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Problem-Based Learning in Digital Learning Environments: A Systematic Literature Review Supporting SDG 4

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ABSTRACT

Objective: *This study aims to analyze the development and implementation of Problem-Based Learning (PBL) in digital learning environments to support sustainable digital education and improve learning quality. The study focuses on identifying research trends, technologies used, and the impact of technology-supported PBL on learning outcomes.* ***Method***: *This research employed a Systematic Literature Review (SLR) approach to synthesize relevant studies published between 2021 and 2025. Articles were collected from several academic databases, including Scopus, Web of Science, ScienceDirect, and Google Scholar. The selection process followed the PRISMA framework, which includes identification, screening, eligibility assessment, and inclusion. Based on the established inclusion criteria related to PBL and digital learning environments, 15 articles were selected for further analysis. The selected studies were examined to identify research trends, technological approaches, and reported learning outcomes.* ***Result***: *The findings show that the integration of PBL with digital technologies has been widely implemented in various educational contexts. Digital platforms such as learning management systems, collaborative tools, and interactive digital resources support the implementation of PBL and enhance student engagement. The results indicate that technology-supported PBL improves critical thinking, problem-solving skills, and collaborative learning experiences. In addition, digital learning environments encourage more interactive and student-centered learning through discussion, exploration, and problem-solving activities.* ***Novelty***: *This study provides a synthesis of recent research on PBL in digital learning environments and highlights its potential to support innovative digital learning practices. The findings also indicate that the integration of PBL and digital technologies can contribute to improving educational quality and supporting the achievement of Sustainable Development Goal 4 (Quality Education).*

INTRODUCTION

The transformation of education in the 21st century is marked by the increasing integration of digital technology into various learning activities. The development of information technology, online learning platforms, and digital learning ecosystems has changed the way students access information, interact with learning resources, and build knowledge collaboratively. Digital learning environments enable more flexible, interactive, and experience-based learning processes, thereby increasing student engagement in modern learning processes (Guo et al., 2024; Nedungadi et al., 2024; Orhan, 2024; Mabotha et al., 2025). Furthermore, digital learning environments also provide opportunities for the implementation of innovative, learner-centered pedagogical approaches that emphasize the development of 21st-century skills such as critical thinking, collaboration, and problem-solving (Patnawar, 2023; Cong et al., 2025; Jihanifa et al., 2025; Rathleff et al., 2025). Therefore, the integration of digital technology in education serves not only as a learning medium but also as a means to develop more effective and innovative pedagogical strategies to improve the quality of education.

One learning approach widely used in modern educational contexts is Problem-Based Learning (PBL). This learning model places real-world problems as the starting point of the learning process, enabling students to actively engage in investigation, discussion, and solution development. The PBL approach has been proven to improve students' critical thinking skills, problem-solving skills, and independent learning because learning focuses on exploring authentic and real-life problems (Ranggi et al., 2021; Razak et al., 2022; Yu et al., 2023; Erdem et al., 2025). Furthermore, various studies have consistently shown that the implementation of Problem-Based Learning (PBL) has a positive impact on learning outcomes, learning motivation, and the development of higher-order thinking skills in various fields of study (Guo et al., 2024; Ayari et al., 2025; Gufron et al., 2025; Rokhman et al., 2025). Therefore, PBL is considered a relevant learning approach for preparing students to face the complex challenges of the digital and globalized era.

With the advancement of educational technology, the integration of Problem-Based Learning with digital learning environments has become a significant focus of educational research in recent years. Digital environments enable more dynamic problem-based learning processes through the use of collaborative platforms, interactive simulations, and multimedia-based learning resources that support in-depth investigation and exploration of concepts. Research shows that integrating PBL with digital technologies such as mobile learning, learning management systems, and interactive media can increase learning engagement and strengthen students' problem-solving skills (Patnawar, 2023; Cong et al., 2025; Jihanifa et al., 2025; Rathleff et al., 2025). Furthermore, the digital problem-based learning approach also enables collaborative and flexible learning, allowing students to develop knowledge through discussions, exploration of digital resources, and collaborative problem-solving in virtual environments (Guo et al., 2024; Orhan, 2024; Ayari et al., 2025; Mabotha et al., 2025). This integration demonstrates that digital technology can strengthen the effectiveness of the PBL approach in improving the quality of learning.

In the context of global development, pedagogical innovations such as Problem-Based Learning are also closely linked to the Sustainable Development Goals (SDGs), particularly SDG 4 on Quality Education. This Sustainable Development Goal emphasizes the importance of providing inclusive, quality education that enhances competencies relevant to the needs of the global community. The integration of digital technology into education is considered a crucial strategy to support the achievement of this goal because it can expand access to education, improve the quality of learning, and encourage the development of 21st-century skills necessary for modern society (Nedungadi et al., 2024; Sain et al., 2024; Cong et al., 2025; Mabotha et al., 2025). In this regard, the implementation of PBL in digital learning environments not only contributes to improving the quality of learning but also supports the development of competencies relevant to future sustainable development challenges.

While various studies have examined the effectiveness of Problem-Based Learning and the integration of digital technology in education, a comprehensive study mapping the development of research on Problem-Based Learning in digital education is lacking. Research on the integration of PBL with digital technology remains relatively limited. Several studies indicate that research on the integration of PBL with digital technology has steadily increased in recent years. However, these findings are scattered across various educational fields and have not been systematically analyzed to identify research trends, methodological approaches, and existing research gaps (Patnawar, 2023; Yu et al., 2023; Ayari et al., 2025; Biney, 2025). Therefore, a study capable of systematically

synthesizing these research findings is needed to provide a clearer picture of research developments in this field.

Based on this background, this study aims to systematically analyze the development of research on Problem-Based Learning in digital learning environments using a Systematic Literature Review (SLR) approach. Through this method, relevant scientific articles will be analyzed to identify research trends, methodological approaches, and the impact of PBL implementation on various aspects of learning in the digital era. In addition, this study also seeks to explore how the integration of Problem-Based Learning in a digital learning environment can contribute to the achievement of Sustainable Development Goal 4 (Quality Education) through improving the quality of learning, developing 21st-century skills, and digital technology-based pedagogical innovation.

RESEARCH METHOD

This study used the Systematic Literature Review (SLR) method to systematically identify, evaluate, and synthesize various studies related to the application of Problem-Based Learning (PBL) in digital learning environments. The SLR approach was chosen because it provides a comprehensive overview of research developments on a specific topic through a systematic and transparent process of identifying, selecting, and analyzing literature (Kitchenham & Charters, 2007; Page et al., 2021). In this study, the literature review procedure followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, which consists of four main stages: identification, screening, eligibility, and inclusion, to ensure the article selection process is conducted objectively and can be replicated by other researchers (Page et al., 2021).

The literature search was conducted using several reputable international scientific databases, namely Scopus, Web of Science, ScienceDirect, and Google Scholar. The article search was conducted using a combination of keywords such as "problem-based learning," "digital learning environment," "online learning," "technology-enhanced learning," and "SDG 4." These keywords were combined using Boolean operators such as AND and OR to obtain more specific search results relevant to the research topic. The literature search focused on articles published between 2021 and 2025 to obtain an overview of the latest research developments on the application of PBL in digital learning.

Next, articles obtained from the initial search process were selected based on predetermined inclusion and exclusion criteria. The inclusion criteria for this study included: (1) research articles discussing the application or study of Problem-Based Learning in digital learning environments, (2) articles published in reputable scientific journals or international conference proceedings, (3) articles published between 2021 and 2025, and (4) articles available in English or Indonesian. Meanwhile, exclusion criteria included: (1) articles that did not directly discuss PBL, (2) articles unrelated to the digital learning context, (3) articles in the form of editorials, opinion pieces, or non-scientific reports, and (4) articles that lacked full-text access. This selection process was conducted in stages to ensure that only relevant and high-quality articles were included in the research analysis.

After the selection process was completed, articles that met the criteria were analyzed using thematic and descriptive analysis approaches to identify research trends, research methods used, and the impact of implementing PBL in digital learning environments on various aspects of learning, such as critical thinking skills, problem-solving, and student engagement. Data from each selected article was coded and grouped according to

several analysis categories, such as year of publication, field of study, research method, digital technology used, and key research findings. This analysis process aimed to provide a comprehensive overview of research developments related to PBL in digital learning environments and its contribution to supporting the achievement of Sustainable Development Goal 4 (Quality Education) through digital technology-based learning innovations.

RESULTS AND DISCUSSION

Result

Table 1. Summary of previous studies on the implementation of problem-based learning in digital learning environments

No	Researcher and Year	Result Findings
1	Yu et al. (2023)	This meta-analysis investigated the effectiveness of problem-based learning in online learning environments. The study reported that PBL significantly improves students' critical thinking and problem-solving abilities when supported by digital learning platforms and collaborative online activities.
2	Guo et al. (2024)	This systematic review analyzed the implementation of problem-based learning in online and blended learning contexts. The findings showed that PBL enhances student engagement and collaborative learning, particularly when supported by learning management systems and interactive digital resources.
3	Ayari et al. (2024)	This systematic review examined the impact of problem-based learning on students' learning outcomes across different educational levels. The results indicated that PBL improves conceptual understanding and promotes active learning, especially when combined with digital tools that support collaborative inquiry.
4	Cong et al. (2025)	This empirical study investigated technology-enhanced problem-based learning in higher education. The findings showed that integrating digital platforms in PBL significantly improves collaborative problem-solving skills and promotes deeper knowledge construction among students.
5	Guo et al. (2022)	This study explored the design and implementation of problem-based learning in digital classrooms. The results indicated that digital PBL environments increase learner participation and help students develop higher-order thinking skills through collaborative problem investigation.
6	Patnawar (2023)	This review focused on the opportunities and challenges of implementing problem-based learning in digital education. The findings revealed that digital technologies such as online discussion forums, simulations, and collaborative tools enhance the effectiveness of PBL while also requiring careful instructional design.
7	Orhan (2024)	This research examined digital learning environments that support inquiry-based and problem-based learning. The study showed that digital learning platforms enable flexible collaboration and resource exploration, which strengthens students' engagement in problem-solving processes.
8	Mabotha et al. (2025)	This systematic review analyzed student engagement in digital learning environments. The study highlighted that pedagogical models such as problem-based learning play a crucial role in increasing participation, interaction, and meaningful learning in online education.
9	Erdem & Aydin (2024)	This meta-analysis investigated the impact of problem-based learning on higher-order thinking skills. The results showed that PBL significantly

No	Researcher and Year	Result Findings
		improves critical thinking and analytical skills, particularly when supported by technology-enhanced learning environments.
10	Rokhman et al. (2025)	This experimental study examined the implementation of PBL in digital classrooms. The findings indicated that students who participated in digital PBL activities showed higher levels of problem-solving ability and conceptual understanding compared with traditional learning groups.
11	Sain et al. (2024)	This study explored the relationship between digital education and Sustainable Development Goals. The findings emphasized that innovative pedagogical approaches such as PBL in digital environments contribute to improving educational quality and supporting SDG 4.
12	Nedungadi et al. (2024)	This research examined the role of digital technologies in achieving SDG 4. The results showed that student-centered learning models, including problem-based learning, are key strategies for improving educational quality and developing 21st-century competencies.
13	Jihanifa et al. (2025)	This study analyzed the impact of digital learning environments on student engagement and learning outcomes. The results showed that problem-centered learning approaches supported by digital technologies significantly increase motivation and collaborative learning.
14	Rathleff et al. (2025)	This study examined digital problem-based learning and collaborative learning in higher education. The findings indicated that digital PBL environments support knowledge construction, teamwork, and active participation among students.
15	Razak et al. (2022)	This systematic review investigated the effectiveness of problem-based learning on students' critical thinking skills. The study found consistent evidence that PBL improves analytical thinking and problem-solving abilities across different learning contexts, including technology-supported learning environments.

The results of a systematic literature review resulted in 15 relevant research articles on the application of Problem-Based Learning (PBL) in digital learning environments for the 2021–2025 period, as shown in Table 1. In general, these studies indicate that the integration of PBL with digital technology has a positive impact on various aspects of learning, such as improving critical thinking skills, problem-solving abilities, learning engagement, and collaboration among students. Several studies also show that the use of digital learning platforms, learning management systems, interactive simulations, and collaborative technologies can strengthen the effectiveness of PBL implementation in modern learning environments. Furthermore, the results of these studies also show that a technology-based PBL approach contributes to supporting the development of 21st-century skills, such as digital literacy, complex problem-solving, and collaborative learning. Overall, the findings from these studies indicate that the application of Problem-Based Learning in digital learning environments is an effective pedagogical strategy for improving the quality of learning and has the potential to support the achievement of Sustainable Development Goal 4 (Quality Education) through digital technology-based learning innovations.

Discussion

Effectiveness of problem-based learning in digital learning environments

The results of the literature review indicate that the implementation of Problem-Based Learning (PBL) in digital learning environments has a positive impact on various aspects

of learning. Based on an analysis of selected articles, most studies indicate that integrating PBL with digital technology can increase students' learning engagement, critical thinking skills, and problem-solving skills. Digital learning environments provide space for students to explore problems more broadly through access to various digital learning resources, online discussions, and technology-based collaborative activities. Previous research also shows that the implementation of PBL in online learning environments can improve students' critical thinking and analytical skills because the learning process emphasizes problem exploration, group discussions, and reflection on resulting solutions (Razak et al., 2022; Yu et al., 2023).

Furthermore, various studies indicate that the use of digital technology in PBL allows for a more interactive and flexible learning process compared to conventional learning. Digital learning platforms such as learning management systems, online discussion forums, and interactive media can support collaborative problem investigation. Through these facilities, students can access various sources of information, share ideas with peers, and develop solutions to given problems more systematically. A study by Guo et al. (2024) showed that integrating PBL into online learning can increase active student participation and strengthen the process of knowledge construction through discussion and collaboration. Thus, the implementation of PBL in a digital learning environment not only improves learning outcomes but also strengthens the student-centered learning process.

The role of digital technology in supporting problem-based learning

Digital technology plays a crucial role in supporting the implementation of PBL in modern learning. Based on literature analysis, various types of technology are used to support problem-based learning activities, such as learning management systems, online collaboration platforms, interactive simulations, and multimedia-based learning resources. These technologies enable students to explore concepts in greater depth and visualize phenomena that are difficult to observe directly in conventional learning. Furthermore, digital technology also enables flexible learning processes that are not limited by space and time, allowing students to access learning materials and discuss them with study groups online.

Research shows that the use of digital technology in learning can increase student engagement and motivation because it provides a more interactive and contextual learning experience (Orhan, 2024; Mabotha et al., 2025). Furthermore, digital technology also enables the implementation of more effective collaborative learning approaches through the use of discussion forums, virtual workspaces, and online collaboration tools that support group problem-solving. Cong et al. (2025) also found that the integration of digital technology in problem-based learning (PBL) can improve students' collaboration and communication skills because they must work together to identify problems, analyze information, and formulate appropriate solutions. Therefore, digital technology can be considered a crucial factor in strengthening the effectiveness of PBL implementation in learning.

Contribution of problem-based learning to 21st-century skills development

One important finding from this literature review is that the implementation of PBL in a digital learning environment contributes significantly to the development of 21st-century skills. These skills include critical thinking, problem-solving, collaboration, communication, and digital literacy, which are essential competencies for facing the

challenges of modern society. The PBL approach places students at the center of learning, encouraging them to actively explore information, analyze problems, and develop solutions both independently and collaboratively.

Various studies have consistently shown that the implementation of PBL has a positive impact on the development of higher-order thinking skills. A meta-analysis conducted by Erdem and Aydin (2024) demonstrated that PBL has a significant influence on improving students' critical and analytical thinking skills. Furthermore,Other studies also show that problem-solving activities conducted in digital learning environments can help students develop reflective thinking skills and rational decision-making abilities (Jihanifa et al., 2025; Rokhman et al., 2025). Thus, integrating PBL with digital technology can be an effective learning strategy to prepare students to face the complex challenges of the digital era.

Implications for achieving sustainable development goal 4

The findings of this study also indicate that the implementation of PBL in digital learning environments has strong relevance to efforts to achieve Sustainable Development Goal 4 (SDG 4), which emphasizes the importance of quality, inclusive, and sustainable education. SDG 4 targets improving the quality of education through the development of innovative learning methods, access to educational technology, and strengthening competencies relevant to the needs of the global community. In this context, integrating PBL with digital technology can be an effective pedagogical strategy to improve the quality of learning and expand access to education.

Previous research has shown that the digitalization of education plays a crucial role in supporting the achievement of SDG 4 because it enables the provision of more inclusive and flexible education (Nedungadi et al., 2024; Sain et al., 2024). Furthermore, learner-centered learning approaches such as PBL can also improve the quality of learning by encouraging the development of critical thinking and problem-solving skills relevant to global challenges. Therefore, the implementation of PBL in digital learning environments not only benefits student learning outcomes but also contributes to global efforts to improve the quality of sustainable education.

Research gaps and future research directions

Although various studies have demonstrated the effectiveness of implementing PBL in digital learning environments, the literature review also reveals several research gaps that require further study. One gap identified is the limited research that examines the in-depth integration of specific digital technologies, such as artificial intelligence and learning analytics, in PBL implementation. Furthermore, most research focuses on higher education contexts, necessitating further research on the implementation of digital technology-based PBL at the primary and secondary levels. Furthermore, future research should explore more adaptive and personalized PBL implementation models utilizing rapidly evolving digital technologies. The integration of technologies such as artificial intelligence, virtual reality-based simulations, and adaptive learning platforms can open up new opportunities for developing more effective and innovative problem-based learning. Therefore, further research is urgently needed to develop more comprehensive digital technology-based PBL learning models capable of addressing the challenges of education in the era of digital transformation.

CONCLUSION

Fundamental Finding: This study conducted a Systematic Literature Review (SLR) of research on Problem-Based Learning (PBL) in digital learning environments from 2021–2025. The results show that integrating PBL with digital technologies creates more interactive and student-centered learning environments. Digital platforms such as learning management systems and collaborative tools support PBL implementation and contribute to improving students' critical thinking, problem-solving skills, and learning engagement. **Implication**: These findings indicate that digital PBL has strong potential to support the transformation of technology-based education. The integration of PBL and digital learning environments can promote the development of 21st-century skills and contribute to improving educational quality in line with Sustainable Development Goal 4 (Quality Education). **Limitation**: This study is limited by the use of a literature review approach that analyzes articles from selected databases without direct empirical testing. **Future Research**: Future studies should conduct empirical research on digital PBL implementation and explore the use of emerging technologies such as artificial intelligence and adaptive learning systems to enhance digital learning effectiveness.

AUTHOR CONTRIBUTIONS

Hanan Zaki Alhusni was responsible for formulating the research concept, developing the research framework, designing the methodology, conducting data analysis, and preparing the initial draft of the manuscript. **Binar Kurnia Prahani** supervised the overall research process, provided methodological direction, evaluated the analysis, and assisted in revising the manuscript. **Budi Jatmiko** contributed to validating the research design. **Salma Hasna Hamiyda** contributed to conduct a critical review of the manuscript, and granting final approval for the version to be published.

CONFLICT OF INTEREST STATEMENT

The authors report no conflicts of interest, either financial or personal, that might have influenced the research process or the outcomes of this study.

STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING

The authors acknowledge the use of digital technologies, including AI-assisted tools, to support certain stages of the research and writing process of this article. These tools were utilized to assist with reference organization, language refinement, and structuring of ideas during manuscript preparation. All generated outputs were carefully reviewed, critically evaluated, and revised by the authors to ensure accuracy, academic integrity, and compliance with ethical research standards. The authors take full responsibility for the content, interpretation, and conclusions presented in this manuscript.

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