which shows the dominance of dynamics compared to other physics topics. Meanwhile, topics such as kinematics and fluids had a more limited number of studies. Modern physics topics, such as quantum physics and applied physics materials, were the least frequently investigated. These findings indicate that research has remained concentrated on fundamental topics and has not yet been evenly distributed across all areas of physics.

Table 5. Distribution by Learning Media

Physics Topic	Frequency	Percentage
Kinematics	3	6%
Dynamics	28	55%
Fluid	3	6%
Waves	7	14%
Optic	2	4%
Electricity and Magnetism	6	12%
Quantum Physics	1	2%
Applied Physics	1	2%
Total	**51**	**100%**

The results of this study show that Problem-Based Learning (PBL) consistently has a positive impact on improving critical thinking skills in physics learning. This finding is consistent with previous studies which have shown that PBL enhances analytical skills, problem-solving abilities, and deep conceptual understanding [13]–[17]. In addition, other studies have also emphasized that PBL not only improves cognitive aspects but also encourages students’ active engagement in the learning process [38]–[40]. Therefore, it can be stated that the effectiveness of PBL in enhancing critical thinking skills is supported by substantial empirical evidence. However, this study provides a broader perspective by highlighting the distribution and characteristics of PBL implementation across various variables.

One of the main findings of this study is the dominance of PBL implementation at the senior high school level. This result supports previous findings which suggest that PBL is more effective when applied to students with more advanced abstract thinking abilities [27]–[29]. At this level, students are able to connect concepts with contextual problems in a more complex manner. Meanwhile, the limited number of studies at the junior high school level indicates that the implementation of PBL at earlier stages remains suboptimal. This condition contrasts with studies that emphasize the importance of developing critical thinking skills from an early age. Therefore, a gap exists between the potential application of PBL across all educational levels and the current research focus.

From the perspective of instructional media, the results of this study indicate that most studies still apply PBL without the support of learning media. This finding suggests that PBL tends to be implemented in a conventional manner. This condition is in line with studies showing that PBL remains effective even without media support [13], [14], [18]. However, other studies show that the integration of media such as videos [38], [39], simulations [41]–[43], and e-modules [8], [45] can significantly enhance the effectiveness of PBL. These media help students understand abstract concepts and increase engagement in learning. Therefore, although conventional PBL is already effective, technology integration provides significant added value.

Furthermore, the use of technology-based media such as simulations and interactive multimedia shows great potential in supporting physics learning. Previous studies have demonstrated that simulations such as PhET improve the understanding of concepts that are difficult to visualize [41], [44]. Similarly, interactive multimedia enhances learning interaction and student engagement [11], [49], [50]. However, the results of this study indicate that the use of such media remains limited compared to PBL without media. This finding reveals a gap between the advancement of educational technology and its implementation in research practice. In other words, the potential of technology has not been fully utilized in PBL implementation.

In terms of learning materials, this study shows that most studies focus on dynamics topics. This finding is consistent with previous research which states that force and Newton's laws are well suited for problem-based approaches due to their contextual and applicable nature [27], [31]. However, other topics such as modern physics, optics, and fluids are still underrepresented [32], [57]. This condition indicates that research remains concentrated on specific topics and has not yet covered the full spectrum of physics concepts. This gap represents an important opportunity for future research.

Based on these findings, this study provides a novel contribution by presenting a comprehensive analysis of trends, distributions, and characteristics of PBL research in improving critical thinking skills. Unlike previous studies that primarily focus on effectiveness, this study integrates various aspects such as educational level, instructional media, and physics topics into a systematic analysis. Therefore, this study not only reinforces previous findings but also expands the understanding of how and in what contexts PBL is most effective.

In addition, this study identifies several research gaps that remain open. First, the limited number of studies at the junior high school and higher education levels indicates the need for further exploration. Second, the low integration of technology-based instructional media suggests that technology integration in PBL is still not optimal. Third, the uneven distribution of learning topics shows that many physics topics have not been explored within the PBL context. Therefore, future research is expected to develop more innovative PBL approaches that are integrated with technology and are applied across various educational levels and learning materials.

IV. CONCLUSION

This study aims to analyze the trends and effectiveness of Problem-Based Learning (PBL) in improving critical thinking skills based on a review of 51 articles published over the past ten years. The findings show that PBL consistently is effective in enhancing students' critical thinking skills, including analysis, problem-solving, and conceptual understanding. However, the implementation of PBL remains dominated at the senior high school level and is mostly conducted without the integration of technology-based instructional media. In addition, the distribution of studies indicates that research focus is still concentrated on specific topics, particularly dynamics, compared to other areas of physics.

These findings address previously identified research gaps, particularly the lack of comprehensive studies that not only evaluate the effectiveness of PBL but also analyze its implementation trends based on educational level, instructional media, and physics topics. This study contributes by providing a comprehensive overview of PBL implementation patterns and identifying underexplored areas. Therefore, this study not only reinforces existing empirical evidence regarding the effectiveness of PBL but also expands the understanding of its application in physics education contexts.

Nevertheless, this study has several limitations. First, the number of analyzed articles is limited to 51 studies that meet the inclusion criteria, which may not fully represent all relevant global research. Second, the analysis is descriptive in nature and is based on a systematic literature review without quantitative effect size calculations such as meta-analysis. Third, variations in research design across the included studies may affect the generalizability of the findings. Therefore, the results of this study should be interpreted with consideration of these limitations.

Based on the findings and limitations, several recommendations are proposed. First, educators are encouraged to integrate PBL with various technology-based instructional media such as simulations, interactive multimedia, and virtual laboratories to enhance learning effectiveness. Second, future researchers are expected to expand investigations at educational levels that remain underexplored, such as junior high school and higher education. Third, further development of PBL is needed across a wider range of physics topics, including modern physics and optics.

For future research, it is recommended to employ meta-analysis approaches to quantitatively measure the magnitude of PBL's impact on critical thinking skills. In addition, future studies may explore the integration of PBL with emerging educational technologies such as augmented reality, artificial intelligence, and adaptive learning systems. Longitudinal studies are also needed to examine the long-term impact of PBL on students' critical thinking development. Therefore, future research is expected to provide more in-depth and comprehensive contributions to the advancement of problem-based learning in physics education.

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