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Computational Thinking in Elementary School Students: A Bibliometric Review

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Abstract

This study aims to provide an in-depth overview of trends in Computational Thinking (CT) learning among elementary school students through bibliometric analysis. The development of CT skills, which include logical thinking, systematic problem-solving, decomposition, pattern recognition, abstraction, and algorithmic design, is essential to prepare students for navigating a technology-driven future. By encouraging CT in primary education, students better understand technology and versatile skills that can be applied in various fields. This study uses a bibliometric approach by systematically collecting and analyzing scientific articles on CT in elementary schools. The analysis used specific metrics, including publication trends, citation analysis, and identifying leading research areas. Data is drawn from leading academic databases and analyzed to track the progress and impact of CT research over time. The results show a significant increase in publications and citations on CT, which peaked in 2021. The main trend highlights the importance of visual programming tools like Scratch in improving students' understanding of programming concepts, logic, and motivation. The study also uncovered research gaps and suggested areas that need further investigation, particularly in developing CT curricula and more effective teaching methodologies. These findings are expected to significantly contribute to advancing CT education and help equip the younger generation with the skills needed.

Keywords Computational Thinking; Elementary School; Trends

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1. INTRODUCTION

Understanding and applying Computational Thinking (CT) has become important in the increasingly advanced digital era, especially among elementary school students. CT includes problem-solving abilities involving problem decomposition, pattern recognition, abstraction, and algorithm design (Acevedo-Borrega, 2022; Wing, 2006). Beyond these technical aspects, CT also includes the capacity to think logically and systematically when faced with complex challenges. It equips students with the ability to use programming tools and languages to create efficient solutions, thus fostering a mindset conducive to innovation and adaptability (Maharani, 2023; Romandoni et al., 2023). This research is based on the argument that early exposure to CT principles in primary education is essential not only to understand and master technology but also to develop important life skills that cover a wide range of areas (Firdaus et al., 2023; Hsu, 2023). By integrating CT into the elementary school curriculum, students can develop critical and creative thinking skills, improve their analytical abilities, and cultivate a structured approach to problem-solving. These cognitive skills are fundamental for future academic success and navigating an increasingly technology-driven world. (Maharani, Mu'arif, et al., 2023; Rich, 2020). Furthermore, in a rapidly growing global economy, there is a growing demand for a proficient workforce in science, technology, engineering, and mathematics (STEM). Early CT education can serve as a strong foundation for students to pursue STEM-related careers, thereby meeting the needs of the future labor market. It also helps close the gap between technological advancements and the readiness of the younger generation to get involved. The study aims to explore trends in CT education for primary school students through bibliometric analysis, thus providing valuable insights into how this educational practice is evolving. This study supports the argument that integrating CT into early childhood education is beneficial and necessary to prepare the next generation to face the challenges and opportunities in the digital age. Through careful analysis of existing research, this study identifies key trends, gaps, and future directions in CT education, which contribute to developing more effective teaching methods and curricula that can equip students with the skills they need to succeed.

The rapid development of technology and the increasingly widespread use of technology in daily life require the younger generation to become passive users of technology and active creators. Therefore, understanding CT at the primary education level is crucial. By learning CT early, students can be better prepared for future challenges and opportunities, as well as become more competitive in a world filled with technological innovations (Amri & Suryanti, 2021; Pardo, 2018). In recent years, many countries have integrated CT into their national curricula. Educational programs focused on teaching CT have been developed and implemented in various schools to strengthen students' skills in problem-solving and critical thinking (Abar, 2021a; Aydeniz, 2018).

Despite many promising initiatives, significant variations in teaching approaches and the effectiveness of Computational Thinking (CT) implementation persist across different educational contexts. This issue is crucial because these disparities can lead to unequal opportunities for students to develop essential CT skills, which are vital in a technology-driven world. Schools with adequate resources and trained teachers can successfully integrate CT into their curricula, while others need more resources and support. Addressing this issue is important for ensuring that all students, regardless of their educational environment, have equal access to the benefits of CT education. Furthermore, the lack of substantial scientific evidence on effective CT implementation in various settings indicates that many current initiatives may need to be grounded in research-based strategies. This study aims to address this gap by examining existing trends and providing insights into best practices, thereby contributing to developing more equitable and effective CT education programs. Bibliometric analysis of the existing literature can provide insights into how CT is integrated into the primary school curriculum and identify key trends, research gaps, and potential areas for further development (Lee, 2020; Lyon, 2020). This research is expected to significantly contribute to the field of education by offering a comprehensive view of the state of CT research and providing recommendations for developing more effective curricula and teaching methods.

This research is important because it explains how CT is integrated into the elementary school curriculum and affects students' problem-solving and critical-thinking skills. The bibliometric analysis conducted in this study provides an overview of the development of research in the field of CT, identifying key trends, research gaps, and potential areas that can be further developed. Currently, many studies have highlighted the importance of CT in primary education. Previous studies have shown that early CT recognition can improve students' analytical and problem-solving skills. However, there are variations in teaching approaches and the effectiveness of CT implementation in various educational contexts. Some of the important publications in this field include works (Wing, 2006). It introduced the concept of CT, as well as the latest research by (Grover & Pea, 2013; Maharani, Susanti, et al., 2023) Which explores pedagogical approaches to teaching CT in primary schools.

There are several different and controversial hypotheses in the literature on CT. For example, there is a debate about the extent to which CT should be integrated into the basic curriculum and whether these skills are more effectively taught separately or integrated with other subjects (Aminah et al., 2022; Manches, 2017). In addition, there was a discussion about the most appropriate assessment method to evaluate students' CT comprehension (Aydeniz, 2018). This study aims to conduct a bibliometric analysis of the literature on CT at the elementary school level. In addition, it is also to identify the main trends and developments in CT research. Uncover research gaps and areas that require further attention and provide recommendations for developing more effective CT curriculum and teaching methods.

The results of this study are anticipated to offer a comprehensive overview of the status of Computational Thinking (CT) research in primary schools, identifying key trends and patterns in the literature. These insights can serve as valuable resources for educators and policymakers aiming to enhance the integration of CT into the primary school curriculum. However, it is essential to address certain limitations before confirming the findings. The study needs a clearly defined research problem to frame the investigation within a scientific context. A theoretical foundation for the data is needed to strengthen the study's ability to establish a meaningful correlation within a research framework further. The study must present a theoretical basis for grounding the research in existing knowledge. Without this, the data lacks a framework that would allow for the establishment of scientific correlations and meaningful conclusions. The current research systematics must establish a scientific correlation, leading to a conceptual gap. This gap suggests that the study needs to adequately bridge the theoretical understanding with the empirical findings, which is necessary to support the existence of an empirical gap in the research. As this research is still in its preliminary stages, it is important to address these issues before the findings can be validated. Further refinement is required to ensure that the study can offer strategic recommendations for the development of CT in primary education. By resolving these gaps, the study will be better positioned to prepare students for a technology-based future and ensure they possess the skills necessary to thrive in an increasingly complex and interconnected world.

2. METHODS

This study uses a bibliometric approach to analyze the literature on CT in elementary school students. Bibliometrics allow researchers to evaluate research trends, identify important publications, and find patterns in relevant literature (Donthu et al., 2021). The subject of the study is scientific publications published in leading journals that address the topic of CT in elementary school students. Publications included in the analysis must meet certain criteria, such as relevance to the topic, publication time, and journal quality. This research procedure is carried out in several stages. First, data is collected through literature searches using the Publish or Perish application with sources from Scopus. The keywords used in the search included "computational thinking" and "elementary school," resulting in 285 identified data. Second, the articles found are then selected based on their relevance to the research topic and the inclusion criteria set, namely publications from the last 10 years, to ensure the relevance of the data. Based on the results of the initial selection, only 200 data were relevant to the research topic, judging from the title. Articles that are irrelevant or do not meet the inclusion criteria are excluded from the analysis. Finally, important data from the selected articles are extracted, including information about the author, year of publication, title, abstract, keywords, journal sources, and number of citations. The flow of data collection is presented in the following table

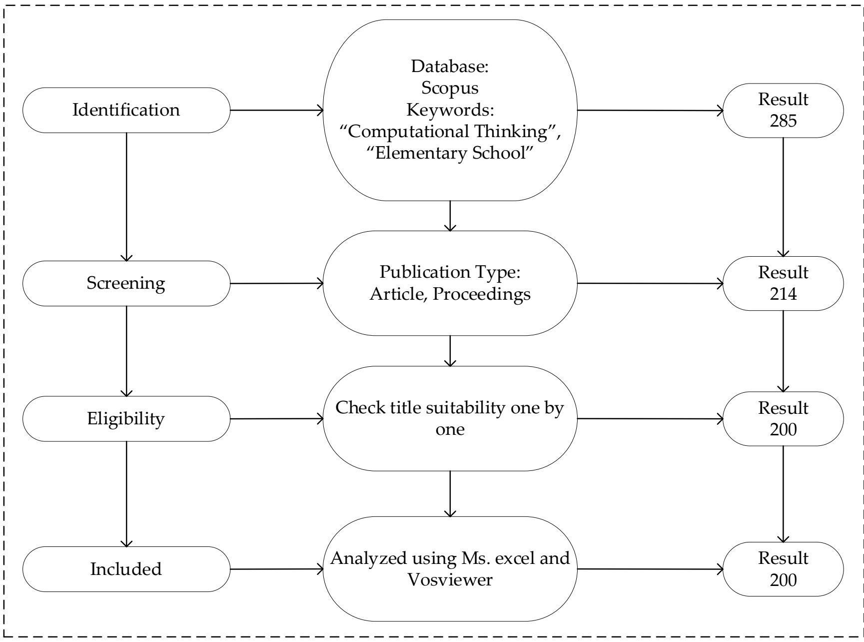

Figure 1. Flow of Data Collection for CT Topic Publication for Elementary School Students

The data was then analyzed to identify citation trends, publication trends, authors with the highest citations as references, and the most productive publication places. In addition, co-authorship analysis and research focus on this topic are also carried out. The analysis is carried out with the help of the VOSviewer application and Microsoft Excel, and the results will be described descriptively. The analysis techniques used in this study include several important steps. First, descriptive analysis is carried out by calculating the number of publications and citations per year and identifying the most productive journals on the topic (CT). Second, network analysis uses VOSviewer software to create a collaborative network map of authors identifying research trends and the most discussed topics. Third, content analysis is carried out by examining the content of the most cited articles to identify the main themes and key findings in CT research in primary schools. With this research method, a comprehensive picture of the trend and development of CT research among elementary school students can be obtained, and areas that require further research can be identified. This study also provides recommendations that educators and policymakers can use to develop more effective CT curricula and teaching strategies. These recommendations are derived from analyzing trends and patterns in existing CT literature, aligning them with the study's objectives. This falls under the category of application analysis, as it translates the findings into actionable strategies. By incorporating these recommendations as part of the concluding analysis stage, the study ensures a coherent progression from data analysis to practical application, thus avoiding disjointedness in the research process.

3. FINDINGS AND DISCUSSIONS

This analysis provides an overview of research trends, important publications, and patterns in the relevant literature. From the initial search using the keywords "computational thinking" and "elementary school," 285 data were identified. After selection based on relevance and inclusion criteria (publications from the last 10 years), only 200 data were considered relevant. Descriptive analysis shows the number of publications per year and the number of citations per year. Several leading journals have become the primary sources for the publication of CT topics in elementary schools. These journals show an increasing trend in CT-related publications and citations.

Identifying authors with the highest citations provides an overview of the most influential individuals in CT research in elementary schools. The analysis of co-authorship shows the network of collaboration between authors and institutions. The geographical location of the publication shows the distribution of CT research in different countries. This analysis also shows cultural differences and education systems between countries that affect CT research. Network analysis using VOSviewer generates a map of author collaborations and the most discussed topics. The main themes in CT research in primary schools were identified through the content analysis of the most cited articles. The content of the most cited articles reveals key findings in CT research in elementary schools. The main themes identified included the effectiveness of CT teaching, the impact of CT on student skills, and innovative CT teaching methods.

Trends Publications

Figure 2. Number of Publication shows the number of publications of Scopus-indexed articles and proceedings regarding Computational Thinking (CT) in elementary school students from 2015 to 2024. This data includes a total of 200 publications spread out every year. From 2015 to 2021, there was a significant increase in the number of publications on CT in primary schools. The peak number of publications occurred in 2021, with around 45 publications. However, after reaching its peak in 2021, the number of publications declined in the following years, especially in 2024, when it only had about five publications. The fluctuations in the data can be seen in Figure 2. The number of Publications is below.

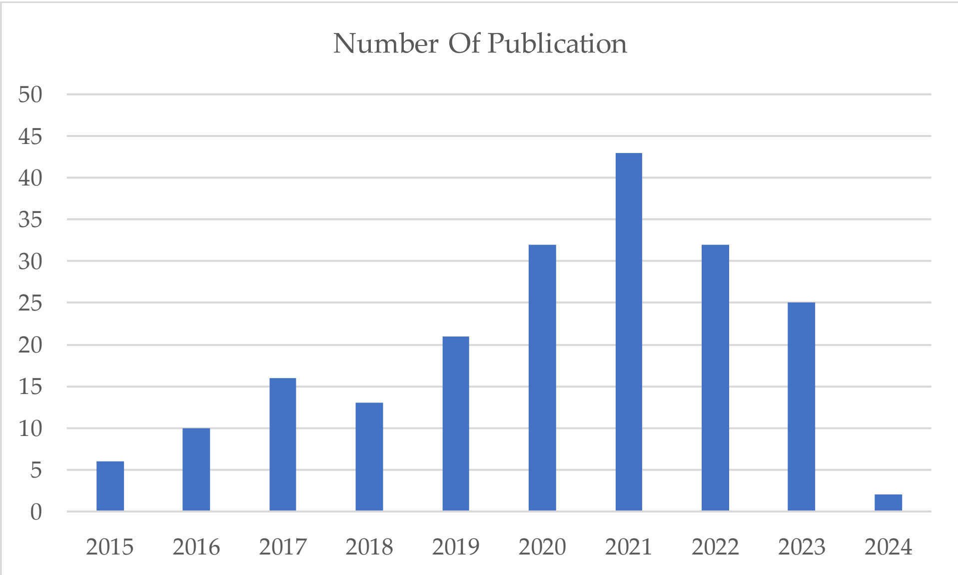

Figure 2. Number Of Publication

Publication trends examine the development and academic attention to Computational Thinking among elementary school students. (Muhammad & Triansyah, 2023). This analysis provides an overview of how this topic has evolved and how much attention has been paid to researchers. This topic peaked in 2021, which can be seen from the number of publications that reached the highest number compared to previous years and after. One of the factors that may have led to its peak in 2021 is the COVID-19 pandemic, which forced many educational institutions to adopt digital learning methods, thus possibly prompting further research in CT as part of online learning solutions, as well as increased awareness of the importance of CT, with encouragement from governments and educational organizations to include CT in the primary education curriculum (Abar, 2021b; Afifah & Istiqomah, 2022; Shamir, 2022). The increase in the number of publications in certain years indicates a great interest and investment in CT research, which can have an impact on education policy, encourage governments and educational institutions to integrate CT into the basic education curriculum, and help develop new learning methods that can improve CT abilities in students (Alkautsar et al., 2023; Kim, 2016). One of the topics that is the focus of this research is the development of learning media to improve CT (Hsu, 2021; Maharani, Susanti, et al., 2023). These studies often explore various tools and methods for effectively teaching CT concepts to elementary school students. Thus, this publication trend provides important insights into the development and direction of research in the field of Computational Thinking in primary education, as well as helps to determine the steps that need to be taken to improve learning in the future.

Citation Trends

Furthermore, the number of article citations and proceedings indexed by Scopus regarding Computational Thinking (CT) in elementary school students from 2015 to 2024 was shown. From 2015 to 2017, there was a significant increase in the number of citations, with the highest peak in 2017 reaching around 1000. After a decline in 2018, there was an increase to the second peak in 2021 with around 900 citations. The following years showed a decline in the number of citations, especially in 2024, with a very low number of citations. The following is Figure 3. Number of Citation.

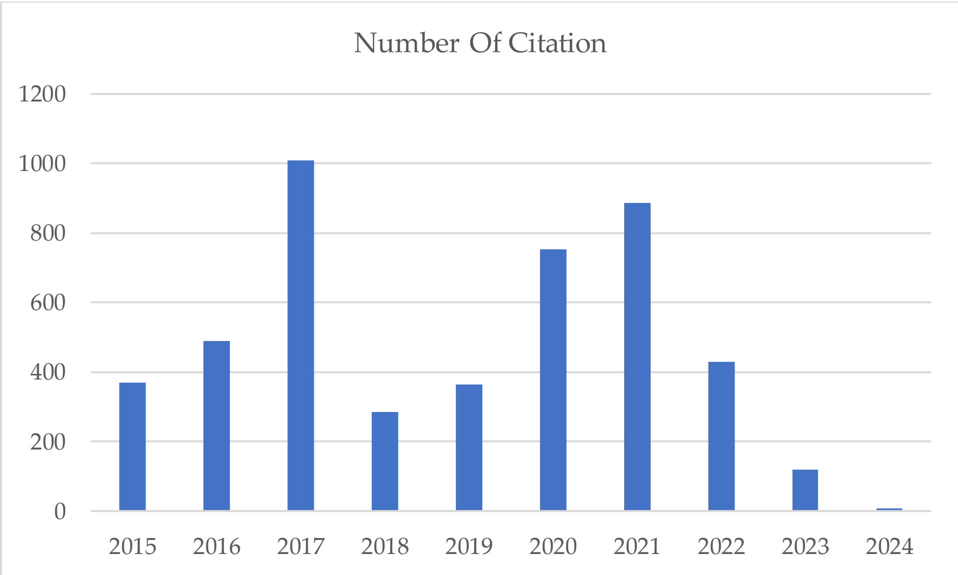

Figure 3. Number of Citation

The trend of CT publication citations in primary schools shows a fluctuating pattern, with two major peaks in 2017 and 2021 and a significant decline after 2021. There were periods of increase in 2015 to 2017 and 2018 to 2021, with a decrease in citations occurring in 2018 and after 2021. Some of the factors that cause this trend are the increase in research and awareness of the importance of CT in primary schools, which encourages further research on CT in learning. The most frequently cited topics are "CT as a thought process" and "learning media," with the focus shifting from "CT as a thinking process" to "learning media" over time (Afif, 2022; Maharani, 2019, 2023). This change is due to the development of digital technology and learning tools and the practical need in schools for more effective methods of teaching CT. This trend of citations impacts education policy, encourages the integration of CT in the basic education curriculum, and motivates the development of new media and learning methods that are more effective in teaching CT. This trend implies that researchers can focus on trending topics and have a big impact, such as learning media for CT. The research results can be used to develop a better curriculum that is more in line with the needs of students in mastering CT.

Most Cited Document

Based on the data obtained, six documents have the highest citations on visual programming and computational thinking in elementary schools. The following are the research results based on the data from the publish or perish view.

Cites	Rank	Authors	Title	Year
350	1	J. Sáez-López	Visual programming languages integrated across the curriculum in elementary school: A two year case study using "scratch" ...	2016
271	2	G. Chen	Assessing elementary students' computational thinking in everyday reasoning and robotics programming	2017
223	3	F. Buitrago Flórez	Changing a Generation's Way of Thinking: Teaching Computational Thinking Through Programming	2017
203	4	M. Israel	Supporting all learners in school-wide computational thinking: A cross-case qualitative analysis	2015
194	5	L.D. English	Advancing Elementary and Middle School STEM Education	2017
132	6	C.P. Brackmann	Development of computational thinking skills through unplugged activities in primary school	2017

Figure 4. Most Cited Document

First article by Sáez-López (2016) This shows that integrating visual programming languages like Scratch into the elementary school curriculum has a significant positive impact. The study observed that Scratch students improved their understanding of programming concepts, logic, and computational practices. In addition, using Scratch also increases students' motivation, engagement, and confidence in learning. This indicates that using visual programming tools can be an effective teaching method at the elementary school level.

Research by Chen (2017) It highlights the importance of assessing students' computational thinking skills in everyday contexts and through robotics programming. The findings of this study show that elementary school students can develop computational thinking skills through various activities, including robotics programming. This emphasizes that learning approaches involving technology, such as robotics, can provide a solid foundation for students to develop computational thinking skills.

Article by Flórez (2017) It emphasizes the importance of teaching computational thinking to the younger generation. According to this study, computational thinking is an important skill that can help students in problem-solving, critical thinking, and collaborating effectively. The article also proposes various methods of teaching computational thinking, including programming, that can be applied in elementary schools to help students develop the necessary skills in the future. Research by (Israel, 2015) They discuss implementing computational thinking in all schools through a case study of two schools. The findings suggest that the comprehensive application of computational thinking can benefit all students, including those usually marginalized in education. This implementation allows students from different backgrounds equal access to computational thinking education, thus creating a more inclusive learning environment.

An article (English, 2017) highlights the importance of STEM education in primary and secondary schools. STEM education is considered to help students develop the skills needed to succeed in the 21st century. This article discusses various ways to improve STEM education in elementary and secondary schools, including the integration of visual programming and computational thinking activities. Based on the findings from these articles, it is recommended that elementary schools integrate visual programming into their curriculum. Visual programming has been shown to help students develop essential skills such as computational thinking, problem-solving, critical thinking, and collaboration (Fofang, 2020). In addition, this integration can also increase students' interest in STEM fields, which is crucial to prepare them for future challenges (Dana-Picard, 2020). Visual programming can be taught to students of all ability levels and is used to teach various subjects, including math, science, languages, and art. Students can develop essential 21st-century skills, such as critical thinking and collaboration, by adopting visual programming. Implementing these recommendations can help create a more dynamic learning environment and support the development of essential student skills in the digital age.

Co-Authorship Analysis

Furthermore, the results of the visualization of co-authorship on the topic of computational thinking in elementary school students were obtained. Co-authorship is the order of author names based on the percentage of contribution to a scientific work (Fried, 2020). Co-authorship analysis is useful for mapping research topics by looking at relationships or collaborations between authors.

(Hidaayatullaah et al., 2021). The figure below shows a visualization of a co-authorship network using VOSviewer on the topic of Computational Thinking (CT) among elementary school students.

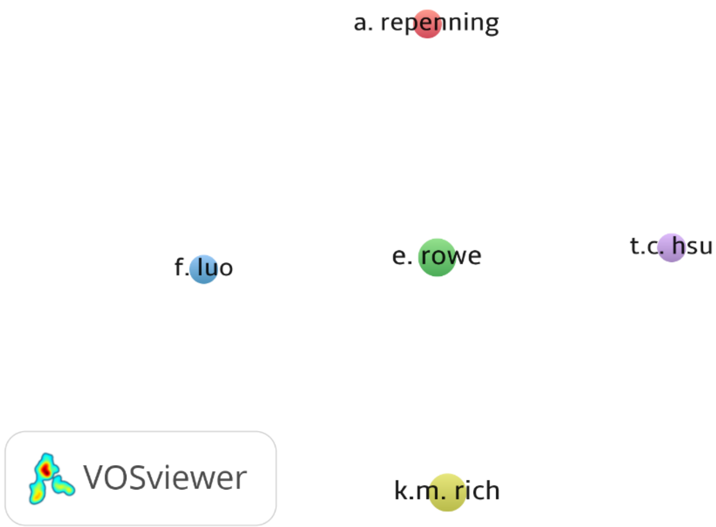

Figure 5. *Co-Authorship*

This visualization helps to identify authors who often collaborate and their influence on CT-related research. Each node in the visualization represents an author. The node size indicates the number of publications or contributions made by that author on the researched topic. Authors with larger node sizes, such as Repenning (2015) and Rowe (2021), significantly contribute to this topic. The node color indicates a cluster or group of authors working together. However, the authors have not collaborated on this topic, suggesting that each author worked independently without collaboration in CT research among elementary school students.

In this study, the most influential authors are (Repenning, 2015) and (Rowe, 2021) Which is indicated by the larger node size in the visualization. The size of these nodes indicates that they have many publications or contributions on Computational Thinking (CT) among elementary school students. The pattern of cooperation between authors in this study shows that each author works independently without collaboration with other authors. This can be seen from the considerable distance between the nodes in the visualization and the absence of connections or lines connecting the nodes.

The gap in this cooperation network became apparent due to the need for more collaboration between authors. The authors appear to be working in isolation, which may indicate a need for more communication or coordination within the CT-focused research community in primary schools. The implications of these findings for future research are the importance of building stronger collaborative networks between authors. By increasing cooperation, researchers can share resources, ideas, and methods, ultimately enriching research and producing more comprehensive and innovative findings in developing Computational Thinking among elementary school students. Researchers can use opportunities to hold conferences, workshops, or discussion groups to strengthen relationships and create a more effective collaborative framework.

Research Focus

The density of CT topics among elementary school students, generated from data from 200 publications in Scopus in 2015-2024, shows various key topics that often appear in the literature. Various terms appear in the images generated by the Vosviewer app. The image is presented in Figure 6 below.

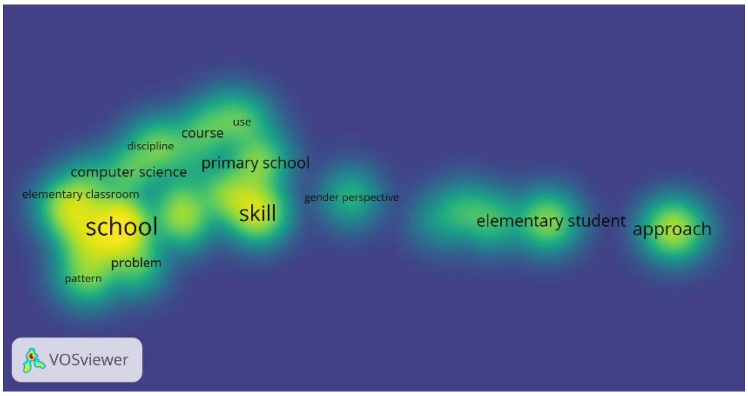

Figure 6. Density Visualization Research Focus

The term "school" is most frequently used, indicating that many studies focus on applying CT in elementary school settings. The term "skill" is also very prominent, highlighting the importance of CT skills developed in elementary school students. The focus of research on the basic education level is confirmed by the frequent appearance of the term "primary school." The close relationship between CT and computer science education in elementary schools is indicated by the frequent mention of "computer science." The term "elementary student" is the main focus, indicating that much research is centered on the students, both in learning and developing CT skills.

The term "approach" indicates the existence of various approaches that have been explored in teaching CT at the elementary school level. The emergence of the term "gender perspective" suggests that some studies consider gender aspects in CT teaching. The terms "problem" and "pattern" frequently suggest that many studies associate CT with students' ability to solve problems and recognize patterns. The terms "course" and "use" indicate that the topic of how an educational course or program is used to teach CT is also quite common in the literature. The term "elementary classroom" highlights the context in which CT is taught, i.e., in an elementary school classroom.

This density map shows that the literature on CT in primary schools is very diverse, primarily focusing on skill development, educational approaches, and contextual and demographic considerations such as gender (Hsu, 2022; Rich, 2022). This research confirms the importance of CT in primary education and the exploration of various methods and approaches for its teaching. The novelties identified from this analysis include a focus on integrating CT in the primary school curriculum, an interdisciplinary approach, a gender perspective, and an evaluation of the effectiveness of various CT teaching approaches. Further research suggestions include longitudinal studies on the effectiveness of CT teaching, the influence of social and cultural contexts, the development and evaluation of teacher training programs, the exploration of new technologies in CT teaching, case studies on the implementation of CT in real classrooms, and the analysis of the impact of CT on students' non-cognitive skills. By identifying these areas, future research can be more focused and significantly contribute to the development and application of CT at the primary education level.

From the analysis of CT topic density images in elementary school students, several novelty points and suggestions for further research can be identified. First, focusing on integrating CT into the elementary school curriculum is an important point. The density map shows that many studies have addressed the application of CT in primary schools. However, details on how CT is effectively integrated into curricula in different countries may still need to be improved. Second, interdisciplinary approaches need to be explored further. Terms like "computer science" and "skill" suggest a close relationship between CT and computer science education. New research could combine CT with other subjects such as math, science, or art. Third, the gender perspective emerged as an area that needed more research. The term "gender perspective" suggests that some studies have already considered gender differences in CT teaching. Still, more research is needed to understand how gender affects the acceptance and development of CT skills in primary school students. Fourth, the teaching and learning approach is also an important focus. The term "approach" indicates the existence of various teaching methods being explored so that new research can focus on evaluating the effectiveness of various CT teaching approaches and developing new, more effective methods.

For further research suggestions, several important areas can be identified. First, a longitudinal study on the effectiveness of CT teaching needs to be conducted to observe the long-term effects of CT teaching on primary school students, including skill development and its impact on academic achievement at higher education levels. Second, the influence of social and cultural context needs to be explored further, given the geographical and cultural variations shown in the density map. This research can explore how social and cultural contexts affect the teaching and acceptance of CT in different countries. Third, developing and evaluating teacher training programs is an important area to research. Research can focus on developing training programs for teachers to teach CT more effectively and evaluating these training programs to ensure the quality of teaching. Fourth, new technologies in CT teaching also need to be explored. With the rapid development of technology, research can explore how new technologies such as AI, VR, and AR can be used to teach CT more engagingly and interactively. Fifth, case studies on CT implementation in real classrooms can provide valuable insights into how CT is implemented in the classroom, the challenges faced, and the solutions implemented. Finally, the analysis of the impact of CT on students' non-cognitive skills, such as creativity, collaboration, and critical problem-solving, needs to be further explored. By identifying these areas, future research can be more focused and significantly contribute to the development and application of CT at the primary education level.

4. CONCLUSION

The conclusion of this study highlights the importance of Computational Thinking (CT) in primary education and various aspects related to it. First, the authors "a. Repenning" and "e. rowe" proved to be the most influential, with significant contributions to CT-related publications. However, the pattern of cooperation suggests that the authors work independently without collaboration, indicating a gap in the cooperation network. The publication trend showed a significant increase from 2015 to 2021, peaking in 2021 before declining in the following years. The increase in the number of publications and citations in a given period indicates a strong interest and investment in CT research, which is influenced by factors such as the COVID-19 pandemic and increased awareness of the importance of CT. Research using visual programming tools such as Scratch positively impacts students' understanding of programming concepts and motivation. Future research should focus on building stronger collaborative networks between authors, integrating CT in the primary school curriculum, interdisciplinary approaches, and gender perspectives, and exploring new technologies in CT teaching. Thus, this study provides a comprehensive overview of the development and direction of CT research in primary education, as well as important implications for education policies and the development of more effective learning methods. This research has several limitations. First, the data is limited to indexed publications in Scopus, so other important studies may need to be included. Second, the co-authorship analysis needs more collaboration between authors with in-depth explanations. Third, the research focuses more on publications and citations than on the real impact of CT implementation in elementary classes. Fourth, contextual factors such as cultural differences and education systems between countries have yet to be explored. For further research, it is recommended to focus on longitudinal studies on the effectiveness of CT teaching, exploration of the influence of social and cultural contexts, development and evaluation of teacher training programs, the use of new technologies in CT teaching, case studies of CT implementation in the classroom, and analysis of the impact of CT on students' non-cognitive skills. Identifying these areas could help future research significantly contribute to the development and application of CT in primary education.

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