



## Learning Strategies of Problem-Based Learning and Project-Based Learning on Students' Programming Skills: A Bibliometric Analysis and Systematic Literature Review

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# Learning Strategies of Problem-Based Learning and Project-Based Learning on Students' Programming Skills: A Bibliometric Analysis and Systematic Literature Review

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## Abstract

The increasing demand for programming logic skills in the era of digital transformation has driven this study to identify and analyze effective learning strategies for their development. This research focuses on the implementation of Problem-Based Learning (PBL) and Project-Based Learning (PjBL) approaches, which are considered essential for enhancing problem-solving, analytical, and developmental processes in programming education. A Systematic Literature Review (SLR) combined with bibliometric analysis was employed to examine relevant studies published between 2020 and 2025. The PRISMA guidelines were applied to select the literature, and data sources were collected using the Publish or Perish (PoP) application. A total of 32 articles met the inclusion criteria and were subsequently analyzed using VOSviewer software to identify research trends, patterns of collaboration among researchers, and keyword co-occurrence networks. The findings indicate that PBL- and PjBL-based learning strategies are effective in improving students' understanding of programming logic, particularly in enhancing creativity, problem-solving abilities, and critical thinking skills. These findings are expected to serve as a foundation for the development of curricula and instructional innovations in programming education that are more responsive to the demands of the digital era.

**Keywords:** Programming; Learning Strategies; *Problem-Based Learning* (PBL); *Project-Based Learning* (PjBL)

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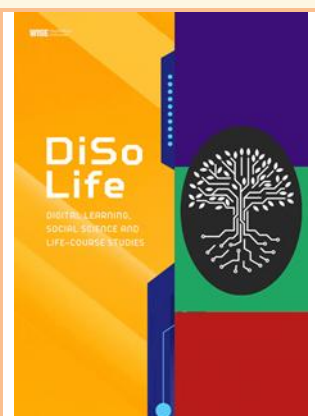
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## INTRODUCTION

In the current era of digital transformation, programming logic skills are critically important for university students, as they enable the development of efficient software solutions and data analysis processes [1]. Programming ability represents a combination of cognitive functions and logical thinking skills employed to solve complex problems [2]. These competencies not only enhance graduates' employability but also equip them to address sophisticated challenges in the information technology industry, where the demand for professionals with strong computational thinking skills continues to grow [3]. However, insufficient computational thinking abilities and an overreliance on trial-and-error approaches without a solid conceptual foundation have led many students to experience significant difficulties in understanding fundamental concepts of logic and algorithms [4]. This condition often results in low academic achievement in introductory programming courses, with failure rates reaching 30–40% across various universities in Indonesia [5].

The primary factors contributing to students' difficulties in mastering programming logic include conventional teaching approaches that excessively emphasize programming syntax, a lack of interactive instructional materials such as e-modules, and limited integration of authentic problem-based projects [6]. Additional factors involve weak mathematical foundations and inadequate computational thinking skills among novice learners, which frequently hinder their comprehension of core concepts such as algorithms and data structures [7]. Nevertheless, only a limited number of studies have specifically examined bibliometric analyses and Systematic Literature Reviews (SLRs) addressing the implementation of Problem-Based Learning (PBL) strategies for developing students' programming logic skills. Moreover, although several literature reviews and small-scale analyses have attempted to synthesize evidence related to programming education, a robust methodological consensus and comprehensive bibliometric mapping that specifically highlights learning strategies for programming logic remain unavailable [8]. Consequently, existing studies have not yet been fully positioned within a coherent framework of thematic development, leading authors, or topic clusters [1]. Furthermore, variations in research design, sample size, and outcome indicators have made the findings difficult to generalize broadly across different academic programs [5].

Learning strategies refer to a set of actions or pedagogical approaches designed to achieve specific learning objectives effectively and efficiently [9]. The educational process is inherently complex, as it involves dynamic interactions among educators, learners, and the instructional media employed [10]. In the context of higher education, numerous empirical studies have examined the effectiveness of various learning approaches and instructional methods in enhancing students' programming logic skills [11]. For instance, a study by [12] reported that Problem-Based Learning (PBL) significantly improved students' understanding of object-oriented programming concepts in an Information Technology Education program. Furthermore, several instructional material development studies have demonstrated that the use of Problem-Based Learning (PBL)-based e-modules in programming courses can enhance students' critical thinking skills while deepening their conceptual understanding [13].

Problem-Based Learning (PBL) is a student-centered instructional approach in which learners are confronted with real-world problems as the starting point of the learning process. Through this method, students work collaboratively in groups to conduct investigations, independently formulate learning objectives, seek relevant information, engage in discussion, and develop solutions to the given problems [14]. The primary aim of PBL is to enhance critical

thinking, problem-solving abilities, communication skills, collaboration, self-directed learning, and knowledge retention [15]. In contrast, Project-Based Learning (PjBL) emphasizes active student engagement in authentic projects designed to address complex real-world problems. Through these projects, students not only acquire theoretical knowledge but also develop critical thinking, collaborative, and creative skills in producing meaningful products or solutions [16]. In programming education, PjBL has been shown to improve students' conceptual understanding and technical competencies by requiring them to apply programming logic within technology-based projects. For example, a study by [17] required students to develop web-based applications using Python and Django to support small businesses in managing inventory. The results demonstrated that the implementation of PjBL significantly enhanced students' programming skills, as well as their teamwork and communication abilities. These findings are consistent with previous research [16] which suggests that project-based learning encourages continuous investigation of real-world problems, thereby strengthening students' problem-solving and critical thinking skills in programming contexts. Consequently, project-based instructional strategies, particularly Project-Based Learning (PjBL), have been widely examined as alternative pedagogical approaches in which students are given opportunities to design and implement practical projects as a means of learning programming. Such approaches have been shown to increase student motivation, collaborative capacity, and proficiency in applying programming logic [18]. Moreover, evidence from higher education indicates that, compared to conventional instructional methods, PBL interventions significantly improve students' critical thinking skills across numerous studies [19].

Based on the foregoing discussion, this study focuses on conducting a Systematic Literature Review (SLR) and bibliometric analysis to examine learning strategies for developing students' programming logic skills. This research aims to map current research trends, identify the most relevant and effective instructional strategies, and provide direction for future studies in the field of programming education.

## METHODS

### *Research Design*

In Indonesian, a Systematic Literature Review (SLR) refers to a systematic review of the literature [20]. An SLR is a literature review method that aims to identify, evaluate, and interpret all relevant findings related to a particular research topic in order to address specific research questions [21].

The primary objective of an SLR is to uncover theories relevant to the research focus and to identify strategies that can be employed to help resolve the issues under investigation. The Systematic Literature Review method consists of five main stages [22].

### *Problem Formulation and Research Question*

The initial stage of this study involves formulating the research problem by identifying the difficulties faced by students in understanding programming logic, as well as the variations in learning strategies implemented by educators. Although numerous studies have examined programming learning strategies, existing findings remain fragmented, and no comprehensive review has yet mapped research trends and evaluated the effectiveness of these strategies, particularly in the context of higher education students. Therefore, this study adopts a Systematic Literature Review (SLR) approach combined with bibliometric analysis to address the following research questions:

**RQ1:** What learning strategies have been implemented to enhance students' understanding of programming logic?

### *Literature Search and Identification*

The second stage involves the process of searching for and identifying relevant literature, which includes retrieving journals and scholarly articles through various academic databases, such as Publish or Perish to access articles indexed in Google Scholar. This process is further complemented by manual searches across multiple online academic journal portals. This approach is intended to ensure that the collected literature is highly relevant to the research topic and encompasses a wide range of recent publications. At this stage, the study employs a research design based on data analysis and synthesis methods that focus on findings from previous studies. This process aims to summarize content, draw conclusions, and establish a conceptual foundation for research planning. The collected literature consists of theories, articles, and research journals from diverse sources, which serve as the basis for discussion in subsequent stages [23].

### *Literature Selection and Quality Assessment*

The third stage, literature selection, involves determining whether the identified journals or articles are suitable for inclusion as analytical materials in the study. At this stage, the researchers apply inclusion and exclusion criteria to ensure that only relevant and high-quality literature is analyzed.

**QA1:** Were the selected journals published between 2020 and 2025?

Based on this criterion, the study analyzes the collected journal data according to predefined selection parameters, namely publication years between 2020 and 2025 and primary topics focusing on programming logic learning strategies, the enhancement of students' understanding of programming logic, or the implementation of innovative approaches in introductory programming instruction.

### *Source Quality and Relevance Control*

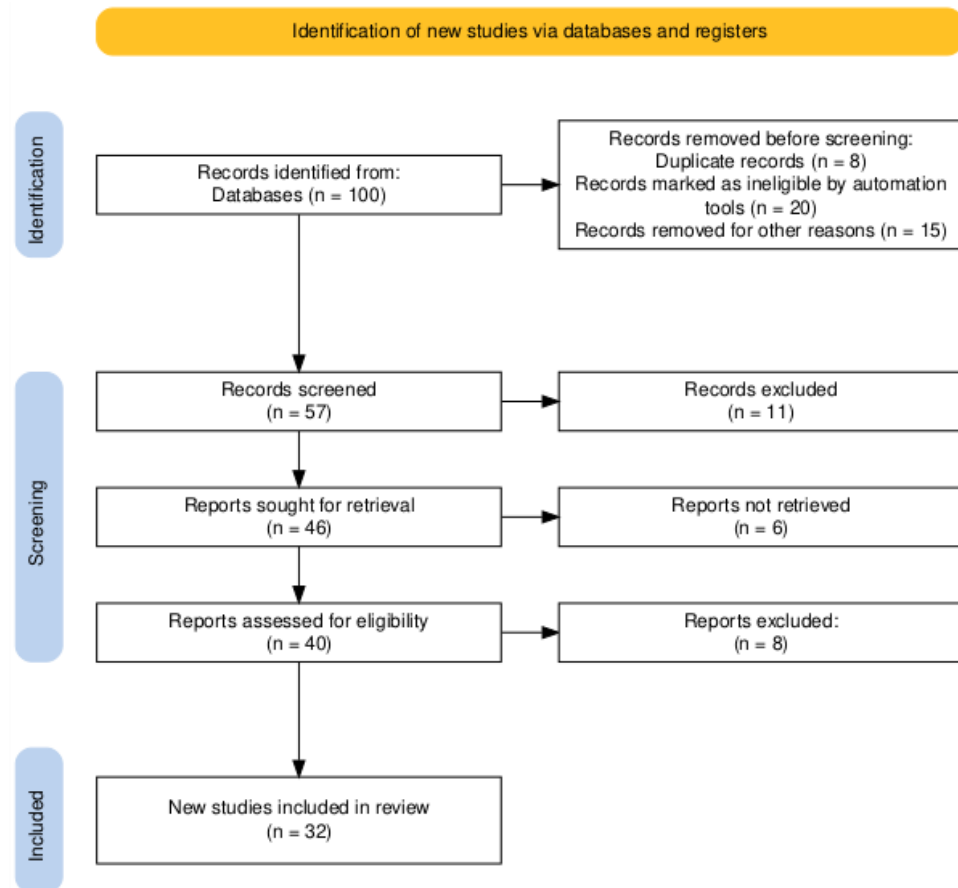
The fourth stage aims to ensure that the journals or articles included in this study demonstrate high quality and strong relevance to the topic under investigation. At this stage, the researchers selected literature obtained from reputable and internationally recognized academic sources, such as SINTA-indexed journals and articles retrieved through Publish or Perish. In addition, only articles published between 2020 and 2025 were included to ensure that the discussion reflects the most recent developments in learning strategies for programming logic among higher education students

### *Data Analysis and Bibliometric Visualization*

This study employs VOSviewer software for bibliometric visualization. VOSviewer is used to generate network visualizations that facilitate the understanding of relationships among selected scientific articles [24]. The study applies a co-occurrence analysis method to examine relationships among articles based on four categories of textual keywords appearing in article titles and abstracts. VOSviewer provides several types of visualizations: (1) network visualization, which illustrates relationships among journal topics based on titles and keywords; (2) overlay visualization, which depicts relationships between research topics and publication years; and (3) density visualization, which aims to identify the most frequently and least frequently discussed subjects through heat maps [25][26].

### *PRISMA Protocol and Study Selection Process*

The guidelines for this systematic review were developed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. In this process, the researchers collected, screened, and analyzed a range of scientific publications that discuss the implementation of Problem-Based Learning (PBL) and Project-Based Learning (PjBL) strategies and their effects on students' programming skills.



**Figure 1.** PRISMA Flow Diagram (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)

By applying the PRISMA flow diagram, this analysis examines the existing literature to identify research topics and types of problem-based learning strategies that influence students' programming abilities. The PRISMA diagram illustrates the sequential process of article selection, beginning with identification, followed by screening, eligibility assessment, and finally inclusion in the systematic review.

### *Identification*

At this stage, the researchers conducted an initial identification of all articles related to the research topic concerning problem-based learning strategies (PBL) and their impact on students' programming skills. A total of 100 articles were identified through searches across multiple databases and reference lists. Prior to further screening, several articles were removed for various reasons: eight duplicate records, 20 articles that did not meet automatic eligibility criteria (e.g., not published in scholarly journals or not relevant to the research topic), and 15 articles excluded due to limited access or inappropriate language. After this initial removal process, 57 articles remained for further examination.

### Screening

At this stage, titles and abstracts were reviewed to ensure alignment with the research focus. Of the 57 screened articles, 46 were considered relevant to the topic, while 11 were excluded for falling outside the scope of the study. Among the remaining 46 articles, six had access issues or could not be downloaded in full. Consequently, only 40 articles were available for further analysis in the next stage.

### Eligibility

During the eligibility stage, a reassessment was conducted, and articles lacking full-text availability were excluded. As a result, eight articles were removed from the initial 40, leaving 32 articles eligible for inclusion in the final review.

### Inclusion

In the final stage, a total of 32 journal articles were selected and evaluated for inclusion in the Systematic Literature Review (SLR).

## RESULTS AND DISCUSSION

### Result of Bibliometric Analysis

This study employs bibliometric analysis to identify recent research trends related to programming logic learning strategies, particularly among higher education students. The analysis visualizes various bibliometric indicators, including the most influential authors, thematic clusters, dominant keywords, and publication distribution patterns across years. Software tools such as VOSviewer and Bibliometrix were utilized to process the data and generate bibliometric maps.

An initial search conducted using the Publish or Perish database revealed a total of 100 research articles published between 2020 and 2025 that address students' programming skills.

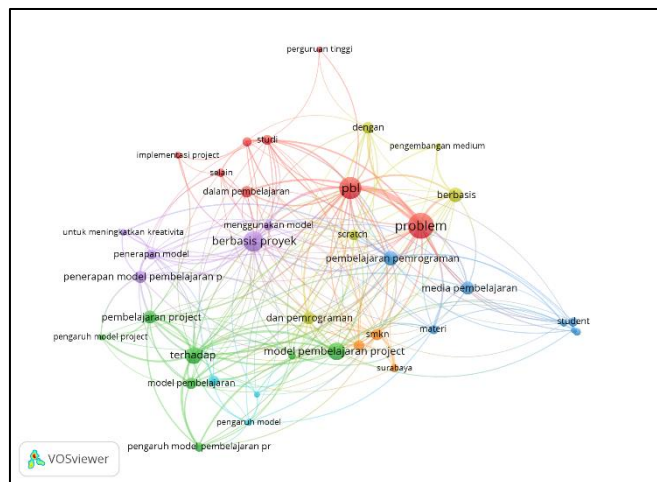


**Figure 2.** Annual Growth of Publications

Based on the publication growth graph depicting studies on programming instruction using Problem-Based Learning (PBL) and Project-Based Learning (PjBL) approaches, fluctuations in the number of publications can be observed across the analyzed years. The graph indicates a significant increase in 2024, with a total of 31 published articles. This peak suggests that 2024 represents the

year with the highest research focus and productivity concerning the integration of PBL and PjBL in programming education.

Furthermore, the bibliometric analysis utilized more than one hundred retrieved articles indexed in Publish or Perish within the 2020–2025 period to identify relationships among research trends and keyword co-occurrences. The resulting network visualization map, generated using VOSviewer, illustrates the interconnections among research themes and keywords, as presented in Figure 3.



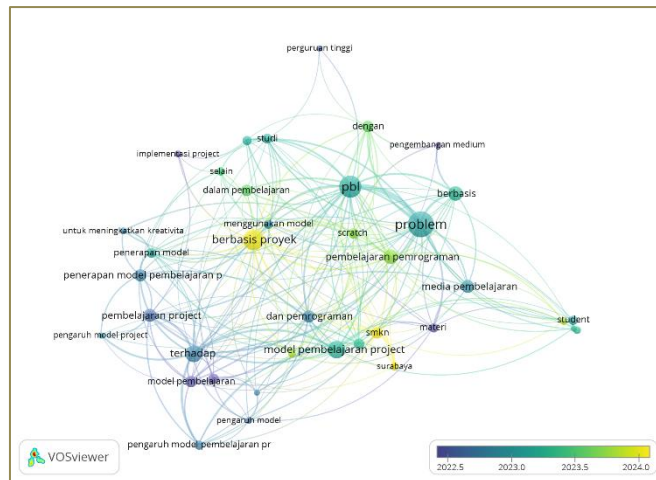
**Figure 3.** Network Visualization Results

Based on the VOSviewer analysis, a total of 38 terms were identified and grouped into seven clusters, with a total link strength of 713. Each cluster represents interrelated themes concerning the implementation of Problem-Based Learning (PBL) and Project-Based Learning (PjBL) in programming education.

The red cluster emphasizes PBL-related themes, featuring core terms such as *PBL*, *problem*, and studies focusing on problem-based instructional strategies. The green cluster relates to the impact of Project-Based Learning, highlighted by terms such as *project learning model* and *project-based learning*. The blue cluster reflects research on learning media and instructional implementation, incorporating terms such as *learning media*, *materials*, and *students*. The yellow cluster represents the use of project-based educational technologies, including terms such as *Scratch* and *project-based*. The purple cluster focuses on the application of innovative learning models aimed at enhancing students’ creativity. The brown cluster illustrates studies emphasizing the objectives and outcomes of implementing learning models. Meanwhile, the orange cluster represents research contexts within vocational education settings, such as *vocational high schools* and specific regional contexts.

Overall, this network map demonstrates strong interconnections between PBL and PjBL approaches in enhancing students’ programming skills and creativity. As shown in Figure 3, PBL and PjBL instructional models play a significant role in improving students’ conceptual understanding, collaborative abilities, and practical skills. These findings are consistent with previous studies [18], which reported that providing students with opportunities to design and implement practical projects as a means of learning programming can increase motivation, collaboration, and proficiency in applying programming logic. This assertion is further supported by findings indicating that PjBL facilitates students’ problem-solving abilities as well as teamwork and creative [27].

Furthermore, Figure 4 indicates a shift in research focus from foundational concepts of project-based learning toward its application in programming education and the enhancement of students' creativity.



**Figure 4.** Keyword Overlay Visualization

The overlay visualization illustrates the evolution of research topics from 2022 to 2024. In the earlier phase, represented by blue–green colors (approximately 2022–2023), research primarily focused on the implementation of Problem-Based Learning (PBL) in programming education. Dominant keywords during this period included *problem*, *PBL*, and *introductory programming*.

Subsequently, keywords such as *project-based learning*, *Scratch*, *creativity*, and *student collaboration* emerged, indicating a shift in research trends toward Project-Based Learning (PjBL) in 2024, as reflected by the yellow color on the visualization. The color transition on the map signifies a shift in research emphasis from problem-based approaches (PBL) to project-based approaches (PjBL). This trend suggests the development of more practical and innovative instructional models aimed at enhancing students' programming skills.

The bibliometric analysis further reveals that research topics related to PBL and PjBL in programming education are predominantly conducted at the vocational education level. This finding indicates that these strategies are more frequently implemented in vocational institutions, while their application in higher education remains relatively limited. Consequently, this study contributes to expanding the scope of PBL and PjBL research within the context of university-level programming education.

### **Result of the Systematic Literature Review**

In this review, the primary focus is placed on Problem-Based Learning (PBL) and Project-Based Learning (PjBL) strategies as efforts to enhance university students' programming skills. The collected articles were sourced from various academic databases, including Publish or Perish (PoP), covering publications from 2020 to 2025. The article selection process emphasized studies that examined the implementation of PBL and PjBL in programming instruction, including analyses of implementation procedures and learning outcomes resulting from these strategies.

The core objective of this review centers on the fundamental question of which instructional methods are most effective in strengthening students' understanding of programming logic. To address this question, the researchers analyzed selected articles using keywords such as *programming* and *learning strategies*. The articles were then evaluated based on topical relevance,

the learning approaches applied (PBL and PjBL), and reported outcomes related to improvements in students' understanding of programming logic.

The following section presents a summary of the research questions formulated at the outset of the study:

**RQ1:** What learning strategies have been implemented to enhance students' understanding of programming logic?

Based on an examination of the 32 articles that successfully passed the selection process in this systematic literature review, several major learning strategies were identified as the most frequently implemented approaches for improving students' programming skills. For example, a study by Hasanah reported that a Problem-Based Learning (PBL)-based instructional module implemented in an Object-Oriented Programming course had a significant effect on students' conceptual understanding of programming, accounting for approximately 40.6% of the observed learning outcomes [28]. The PBL approach emphasizes the resolution of practical problems as a means of fostering students' critical and analytical thinking skills in understanding programming logic. Through PBL, students are encouraged to apply algorithmic concepts and logical structures in meaningful contexts, rather than merely memorizing programming syntax rules. Similarly, findings reported in [27] indicate that the implementation of the PBL model significantly enhances problem-solving skills among Computer Science students in application development tasks.

The results of studies published between 2020 and 2025 consistently demonstrate that PBL and PjBL are more effective in improving students' understanding of programming logic than traditional instructional methods, such as syntax-focused exercises or lecture-based teaching. These improvements are particularly evident in areas related to problem-solving abilities, collaborative skills, and the application of algorithms. Experimental and quasi-experimental studies further reveal that students participating in PBL and PjBL-based learning exhibit higher programming competence and academic achievement. In addition, students report increased motivation and engagement when learning activities are contextualized through real-world problems or projects [29].

**Table 4.** Results of Article Analysis

No	Author(s) (Year)	Learning Strategy	Key Findings
1	I Gede Bendesa Subawa dkk., (2025)	PjBL	Improved students' understanding and engagement. [30]
2	Roig, P. J. (2024)	PjBL	PjBL increased learning achievement and student engagement based on implementation reports and quasi-experimental data.[31]
3	Juanta, P., et al. (2025)	PjBL	Enhanced students' problem-solving skills, teamwork, and creativity. [27]
4	Zainol and Almukadi (2020)	PBL	Reduced the theory–practice gap and improved student engagement in programming learning. [32]
5	Hartono and Dermawan (2021)	PBL	Fostered students' critical thinking skills. [33]
6	Fitria Nur Hasanah (2021)	PBL	Significantly improved students' understanding of programming concepts. [28]
7	Yoem et al. (2022)	PjBL	Enabled students to solve problems, develop collaborative skills, and apply algorithms effectively. [29]
8	Widia Astuti, (2023)	PBL	Improved students' critical and creative thinking skills. [14]

9	Moreno-Palma et al., (2024)	PBL	Enhanced students' unplugged computational thinking, supported by quantitative improvements in competency scores. [17]
10	Zhang et al., (2023)	PjBL	Demonstrated positive effects on technical skills when applied in real-task contexts. [16]
11	Alsmadi et al., (2024)	PBL	Improved work readiness, collaboration, and several aspects of programming technical skills. [34]
12	Bertacchini et al., (2022)	PjBL	Increased practical programming competence and motivation; real-world projects facilitated skill transfer. [35]
13	Gu et al., (2025)	PjBL	Showed improvements in C programming performance and students' self-regulated learning. [36]
14	Qasem et al., (2025)	PjBL	PjBL was effective in improving C# programming competence among educational technology students. [37]
15	Su et al., (2022)	PBL	Enhanced students' learning perceptions and learning behaviors. [38]
16	Naseer et al., (2025)	PjBL	Demonstrated relevance for project-based programming curriculum development. [39]
17	Spirina, Y. (2025)	PjBL	Integration of PjBL with cloud tools supported project work and software development skills. [40]
18	Lesman et al., (2023)	PjBL	Strengthened critical thinking, innovation, and production of creative outputs aligned with workplace needs. [41]
19	Ubaidah and Loeis (2022)	PjBL	Immersive PjBL significantly increased student engagement and programming competence. [42]
20	Omeh, C. B. et al. (2025)	PBL	PBL supported by AI scaffolding significantly improved programming skills. [43]
21	Wulansari et al., (2024)	PBL	Quasi-experimental results showed better programming learning outcomes using the KND-PBL model. [44]
22	Alshaye, I. A. (2023)	PBL	Online PBL improved problem-solving skills and several programming skill indicators. [45]
23	Setyani, N. S. (2022)	PBL	E-PBL increased students' interest and engagement, particularly during distance learning. [46]
24	Ghani, A. S. A. (2021)	PBL	PBL components promoted communication, problem-solving, and critical inquiry, forming the foundation of active programming courses. [47]
25	Ponticorvo, M. et al. (2022)	PjBL	Peer-based PjBL supported inclusion and the development of coding skills. [48]
26	Maulana et al. (2024)	PjBL	Implementation of PjBL improved learning outcomes and engagement in introductory programming courses. [49]
27	Wicaksana et al., (2022)	PjBL	Real-world projects in PjBL for object-oriented programming increased creativity and learning outcomes. [50]
28	Baharudin and Awaluddin, (2024)	PjBL	PjBL supported by online media enhanced students' understanding and learning motivation. [51]
29	Tarigan et al., (2025)	PjBL	PjBL integrated creativity and computational thinking, two core competencies in programming education. [52]
30	Nursalam and Suardi (2024)	PjBL and PBL	The combination of PjBL and PBL improved creativity, teamwork, and students' learning motivation. [53]
31	Jabbar and Abd Halim (2024)	PjBL	Students' programming skills and collaborative abilities improved through technology integration and PjBL. [18]
32	Yusra and Sinaga (2022)	PjBL	PjBL enhanced learning reflection, planning, and student interaction. [54]

33	Selano, Y. P. et al. (2024)	PjBL	Web-based PjBL improved students' computational thinking skills and learning motivation in introductory programming. [55]
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As indicated by the results summarized in the Systematic Literature Review (SLR) on the implementation of Problem-Based Learning (PBL) and Project-Based Learning (PjBL) in relation to students' programming skills during the 2020–2025 period, the majority of studies demonstrate that both instructional strategies enhance students' computational thinking abilities, their understanding of programming concepts, and their motivation to learn. The table presented above provides a detailed synthesis of findings derived from various studies.

Study [17] reports that the application of PBL through unplugged computational thinking activities increases student engagement and conceptual understanding, although the improvement in learning outcomes was not statistically significant. These findings are consistent with those of [56] which integrated PBL with online programming systems and found improvements in students' learning behaviors and perceptions, particularly in STEM-related learning contexts. In contrast, PjBL approaches exhibit stronger effects on the development of practical programming skills. The analysis conducted by [16] indicates that PjBL has a moderate positive effect on learning outcomes. Moreover, PjBL has been shown to enhance student engagement and creativity. Similar results were reported by [35], who implemented PjBL in a robotics laboratory setting and observed substantial improvements in students' technical programming skills and motivation to pursue engineering-related learning. Furthermore, [34] noted that integrating PjBL with real-world projects improves students' work readiness and collaborative competencies in computing disciplines. More recent research by [36] found that combining PjBL with self-regulated learning strategies enhances students' self-regulation skills as well as their proficiency in the C programming language. These findings are further supported by [37], who demonstrated that PjBL is highly effective in improving students' mastery of the C# programming language.

When comparing the two approaches, PjBL appears to be more effective in fostering logical reasoning, reflective thinking, and foundational conceptual understanding, whereas PBL is more effective in facilitating the practical application of programming problem-solving skills. Nevertheless, several studies [34], [36] suggest that integrating both approaches, such as employing PBL for problem analysis followed by PjBL for solution implementation, yields broader learning outcomes encompassing cognitive, affective, and psychomotor domains.

Overall, the findings of this SLR confirm that PBL and PjBL are complementary instructional strategies, and both are effective in enhancing university students' programming skills in the current era of digital transformation.

## CONCLUSION

Both Problem-Based Learning (PBL) and Project-Based Learning (PjBL) approaches have been proven effective in enhancing university students' programming skills. PBL contributes to strengthening students' understanding of programming logic and fundamental algorithmic concepts through contextual problem analysis, whereas PjBL emphasizes the application of programming concepts through structured projects that foster collaboration, responsibility, and self-directed learning. Both approaches are capable of promoting critical, creative, and analytical thinking skills through problem-solving activities and the development of authentic projects aligned with real-

world contexts. Meaningful and active learning experiences that respond to the demands of the digital transformation era can be achieved by integrating these two instructional strategies. Accordingly, PBL- and PjBL-based learning strategies should be optimized through adequate digital infrastructure and supportive collaborative learning environments. To enable students to apply programming concepts effectively, instruction should focus on real-world problem solving and project development. Furthermore, to gain a deeper understanding of how these approaches influence students' programming logic and algorithmic skills, future research should investigate their effectiveness using experimental designs or mixed-method approaches.

## LIMITATIONS

This study has several limitations. First, the review is restricted to articles published between 2020 and 2025, which ensures relevance to recent developments but may exclude earlier foundational studies on PBL and PjBL in programming education. Second, the literature search relied primarily on Publish or Perish and Google Scholar, supplemented by manual searches; therefore, some relevant studies indexed in other major databases may not have been captured. Third, the SLR synthesizes findings from studies with diverse methodologies, sample characteristics, and educational contexts, which limits the generalizability of the results across different higher education programs. Finally, as the bibliometric analysis examines publication patterns rather than causal relationships, and no experimental comparison was conducted, conclusions regarding the relative effectiveness of PBL and PjBL should be interpreted with caution.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## DECLARATION OF USE OF AI IN SCIENTIFIC WRITING

The authors used several generative AI tools in the process. ChatGPT was used to help organise complex concepts, while Grammarly was employed to enhance the grammar, style, readability of the text and improve the overall clarity of the writing. Although these tools provided valuable support, the researcher wrote all the content and conclusions.

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