Al-Ishlah: Jurnal Pendidikan
Vol.17, 1 (March, 2025), pp. 39-48
ISSN: 2087-9490 EISSN: 2597-940X, DOI: 10.35445/alishlah.v17i1.3161

Publication Trends of Computational Thinking in Elementary School Students: A Bibliometric Review

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ARTICLE INFO

Keywords:

Computational Thinking;
Elementary School;
Bibliometric

Article history:

Received 2022-12-20
Revised 2024-07-03
Accepted 2025-01-21

ABSTRACT

This study investigates publication trends, citation trends, keyword distribution, and novelty potential in research on computational thinking (CT) in elementary schools over the past decade. It conducted a bibliometric analysis of English articles and proceedings published between 2015 and 2024. Data sources included academic databases, with article selection based on defined inclusion criteria. Bibliometric techniques such as co-citation analysis and keyword co-occurrence were utilized to explore trends and patterns. The number of publications on CT in elementary education has increased significantly, particularly in 2021 and 2023. Citation analysis revealed a variety of research focuses, with clusters highlighting the growing prominence of specific topics. The integration of games as a tool for teaching CT is a notable trend, with research emphasizing game design, effectiveness evaluation, and curricular applications. Keyword distribution reflects diverse methods and approaches to teaching CT in elementary settings. The findings underscore the growing interest in CT research for primary education and its evolving focus on innovative strategies, particularly educational games. Future trajectories suggest continued exploration in this area, with implications for curriculum design and teacher training. This study provides a comprehensive overview of trends in CT research in elementary schools, offering insights for educators, policymakers, and researchers. Further work is needed to explore the practical integration of CT through innovative approaches, including games, to advance primary education.

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1. INTRODUCTION

In today's digital age, where technology permeates nearly every aspect of daily life, the ability to think computationally has become a critical skill (Acevedo-Borrega, 2022). Computational thinking (CT) encompasses the capacity to solve problems, analyze data, and design solutions using fundamental principles of computer science (Angeli, 2020; Wing, 2006). It involves mastery of algorithms, abstraction,

modeling, and logical reasoning—skills essential for effectively addressing complex challenges with computational tools (Maharani et al., 2019). In education, fostering CT skills is vital not only to prepare students for future technological demands but also to cultivate critical, creative, and analytical thinking abilities. Incorporating CT into curricula equips learners with essential problem-solving skills applicable across diverse disciplines, including computer science, STEM fields, and beyond (Kawada et al., 2019; Shin, 2021). Moreover, embedding CT within educational practices bridges the gap between theoretical knowledge and practical application, enhancing students' ability to address real-world challenges and fostering transferable skills that benefit various aspects of life (Oomori et al., 2019).

In the context of education, the integration of computational thinking in the educational curriculum is not just about preparing students for future jobs that require technological expertise. More than that, it's about forming the critical, creative, and analytical thinking base essential for success in multiple fields. Through computational thinking learning, students not only learn how to use technology, but also understand the logic behind it (Tsortanidou et al., 2021). They learn to see the relationship between theoretical concepts in computer science, science, mathematics, and engineering with practical applications in everyday life (Hooshyar et al., 2021). Thus, the use of computational thinking in learning is not just about preparing students for careers in technology, but also about providing them with problem-solving skills that can be applied across a variety of life contexts, from everyday decision-making to responding to global problems.

By understanding the importance of computational thinking in an educational context, we can highlight the urgency to explore publication trends related to the development and application of this concept in learning, particularly at the primary school level. Within this framework, a bibliometric analysis of publication trends of computational thinking in primary school students will provide a better understanding of research developments in this domain and provide a foundation for further development in STEM education. Although computational thinking has been an important focus in the development of educational curricula, there is a lack of adequate understanding of publication trends related to the application of this concept at the primary school level. Related studies may be scattered across journals and conferences, but there has been no comprehensive analysis describing how the literature in this domain has evolved over time and what research focus dominates (Stewart & Baek, 2023). While bibliometric research has been a useful tool in analyzing publication trends in a variety of fields, there are limitations to bibliometric research that specifically examines the topic of computational thinking in elementary school students (Huda et al., 2023). Some limitations include a selection of inclusion and exclusion criteria that may be inadequate to capture all relevant literature, as well as a lack of understanding of how to map computational thinking concepts into an appropriate bibliometric framework.

The main aim of this research is to conduct an in-depth exploration of the published literature on computational thinking in elementary school students. Through careful bibliometric analysis, this research aims to identify and disseminate publication trends over time, including growth in the number of publications, the geographic distribution of researchers, as well as dominant research approaches. Specifically, this research will answer several main questions: What is the trend in the growth of the number of publications regarding computational thinking in elementary school students from year to year? Which countries or regions have contributed the most to research on computational thinking in elementary school students? What are the research methods and approaches most frequently used in studies of computational thinking in elementary school students? By answering these questions, it is hoped that the research will provide deeper insight into the status and development of research in the field of computational thinking among elementary school students.

In addition, this study aims to provide deeper insight into the development and focus of research in the domain of computational thinking in elementary school students. By analyzing various aspects, such as the dominant research topic, the research methods used, and the major contributors in this domain, the research will provide a better understanding of the direction of research development and the growing academic importance in basic education. This study will use a bibliometric approach to analyze

publication trends in the domain of computational thinking in elementary school students. This approach involves collecting and analyzing bibliographic data from scientific journals, conferences, and other relevant literature sources. Bibliometric data will be used to identify publication trends, including growth in the number of publications, geographic distribution of researchers, collaboration networks, as well as dominant research approaches.

To ensure the accuracy and relevance of the analysis, the study will use carefully defined inclusion and exclusion criteria. Inclusion criteria will include literature that explicitly addresses computational thinking in primary school students, in both formal and non-formal educational contexts. On the other hand, literature that is not directly relevant to the research topic or does not meet certain quality standards will be excluded from the analysis. This research is expected to make a significant contribution in providing a better understanding of publication trends in the domain of computational thinking in elementary school students. By comprehensively analyzing the relevant literature, the study will reveal recent developments in this field, map publication trends over time, and identify dominant research focuses. This research can be a valuable reference for educators, researchers, and policymakers in designing forward-looking learning strategies and developing curricula relevant to future demands in STEM education at the elementary level.

2. METHODS

The study design applied in this article is Bibliometric Analysis, which aims to explore and analyze publication trends related to Computational Thinking among elementary school students. This approach utilizes bibliometric methods to explore and understand the distribution, patterns, and trends of scientific publications within the domain (Muhammad & Triansyah, 2023). With a focus on the use of the Dimension AI database, this study aims to examine the number of articles and related proceedings as well as evaluate how the topic of Computational Thinking has evolved over time. Bibliometric analysis allows researchers to explore interactions between authors, institutions, countries, and research topics in existing literature, as well as identify important patterns that may not be seen in other research approaches. Thus, the design of this study provides a systematic and structured framework for understanding and presenting current publication trends related to Computational Thinking at the primary school level.

To collect relevant data in this study, starting with the use of the Dimension AI database as the main source of information. The use of Dimension AI as a database in order to collect data from both reputable and non-reputable journals to enrich the variety of data used, considering the lack of publications related to the topic of computational thinking. The keywords "Computational Thinking" and "Elementary School" are included in the identification process to perform an accurate search. As a result, 360 records were identified based on titles and abstracts. The next stage involves filtering data, where only data published in the last 10 years, i.e., between 2015 and 2024, are retained for further analysis. After the initial screening process, 353 relevant data were successfully retained. This data was then filtered again at the eligibility stage to ensure that only English-language articles and proceedings would be analyzed, thus ensuring equality of data used. From this process, 311 data met the criteria and were ready for more in-depth analysis. The screening criteria used include several aspects. Inclusion criteria included articles and proceedings written in English, published between 2015 and 2024, relevant to the topic of computational thinking in elementary schools, and originating from peer-reviewed journals or conference proceedings. Exclusion criteria included publications that were not in English, and not relevant to the topic of computational thinking in elementary schools, as well as non-peer-reviewed sources such as articles from magazines, blogs, or other non-academic sources. By applying these criteria, we ensure that the dataset used for bibliometric analysis is robust and focused, aiming to uncover trends and developments in this field.

In analyzing publication trends on Computational Thinking in elementary schools, the technical approach used consists of two main aspects. First, the analysis is carried out qualitatively with the aim of gaining a deep understanding of the trend. It involves exploring data in depth to identify patterns, themes,

and changes in the published literature. Second, to visualize the findings more clearly, the data is analyzed using Microsoft Excel to produce graphs that provide a visual picture of publication trends. In addition, VOSviewer software is used to get a deeper insight into the distribution of quotes, country of origin, and popular keywords. Using VOSviewer, researchers identified novelties in research on computational thinking in elementary schools, as well as looking at relationships between relevant concepts and entities in the existing literature. With a combination of qualitative analysis techniques, graphical visualization, and the use of software such as VOSviewer, this research can provide comprehensive insight into recent trends and developments in this domain.

3. FINDINGS AND DISCUSSION

A total of 311 data entered the inclusion stage in the form of data from 2015-2024. The data is in the form of articles and proceedings in English, with a percentage of articles being more than proceedings, namely 218 articles and 93 proceedings.

3.1. Publication Trends

The distribution of publication data on the topic of computational thinking in elementary schools for the last 10 years of the 2015-2024 period is presented in Figure 1. A total of 311 data obtained 71 data were published in 2023, which means that 22.8% of the total makes 2023 the year with the highest publication.

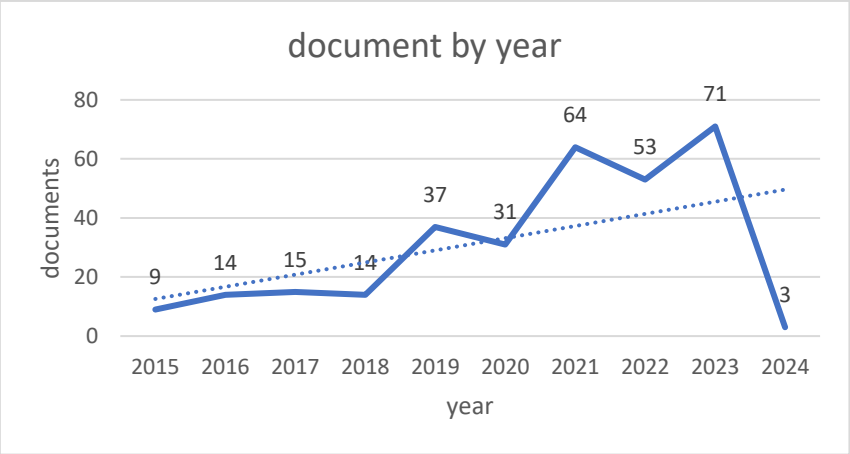

Figure 1. Publication Trend Graph

Meanwhile, in 2021, the publications produced are also quite high, where there are 64 or as many as 20%. It is interesting to see that 2022 experienced a decline in publications before the surge that occurred in 2023. The year 2024 started quite well with 3 publication data at the time this data was taken, namely February 15, 2024. From 2015 to 2020, not too many publications were produced, it can be seen from the average publication for the 6 years was 20 articles each year. 2015 was the year with the lowest publication at only 2% of the overall data.

3.2. Document Citation Trends

Document citation trends are visualized using VosViewer software by setting a threshold of at least one cited analyzed in full counting. Of the 311 data, only 181 met that threshold and only 69 connected data formed related clusters. The visualization can be seen in Figure 2.

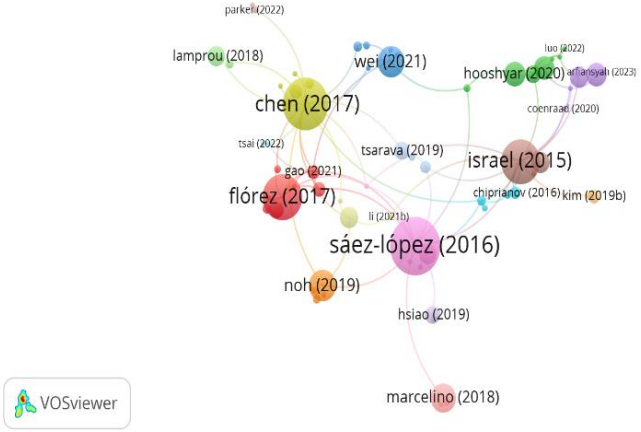

Figure 2. Document Citation Trend Visualization

In Figure 2. 18 different colors are shown indicating that there are 18 clusters generated from 69 relevant data. The three largest clusters are the red cluster with 8 documents, the green cluster with 7 documents and the blue cluster with 6 documents. The smallest cluster has only 1 document, namely cluster 18.

3.3. Citation Trends Between Countries

Visualization of the distribution of quotes between countries is also obtained from VosViewer software. A total of 35 data from the inclusion stage were spread across 35 countries. Furthermore, by applying a minimum limit of a country having at least 5 publications and at least 1 time quoted, 9 countries meet the threshold. Of the 9 countries, only 8 countries have citation relationships, forming 3 clusters. The visualization is presented in Figure 3.

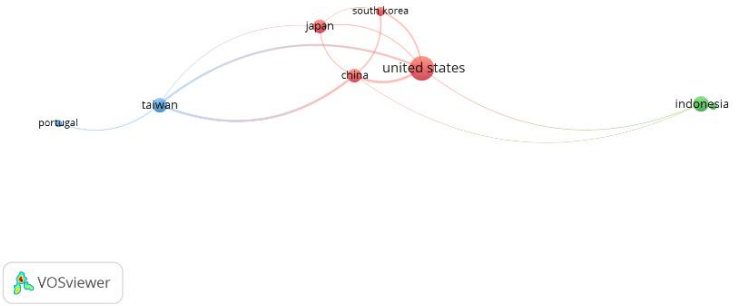

Figure 3. Visualization of Citation Trends Between Countries

In Figure 3. It is shown that there are 3 clusters, namely red, green and blue color clusters. In the red color cluster, there are 4 interconnected countries, namely Japan, South Korea, China and the United States. There are 2 countries in the green color cluster, namely Indonesia and Canada. Furthermore, the last cluster, namely blue, there are also 2 countries, namely Portugal and Taiwan.

The United States is the country with the highest number of publications, with 57 publications that have been cited 972 times. In the number of publications followed by Indonesia with 22 publications, 22 publications from Indonesia have only been followed 33 times. China's 18 publications have been cited 531 times. This can be seen in Figure 4. data before visualizing.

Create Map

Verify selected countries

Selected	Country	Documents	Citations
☑	china	18	531
☑	united states	57	972
☑	taiwan	21	234
☑	south korea	8	306
☑	japan	17	21
☑	indonesia	22	33
☑	portugal	6	105
☑	canada	5	24

Figure 4. Data Before Visualization

3.4. Keyword distribution

Visualization of keyword distribution is also obtained from VosViewer by analyzing the title and abstract in full counting with at least 10 times the keyword appears. From 6945 words, 208 related keywords were obtained and from 208 keywords, only 125 keywords were interconnected to form a cluster. The visualization is shown in Figure 5.

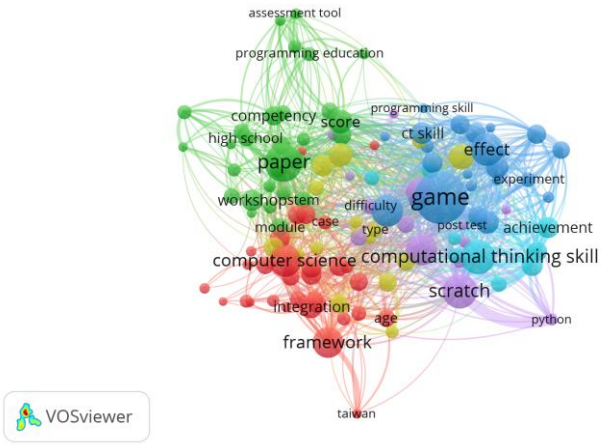

Figure 5. Visualization of Keyword Distribution

125 keywords form 6 clusters, namely red, green, blue, yellow, purple and light blue clusters. The red cluster has 32 keywords, green 31 keywords, blue 23 keywords, yellow 16 keywords, purple 14 keywords and light blue 9 keywords. Figure 5 also shows circles of circles with different diameters, these diameters illustrate the frequency with which keywords appear. The bigger it shows the more often those keywords appear or are talked about. Game keywords on blue clusters, computer science keywords on red clusters, scratches on purple clusters, paper on green clusters are popular keywords on the topic of computational thinking in elementary schools.

Discussion

Publication trends

The trend of publications on this topic illustrates a significant jump in the number of publications in recent years and a lack of interest in this topic in early 2015. The surge in publications in recent years, particularly in 2021 and 2023, reflects an increase in research interest and focus that may be triggered by a number of factors. One of the factors causing the surge is the increasing awareness of the importance of computational thinking at the primary school level in facing the digital challenges of the 21st century. This is in line with Maharani et al. (2020), who state the importance of computational thinking skills in the digital age of the 21st century. In addition, the efforts of governments, educational institutions, and non-governmental organizations to encourage the integration of technology and computational thinking in school curricula are also a major driver (Princess et al., 2022). One interesting article from 2023 highlights a digital game that focuses on organization and information retrieval, with the aim of introducing some concepts and techniques of computational thinking. Introducing computational thinking to elementary school students through an interesting and interactive approach using digital games with the hope that students can understand the basic concepts of computational thinking from an early age (Silva et al., 2023) .

On the other hand, the lack of interest in early 2015 reflects a lack of understanding or appreciation of the importance of computational thinking among academics and education practitioners. This is due to a lack of research or a lack of understanding of the potential applications of computational thinking at the elementary school level (Lee & Jang, 2020). However, with the rapid development of technology and the need for future computational skills, the interest and research focus towards this topic seems to have increased over time.

Quote Trends

In the document citation trend, 18 related clusters were formed, showing the complexity and diversity of the topics discussed in the study. The largest cluster shows the most dominant research focus, which in this case is the red color cluster with 8 documents, followed by the green and blue color cluster. This clustering highlights variations and peculiarities of topics that may be the focus of attention for researchers. One cluster highlighted the importance of integrating computational thinking into students' daily thinking (G. Chen et al., 2017). became the most popular article with the most citations. The development of computational thinking in elementary school students can provide a solid foundation for their development in the current and future digital era

The analysis reveals that while research on computational thinking (CT) in primary schools has gained global interest, only a small proportion of studies significantly contribute to the core body of literature. The United States emerges as a leader, with the highest number of publications and citations, reflecting its dominant role in advancing the field. Countries such as Indonesia, China, and others have made noteworthy contributions, though on a smaller scale. A state clustering analysis highlights distinct patterns of collaboration, with certain clusters showing strong citation relationships. For instance, the "red cluster," which includes Japan, South Korea, China, and the United States, demonstrates an interconnected network of influence and cooperation in CT research. This underscores the importance of cross-border collaboration in fostering global progress in the field (Yang & Feng, 2022).

Several factors contribute to these citation relationships. Shared educational priorities, such as integrating CT into early education, often lead to collaborative research among countries with similar goals, such as the United States, Japan, South Korea, and China. International conferences, academic exchanges, and funding programs also facilitate joint projects and idea sharing, strengthening citation networks. The presence of leading research institutions and influential scholars in these nations further drives their prominence in CT research. For instance, top-tier universities in the United States frequently set benchmarks that attract global citations.

To maximize the benefits of international collaboration, future efforts could focus on expanding cross-border research initiatives, co-authored publications, and joint educational programs. These strategies would not only enhance the scope and quality of CT research in primary schools but also contribute to a more unified and globally informed understanding of the discipline.

Keyword Trends

The diversity of keywords in the visualization showed significant variation in the topic of computational thinking in elementary schools. Although multiple keywords appear in the same cluster, there are also a large number of keywords connected in different clusters. This shows that computational thinking in elementary schools includes a variety of interrelated but unique concepts, methods, and approaches.

The red cluster, which is dominant with the keyword "computer science", highlights the importance of basic computer science concepts in primary school students' learning (Bertram, 2020; Bouck, 2021). However, blue clusters that include the keyword "game" indicate a different approach to teaching computational thinking through the use of games or games. The role of games in improving the computational thinking of elementary school children will have a significant impact in the field of education (Asbell-Clarke, 2021; Chen & Thi The Nguyen, 2023). With a focus on educational game design, evaluation of game effectiveness, curriculum integration, and student motivation and engagement factors, this research will provide a deeper understanding of how games can be effective learning tools in this context (Alam, 2022). This not only provides valuable insights for educators and researchers, but can also lay the foundation for the development of more innovative and relevant learning strategies in teaching computational thinking to primary school children.

A purple cluster with the keyword "scratch" indicates the popularity of visual programming platforms like Scratch in teaching programming to young students. Green clusters containing the keyword "paper" demonstrate the importance of literature and research in guiding the development of computational thinking in primary schools. In this case, the diversity of literature can be a source of inspiration and knowledge for educators in designing effective learning programs (Lodi, 2021). Then, the yellow and light blue clusters show the potential for additional concepts or approaches that have not yet been identified in this analysis, suggesting room for further research in this field.

This diversity analysis suggests that a holistic approach that incorporates a variety of concepts, methods, and learning resources can be key in developing strong and sustainable computational thinking in elementary school students. By understanding the diversity of keywords and clusters formed, educators and researchers can design diverse learning approaches that are relevant to students' needs in developing their computational thinking.

4. CONCLUSION

Conclusions from an analysis of publication trends, citation trends, keyword spread, and novelty potential in research on computational thinking in elementary schools reveal interesting dynamics over the past decade. Publication trends show a consistent increase in research interest, especially in recent years. A significant surge occurred in 2021 and 2023, indicating an increasing awareness of the importance of computational thinking in the digital age. Researchers such as Maharani and Putri from Indonesia, as well as Lee & Jang from South Korea, have highlighted the importance of computational thinking skills in the future of education. Analysis of document citation trends shows the complexity of the topics covered in the study, with clusters reflecting the various research focuses of various authors, including G. Chen of China and Silva of the United States. The use of games as a computational thinking learning tool in elementary school children is becoming an interesting trend, with in-depth research on educational game design, evaluation of game effectiveness, and curriculum integration. Other studies from different countries have highlighted the great potential in the use of games for this educational purpose. The distribution of keywords reflects the diversity of concepts, methods, and approaches in teaching computational thinking, with the use of games, basic computer science

concepts, and visual programming platforms such as Scratch being popular topics. From this analysis, there is great potential for further development in this field, especially in the use of games and other innovative approaches in teaching computational thinking to elementary school children. Future research needs to focus on longitudinal studies of long-term impacts, comparative studies of teaching methods, and cross-cultural research to understand the influence of cultural context. The integration of advanced technologies such as artificial intelligence and virtual reality also needs to be explored. In educational practice, the development of curricula that integrate computational thinking skills, teacher training, and the development of interesting and effective educational games is essential. Innovative assessment tools are also needed to measure student skills. In policy, allocation of funds for research and development, national or regional standards, equitable access, and increasing public awareness about the importance of these skills are very necessary. Engaging in these areas can improve the teaching and learning of computational thinking in elementary schools, preparing students for the challenges of the digital age.

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