

# Systematic Literature Review: The Impact of Coding Education on Computational Thinking Skills in Elementary School (2020-2025)

## Author:

Okta Suphia Mawaddah<sup>1</sup>  
Mintarsih Arbarini<sup>2</sup>  
Bambang Subali<sup>3</sup>  
Arif Widiyatmoko<sup>4</sup>

## Affiliation:

Elementary Education Study  
Program, Pascasarjana,  
Universitas Negeri Semarang<sup>1</sup>  
Universitas Negeri  
Semarang<sup>2,3,4</sup>

## Corresponding email

[oktashm@students.unnes.ac.id](mailto:oktashm@students.unnes.ac.id)

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## Abstract:

Early coding education has been implemented in various elementary schools to improve digital literacy with relevant 21st-century skills. The main focus of the competencies to be developed through coding education is computational thinking skills. This study aims to explore the impact of coding education on improving the computational thinking skills of elementary school students over the past five years. This study applied the Systematic Literature Review (SLR) method, searching for articles using Publish or Perish (PoP) software with Crossref as the data source. Bibliometric analysis was performed using VOSviewer to map publication trends, authors, citations, article sources, and research theme clusters. From a total of 1,000 identified articles, relevant publications were selected through a screening process based on the PRISMA protocol, resulting in 235 articles ready for further review and deeper analysis of coding education research trends related to computational thinking development in elementary school contexts. Coding education has been proven to contribute positively to the development of students' computational thinking skills in elementary school students, especially fifth graders, although its effectiveness is influenced by teaching methods and the context of implementation. This study provides an overview of the development of research related to coding and computational thinking education during 2020–2025, while identifying research gaps that can be explored further in subsequent studies.

**Keywords:** Coding; Computational Thinking; Elementary School.

## Introduction

The rapid development of digital technology has reshaped the skills students need to thrive in the 21st century. One of the most essential competencies is computational thinking. Computational thinking is the ability to think in terms of designing problems and then presenting solutions or strategies that are developed effectively and efficiently so that students' thinking can be optimized (Mardianto & Yahfizham, 2024). Computational thinking, which includes problem solving, algorithmic thinking, and understanding systems, is essential (Marhadi et al., 2023). Furthermore, the implementation of computational thinking plays a crucial role in enhancing students' ability to learn independently.

An & Shin (2024) explain that computational thinking is a mindset that mimics the way computer scientists analyze and solve problems through core concepts of computer science, system architecture, and human behavioral understanding. According to Gadde et al. (2024) computational thinking is one of the prerequisites for coding.

This study aims to identify research trends regarding the impact of coding education on computational thinking skills in science and technology education during the period 2020–2025. Several aspects are the main focus of this study, namely the number of scientific publications produced, the types of publications published, and an analysis of research trends on arguments mapped using VOSviewer. The findings of this study provide benefits for teachers and curriculum developers in providing new lessons on how coding education in elementary school students can improve problem-solving skills, deepen understanding of computational thinking, and further develop long-term programming learning outcomes. Therefore, further research is needed to investigate the obstacles to coding learning in developing comprehensive computational thinking skills, especially in primary education environments where access to digital devices is still limited.

## Literature Review

Recent studies consistently indicate that coding education plays a significant role in enhancing students' computational thinking skills, particularly in elementary education. Coding activities are often associated with improvements in problem-solving, logical reasoning, and creativity, as they require students to construct solutions systematically and reflect on their thinking processes. For example, Zeng et al. (2023) examined how programming activities can be integrated into early childhood education, while emphasizing pedagogical opportunities and challenges. Meanwhile, Ramadhan et al. (2020) also stated that coding education can teach children to communicate with structured logic like computer programs, helping them solve problems with computer technology. However, while these benefits are widely acknowledged, the extent and mechanisms through which coding contributes to computational thinking remain insufficiently examined.

A number of empirical studies highlight that introducing programming at an early age can support structured thinking and the ability to decompose complex problems. For instance, coding tasks encourage students to apply step-by-step reasoning and iterative problem-solving strategies. Coding education for elementary school students can foster their creativity and innovative thinking (Alindra et al., 2024). Research conducted by Awaluddin & Hadi (2025) found that although there is great potential for coding and AI learning to develop creativity and computational thinking, there are still real obstacles, including infrastructure limitations, a lack of human resources with adequate competencies, and the digital divide, especially in remote areas. Based on the background description, the research questions in this study are: what are the findings of research on coding education for fifth-grade elementary school students during the period 2020–2025, what is the impact of such education on computational thinking skills, and what methods and factors influence the effectiveness of its implementation.

Importantly, there remains a gap in connecting theoretical concepts of computational thinking with their practical implementation in classroom settings. While computational thinking is often defined through core components such as abstraction, decomposition, and algorithmic thinking, few studies critically analyze how these components are explicitly developed through coding activities in elementary education. This disconnect suggests the need for a more integrated analytical approach that links theory, instructional practice, and measurable learning outcomes. Based on these gaps, this study positions itself to provide a more systematic and analytical examination of coding education research, focusing on how it contributes to computational thinking development, what methodological trends emerge in recent studies, and which contextual factors influence its effectiveness.

Recent research shows that the development and application of computational thinking in learning is beginning to be implemented at various levels of education, from primary school to high school. Studies

by (Liu, 2023) show that the integration of computational thinking into K-12 curricula still faces a gap between theory and practice, especially regarding how teachers implement computational thinking into STEM subjects. Other studies mention specific challenges in implementing computational thinking at the basic and very basic levels (early childhood), one of which is the lack of consistent measurement tools and adequate teacher training (Valdes et al., 2025). Many studies still focus on specific programming tools (e.g., Scratch) and less on cross-disciplinary contexts or non-computer domains (Stewart & Baek, 2023).

## Methods

This study employed a Systematic Literature Review (SLR) combined with bibliometric analysis to examine the impact of coding education on students' computational thinking skills in elementary education. The SLR approach was used to ensure a transparent, structured, and reproducible process for identifying, selecting, and analyzing relevant studies. The systematic literature review studies reveal the current state of research and provide support for identifying research gaps in a specific area (Lo, 2020).

This approach follows a structured methodology, which includes defining clear research questions, establishing study inclusion and exclusion criteria, conducting systematic searches through various databases and sources, and assessing the quality of the studies included (Suarsana et al., 2024). Karyana et al. (2024) research states that bibliometric analysis provides a robust and systematic approach for analyzing an extensive scientific database. Bibliometric analysis is carried out with the help of Publish or Perish (PoP) software as a tool for retrieving article and journal databases, while VOSviewer serves as the tool for the visualization of bibliometric data. Database searches are conducted more optimally with the Publish or Perish software, as previously done by researchers (Dewi et al., 2021; Muhammad et al., 2022; Mulyani et al., 2024), while the application for visualizing bibliometric data uses VOSviewer (Abdullah, 2022; Arruda et al., 2022; Cheng et al., 2021; Dede & Ozdemir, 2022; Nordin, 2022; Ubaidillah et al., 2023). Articles found through Publish or Perish are then mapped using VOSviewer. The data displayed in Publish or Perish were metadata, not full text, which includes the author's name, title, year, journal where the article was published, and the publisher of the article (Husaeni et al., 2022).

The data source (articles) was obtained from Crossref using PoP software from 2020 to 2025, which is one of the academic bibliographic databases that provides extensive metadata on scientific publications. Crossref is an academic bibliographic database that provides extensive scientific publication metadata, including article titles, authors, publication years, journals, and publishers. The search strategy employed two main keywords: "coding education" and "computational thinking," which aimed to include studies investigating the impact of coding-oriented education on students' computational thinking skills. Initial search results showed that 1,000 articles were available during that period.

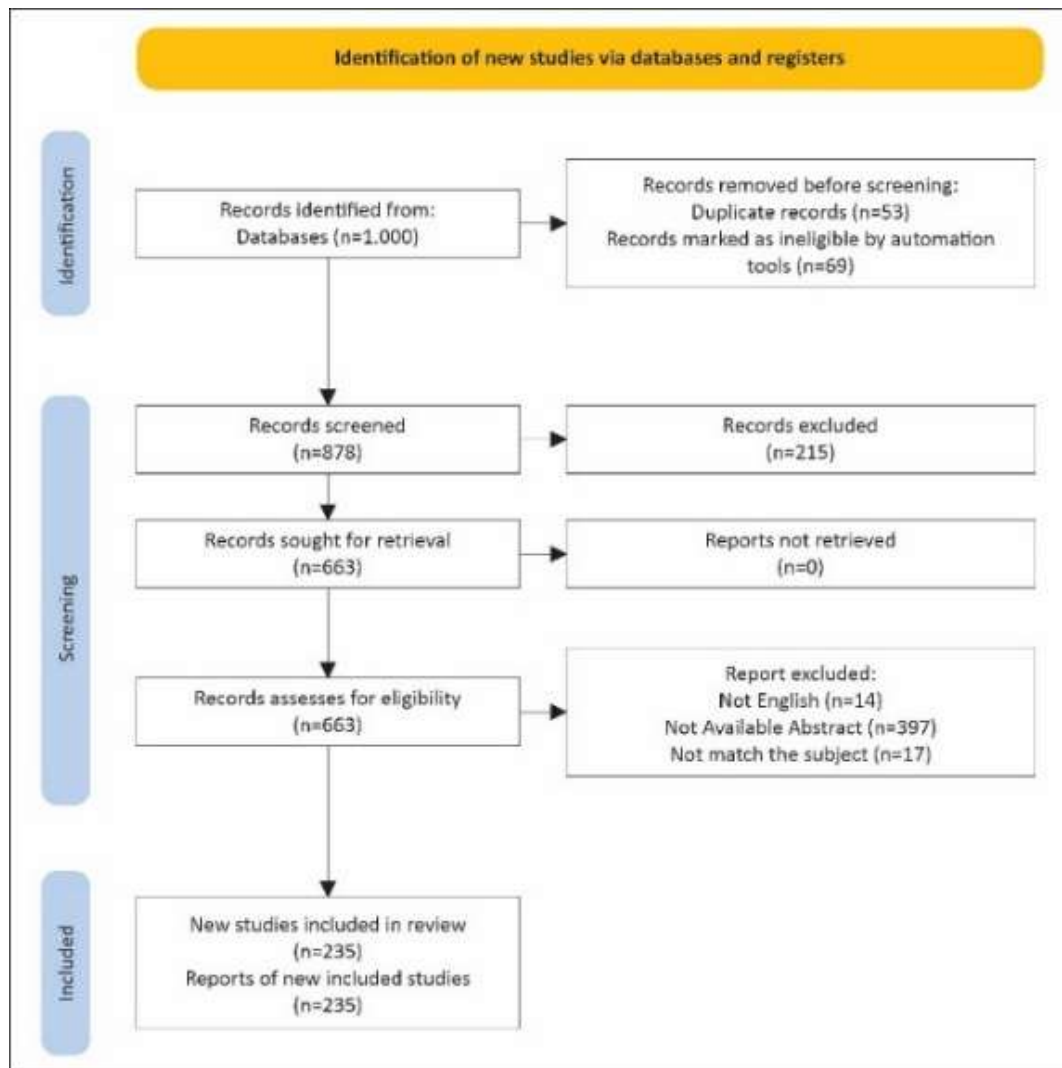
Data selection in this study followed the planned inclusion and exclusion criteria, so that the data would be filtered as expected and more focused on the research theme. Details of the inclusion and exclusion criteria can be seen in Table 1 below.

**Table 1. Inclusion and Exclusion Criteria**

Criteria	Inclusion	Exclusion
Type of Publication	Journals and Proceedings	Books, Magazines, other
Year of Publication	2020-2025	Less than 2020
Data Source	Crossref	Other than Crossref
Journal Language	English	Other

Research Subject	Coding education, Computational thinking, Elementary/School, Other Primary
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This research employs the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram. The data analysis process follows the detailed stages outlined in the PRISMA chart, as illustrated in Figure 1.



**Figure 1. PRISMA Flow Diagram**

The article search was conducted through Crossref with the Publish or Perish (PoP) tool using the keywords “education coding” and “computational thinking.” The search period was limited to 2020–2025. As shown in Figure 1, the search on this theme initially yielded 1,000 articles. During the identification stage, 53 duplicate articles and 69 additional duplicates were removed, leaving 878 articles that were then selected based on their titles and abstracts. This screening process resulted in 663 articles that were considered relevant for full-text evaluation. In the next stage, a comprehensive feasibility check was implemented,

through which 235 publications meeting the predefined inclusion parameters were retained for deeper analytical investigation.

Data analysis was conducted in two main stages. First, bibliographic metadata obtained from Crossref via PoP including authors, publication years, article titles, journal sources, and publishers were analyzed to identify publication trends and research productivity patterns. Second, the selected metadata were processed using VOSviewer to perform bibliometric visualization analyses. Bibliometric analysis is carried out in three key visualization forms, which include network visualization, overlay visualization, and density visualization. These three forms of visualization allow researchers to see patterns of connections between researchers, the dynamics of research over time, and the density of topics that are of interest to researchers in the field of coding education.

The data collected also underwent a cleaning and filtering process in accordance with the inclusion and exclusion criteria specified in the methods section. After screening using the PRISMA protocol, 235 articles were found to meet the criteria for further analysis. This analysis stage formed the basis for identifying research trends, the most active scientific fields, and factors influencing the development of coding and computational thinking topics in elementary schools.

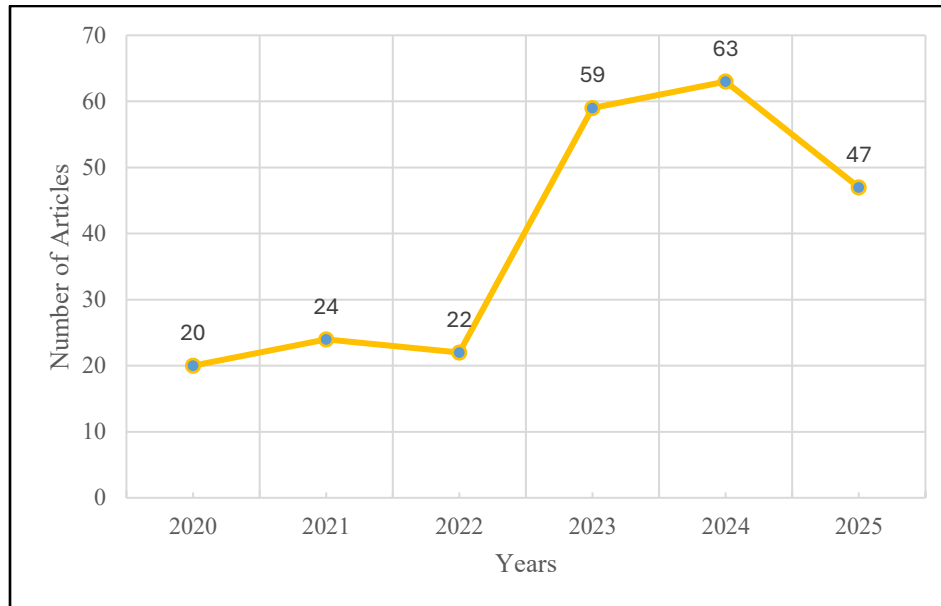
## Results

This section presents the findings of the bibliometric analysis on research related to coding education and computational thinking skills during the period 2020–2025. The bibliometric results show an overall increase in the number of scientific publications addressing coding education and computational thinking skills over the past five years. In general, the number of scientific publications shows a fluctuating trend but tends to increase every year. Table 2 presents the number of scientific publications that examine the impact of coding education on computational thinking skills during the period 2020–2025.

**Table 2. Scientific publications on the trends of the impact of coding education on computational thinking during 2020-2025**

Year	Total Publication
2020	20
2021	24
2022	22
2023	59
2024	63
2025	47

To illustrate the dynamics of research output over time, the annual publication trend is visualized in Figure 2, which depicts the growth pattern of studies related to coding education and computational thinking during the 2020–2025 period.

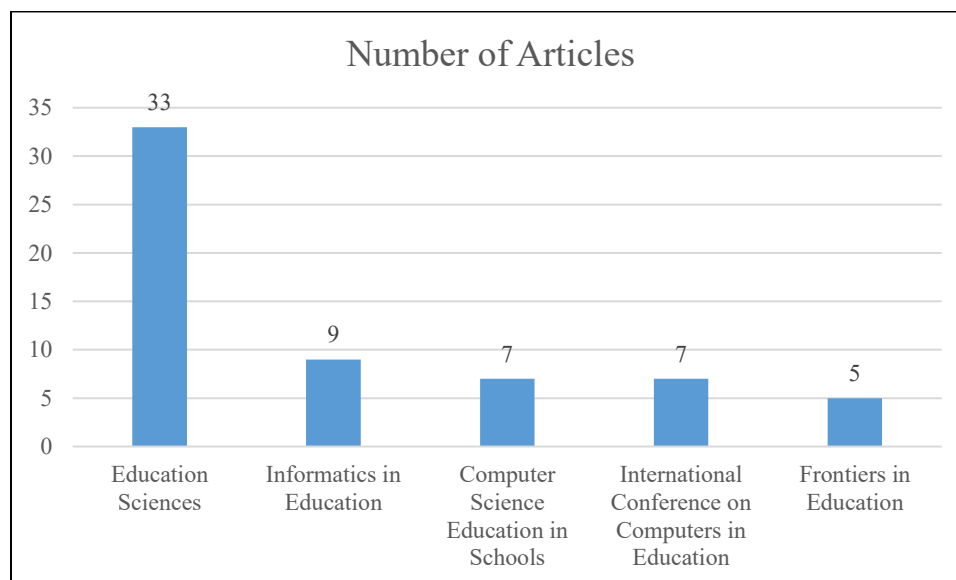


**Figure 2. Number of articles per year on coding education for computational thinking**

Figure 2 suggests that the number of articles produced each year during 2020–2025 fluctuated. Publication trend analysis shows an increase in the number of studies since 2020. The data marked that 2024 the most productive year in terms of research output, with 63 publications released. This was also influenced by conditions after the COVID-19 pandemic era, with an increased attention to digital literacy. The projection for 2025 (as of September, there are 47 journals) is also estimated to reach more than 50 publications.

The bibliometric analysis revealed a consistent expansion of research themes, shifting from fundamental introductions to coding in 2020–2021 toward more complex studies integrating computational thinking with science, mathematics, and artificial intelligence contexts by 2024–2025.

In addition to analysis based on the year of publication, this study also identifies the journal sources that publish the most related articles. Information on the five journals with the highest number of publications is presented in Figure 3 below.



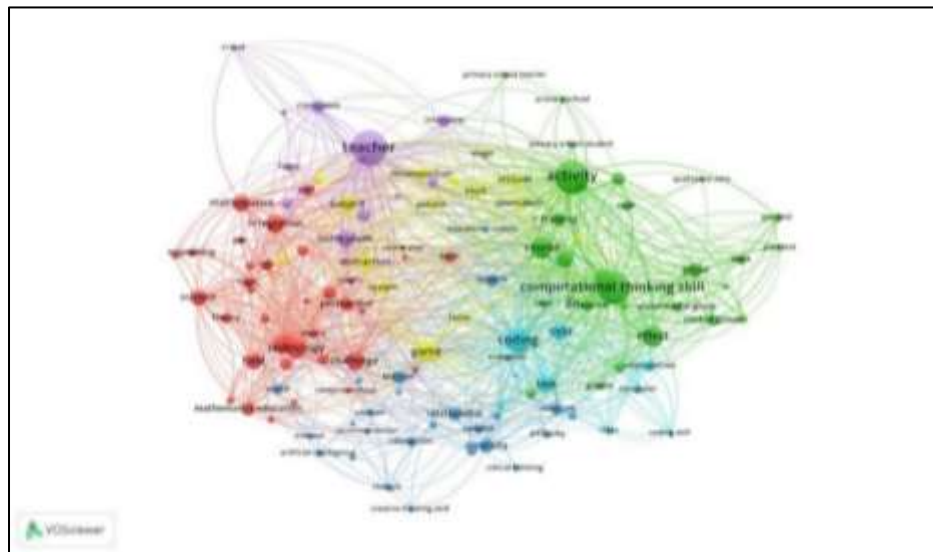
**Figure 3. Top Journal Sources on the Impact of Coding Education on Computational Thinking Skills during the Period 2020–2025**

Research on the impact of coding learning on computational thinking skills, as shown in Figure 3, is most prevalent in the field of education compared to other fields such as information in education, computer science education in schools, international conferences on computers in education, and recent developments in this field. Research in the field of education is the most prevalent among other fields. Further research was conducted on the most productive and frequently cited authors in studies on coding learning and computational thinking. The list of authors and the number of references discussing this topic can be seen in Table 3 below.

**Table 3. Top Journal Sources on the Impact of Coding Education on Computational Thinking Skills during the Period 2020–2025**

No	Author	Number
1	Yasmin B. Kafai, Chris Proctor	115
2	Stamatis Papadakis	87
3	João Piedade, Nuno Dorotea, Ana Pedro, João Filipe Matos	53
4	Anita Juškevičienė, Gabrielė Stupurienė, Tatjana Jevsikova	52
5	Valerie Critten, Hannah Hagon, David Messer	50
6	Vladimiras Dolgopolas, Valentina Dagienė	44
7	Papadakis Stamatios	38
8	Jing Ru Qu, Ping Kwan Fok	30
9	Judy Robertson, Stuart Gray, Toye Martin, Josephine Booth	28
10	Noor Desiro Saidin, Fariza Khalid, Rohanilah Martin, Yogeswary Kuppusamy, Nalini A/P Munusamy	26

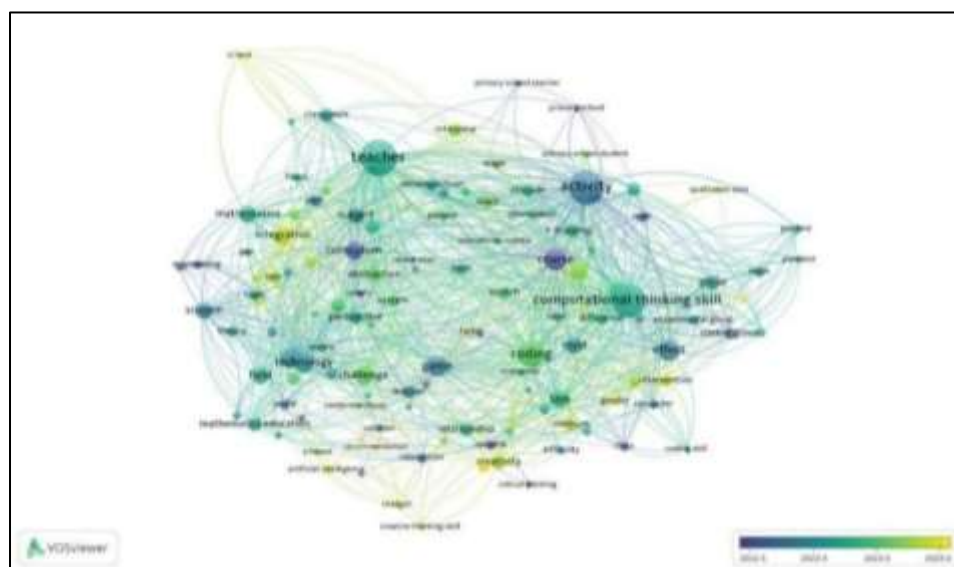
Figure 4 shows the relationship between various topics and keywords that frequently appear in similar publications. This visual display serves to identify the main focus of research and patterns of interconnection between topics in the field of coding education.



**Figure 4. Network Visualization of the Impact of Coding Education on Computational Thinking during the Period 2020–2025**

Figure 4 illustrates the strong correlation between various research topics. There are six main groups classified based on clusters. There are six clusters with six color categories, namely red, purple, yellow, green, blue, and light blue. The topic of computational thinking shows a broad relationship with various other topics, so it can be concluded that this theme is one of the most discussed in various research publications.

Figure 5 presents an overlay visualization that shows the temporal development of research topics. The colors in the visualization illustrate the period of emergence of the topic, so that research trends that are developing and those that are declining can be identified.



**Figure 5. Overlay Visualization of the Impact of Coding Education on Computational Thinking during the Period 2020–2025**



examined programming as a complementary practice to CT in a case-based context, the present review demonstrates that this relationship is now more consistently supported across multiple studies, learning environments, and student age groups. This suggests that recent research has moved beyond exploratory implementations toward stronger empirical evidence on the educational value of coding.

The keyword co-occurrence and cluster analyses further reveal that CT is strongly associated with programming, problem-solving, STEM education, and digital literacy. These thematic relationships indicate a shift from viewing coding as a purely technical skill toward understanding it as an interdisciplinary pedagogical approach that promotes higher-order thinking, creativity, and analytical reasoning. This result extends previous findings by Isharyadi & Juandi (2023) and Papadakis (2025), who highlighted the role of CT in logic and algorithmic reasoning, by showing that more recent studies increasingly connect CT with broader educational outcomes such as collaborative learning, creativity, and innovation. The inclusion of learning media such as CodeSTEM (Rati & Esaputra, 2025) further demonstrates that digital instructional tools are becoming central in supporting CT development.

In comparison with prior studies, this review also confirms the effectiveness of diverse instructional approaches, including block-based programming, unplugged coding, game-based learning, and AI-assisted programming environments. Earlier studies frequently emphasized the benefits of block-based tools such as Scratch for improving student engagement and foundational logic skills (Totan & Korucu, 2023). The present synthesis expands this perspective by showing that block-based programming is now frequently integrated with mathematics learning, digital games, and AI-based scaffolding tools such as ChatGPT, leading to improvements not only in CT but also in academic achievement (Febriantoro et al., 2025). This indicates a methodological progression from single-tool interventions toward more integrated and adaptive learning ecosystems.

Similarly, unplugged coding remains highly relevant, especially in resource-constrained contexts. While Bell & Henderson (2022) emphasized its conceptual benefits, more recent studies such as Dağ et al. (2023), Kasiono et al. (2025), and Ugur & Çakiroglu (2024) provide stronger evidence that unplugged approaches can be equally effective across elementary education settings. The finding by Yilmaz & İzmirli (2023), which reported no significant difference between device-based and non-device-based coding instruction, reinforces this conclusion and suggests that pedagogical design may be more influential than technological availability.

Another important contribution of this review is the identification of broader educational implications. Compared with earlier studies that primarily focused on student outcomes, recent literature increasingly highlights teacher readiness, pedagogical design, curriculum integration, and learning media innovation as critical success factors. For example, Sripan & Manyam (2025) emphasize the importance of teacher professional development, while Dahshan & Galanti (2024) reveal variations in teachers' ability to implement CT concepts effectively in mathematics instruction. In addition, the use of coding-based instructional media such as flipbooks has also been shown to effectively enhance students' creativity and computational thinking in science learning contexts, particularly in topics such as ecosystem energy transformation (Listyana et al., 2024). This finding strengthens earlier arguments by Mills et al. (2025) that the urgency of computational thinking development extends across all areas of education, not only technology-related subjects. Furthermore, Baghiro et al. (2025) underline that programming contributes beyond cognitive skill development by fostering teamwork, creativity, and problem-solving competence, which further broadens the educational relevance of coding instruction. These findings suggest that the

success of coding education depends not only on student-facing tools but also on sustained teacher support, innovative media, and cross-disciplinary curriculum alignment.

At the same time, this review identifies several continuing challenges. Some studies report that coding activities may fail to attract student interest when instructional design is not sufficiently engaging (Koray & Bilgin, 2023). Compared with studies reporting positive outcomes through integration with mathematics and science (Saptajiah & Slameto, 2024), this contrast highlights that student motivation is strongly influenced by contextual relevance, media interactivity, and pedagogical innovation. Therefore, future implementations should prioritize meaningful real-world tasks, adaptive media, and collaborative learning experiences.

Although the number of studies continues to grow, publication trends remain fluctuating rather than fully stable, indicating that the field is still evolving. Unlike earlier research concentrated mainly on specific educational stages, the current body of literature spans elementary, secondary, and higher education, suggesting a broader recognition of CT as a lifelong learning competency. Overall, the comparative evidence presented in this review strengthens the conclusion that coding-based learning consistently enhances cognitive, creative, and problem-solving skills across diverse educational settings.

## Conclusions

This systematic literature review demonstrates that coding education between 2020 and 2025 has significant potential to foster students' computational thinking skills across multiple educational contexts. By synthesizing trends in publication growth, thematic relationships, and instructional approaches, this study confirms that coding education has evolved into a major research focus in educational technology and curriculum innovation.

A key contribution of this review is its integration of bibliometric mapping using VOSviewer with a qualitative synthesis of instructional strategies and educational outcomes. This combined approach provides a clearer understanding of how computational thinking is positioned within contemporary educational research and how it connects with related themes such as problem-solving, STEM learning, digital literacy, creativity, and AI-supported instruction. This represents an important contribution to the literature because previous reviews often focused on either trend mapping or intervention effectiveness, whereas this study bridges both perspectives.

From a practical perspective, the findings suggest that coding education is most effective when integrated into core academic subjects such as mathematics and science, supported by interactive media, and reinforced through teacher professional development. These insights can serve as an evidence-based reference for curriculum designers, teachers, and educational researchers seeking to strengthen computational thinking instruction.

This review also identifies several directions for future research. First, more longitudinal studies are needed to examine the long-term impact of coding education on students' higher-order thinking and academic performance. Second, future studies should investigate how different pedagogical models—such as unplugged learning, game-based coding, and AI-assisted programming—perform across diverse learner characteristics and cultural contexts. Third, additional research is recommended to explore teacher readiness, student motivation, and curriculum scalability in underrepresented educational settings.

In conclusion, this study contributes a comprehensive and up-to-date reference for understanding how coding education can be effectively applied to develop computational thinking skills. It not only

consolidates current evidence but also highlights research gaps and practical implications, thereby providing a strong foundation for future studies and educational innovation in this field.

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