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Trends in Computational Thinking Research in Science Education: A Systematic Review

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Abstract

This study aimed to investigate patterns in the application of computational thinking (CT) in scientific education. This study used a systematic review. Eleven papers from the ERIC database that were published between 2021 and 2025 were analyzed using the qualitative descriptive method. According to the review's findings, CT has been extensively employed across a range of educational levels, most notably in scientific and physics courses, as well as at the elementary school and high school levels. STEM is the most often utilized technique. CT has been used extensively in education and has been shown to improve student learning results, scientific idea comprehension, and critical thinking abilities.

Keywords: Systematic Review, Computational Thinking, Science Learning

INTRODUCTION

In some countries such as United Kingdom, Singapore, Finland, and South Korea have integrated computational thinking (CT) into their curricula (Shute et al., 2017). Students' capacity to comprehend and resolve issues using methodical and logical techniques can be improved by incorporating CT into scientific instruction (Asrial et al., 2022). Algorithmic thinking, on the other hand, is the ability to think in a systematic and orderly manner to address problems or gain a better understanding of a situation by developing solutions to the problems encountered (Syahputra & Sinaga, 2024).

In Indonesia, the government has taken steps to incorporate CT into the education curriculum. Currently, the independent curriculum has become the national education curriculum. Through this curriculum, CT can be applied to subjects such as mathematics, science, and language at the primary and secondary education levels. However, the implementation of CT in practice still faces challenges, such as a lack of understanding among educators regarding the concept of CT and limitations in lesson planning that incorporates CT (Sondang & Yusdani, 2023). To support the implementation of CT, various measures have been taken, including training for educators to apply CT in teaching. For example, SEAMEO QITEP in Science (SEAQIS), a unit under the Ministry of Education, Culture, Research, and Technology, has conducted teacher training as part of the Merdeka Belajar and Guru Penggerak programs with the aim of enhancing teachers' competencies in developing CT-based learning (SEAQIS, 2021).

Previous research shows that exploration of improvements in students' CT is more dominant in mathematics (Fitria et al., 2024). However, two previous studies provide insights that are consistent with the context of science. Azkia et al. (2024) found that the problem-based learning (PBL) model assisted by liveworksheet significantly improved students' CT on environmental change material. Meanwhile, a systematic review by Rahim et al. (2024) revealed that CT research has been conducted at various educational levels using diverse evaluation tools, with portfolios being the most dominant. As a result, this systematic review will investigate the efficacy of different science learning models, such as PBL, and assess the applicability and efficacy of different assessment instruments, such as portfolios, in gauging and enhancing students' CT abilities within the framework of science education. In order to thoroughly investigate how different science learning models might be implemented to enhance students' CT skills, a systematic study was carried out. It is anticipated that the review's findings would give researchers and educators precise instructions on how to successfully incorporate CT into science teaching methods.

The advancement of science education will benefit from this research, especially when it comes to using CT as a teaching strategy or improving 21st-century abilities that promote science and technology literacy in the twenty-first century. By carrying out a comprehensive review, this study significantly advances our understanding of how CT is used in science instruction at different educational levels. In order to identify research gaps, such as the need for more precise CT research instruments and science education that looks at the long-term effects of CT integration on student learning outcomes, the results of this study will give a summary of CT implementation in learning at different levels from 2021 to 2025 (Suharto, 2022). Furthermore, the results of this analysis provide references on CT-based learning strategies that may be applied to more cognitively meaningful science education, which can be used to design more contextualized future research (Weintrop et al., 2021).

METHOD

The method used in this study was a Systematic Review. In general, the literature review was conducted by collecting research materials in the form of journals, noting down the necessary points, and processing the results. Through the Systematic Review method, researchers select, identify, examine, research, and investigate specific data or evaluate relevant research to answer the research questions that have been formulated (Pitaloka et al., 2023). Data collection was carried out through a literature review in the Eric database using the Publish or Perish tool and the Eric journal website. Article searches were conducted using the keywords “computational thinking” and “science learning” both nationally and internationally. There were 43 articles relevant to these keywords. The relevant articles were then reanalyzed using the Criteria in Table 1.

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Journal articles	Book chapters, proceedings, book, review literature
Articles published between 2021 and 2025	Articles not published between 2021 and 2025
Articles related to computational thinking in science education	Articles unrelated to computational thinking in science education
The article is available in full text	Article not available in full text version
Articles published in English	Articles not published in English

RESULTS AND DISCUSSION

Based on the results of searching various articles that met the criteria, there were 11 (eleven) articles relevant to computational thinking skills, with details of the analysis of the articles shown in Table 2 and Figure 1.

Table 2. Results of the Analysis of Articles on Computational Thinking Skills

No.	Authors	Journal Name
1.	Panupong & Worapun (2023)	Journal of Education Learning
2.	Agustiningrum & Demboh, 2024	Journal of Science Learning
3.	Cabrera et al. (2024)	Journal of Research in Science Teaching
4.	Tan et al. (2021)	Journal of Mathematics, Science, and Technology Education
5.	Galoyan et al. (2022)	International Journal of Instruction
6.	Yang et al. (2021)	European Journal of STEM Education
7.	Pratidhina et al. (2023)	Journal of Education and e-Learning Research
8.	Samad et al. (2023)	International Journal of Educational Methodology
9.	Lore et al. (2023)	International Journal of Science and Mathematics Education
10.	Arık & Topçu (2022)	Journal of Science Education and Technology
11.	Prajuabwan & Worapun (2023)	Journal of Education and Learning

Table 2 shows articles from various journals that were used as sources for data retrieval in the literature review. There are 11 articles on CT implementation from various different journals. These articles were obtained from the Eric database between 2021 and 2025 and then filtered based on specified criteria. The diversity of journals that are the sources of these articles shows that the topic of CT implementation attracts the attention of researchers from various fields of focus in education. Journals in Table 2 represent diverse interests in the field of educational research. The relevant articles come from various different scientific journals, indicating that the application of CT is an active and important topic in education today. Each journal typically has slightly different focuses and scopes, so the research approaches, methods used, and educational contexts discussed in each article also vary.

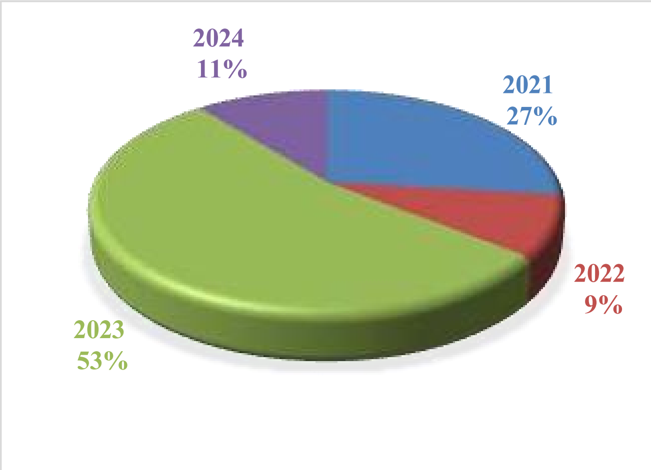

Figure 1. Diagram of Articles per Year

Computational Thinking Based on Material Aspects

CT has been widely applied to various subject contents in schools, from elementary schools to junior high schools and high schools. The articles obtained were then grouped based on several aspects, namely school level, subject, and content, resulting in the data shown in Table 3 and Figure 2.

Table 3. School Levels, Subjects, and Content

No.	Authors	School Level	Subjects	Material
1.	Panupong & Worapun (2023)	Elementary school	Natural science	Respiratory, circulatory, and digestive systems
2.	Agustiningrum & Demboh, 2024	Senior high school	Physics	Electrical circuit
3.	Cabrera et al. (2024)	Elementary school	Natural science	Water cycle
4.	Tan et al. (2021)	Senior high school	Physics	Electric current, voltage, and resistance
5.	Galoyan et al. (2022)	Senior high school	Physics	Vector measurement
6.	Yang et al. (2021)	Elementary school	Natural science	Geosciences – Mars
7.	Pratidhina et al. (2023)	Senior high school	Physics	Hooke's Law and spring adjustment
8.	Samad et al. (2023)	Senior high school	Chemistry	Chemical equilibrium
9.	Lore et al. (2023)	Junior high school	Natural science	Geosciences – Earth processes and systems
10.	Arık & Topçu (2022)	Elementary school	Natural science	Digestive system
11.	Prajuabwan & Worapun (2023)	Elementary school	Mathematics	Programming basics

Based on the findings in Table 3, out of the 11 articles found in the school level aspect, the most dominant were elementary and high school levels, with 5 articles each, meaning that more research articles implementing CT were found in elementary and high school levels. In addition, there was also one article on junior high school level. From the perspective of subjects and content, for the high school level, the articles were found in the subjects of chemistry and physics. However, physics dominated with 4 articles, covering topics such as electrical circuits, electric current, voltage, resistance, vector measurement, Hooke's law, and spring regulation (Agustiningrum & Demboh, 2024; Galoyan et al., 2022; Tan et al., (2021); Pratidhina et al., 2023). Meanwhile, in chemistry, there is 1 article applied to chemical equilibrium (Samad et al., 2023). Additionally, for the elementary school level, there are 4 articles with natural science subject content, namely on the concepts of the respiratory system, circulatory system, digestive system, water cycle, geoscience on Earth processes and systems, and Mars (Panupong & Worapun, 2023; Cabrera et al., (2024); Lore et al., 2023; Arık & Topçu, 2022), and mathematics on programming fundamentals (Prajuabwan & Worapun, 2023).

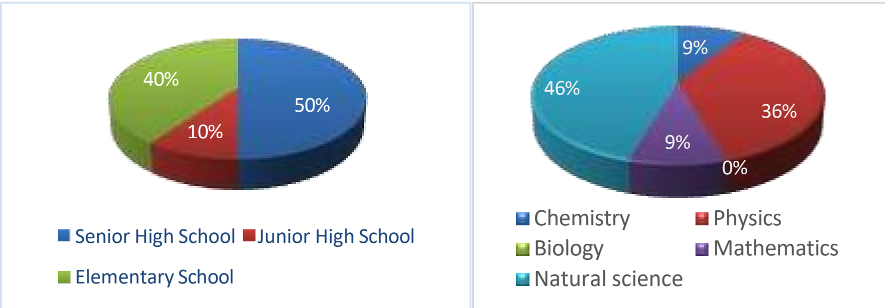

Figure 2. CT Distribution Diagram by School Level and Subject

Computational Thinking Based on Approach and Learning Achievement Aspects

CT has been widely integrated with various learning approaches. Based on 11 articles, 4 articles integrated their research with various learning strategy such as STEM (Science, Technology, Engineering, and Mathematics), followed by the STEAM approach, the Design-Based Research (DBR) approach, PjBL, Engineering Design Process (EDP), model-based explanations (MbEs), modeling-based learning, and authentic inquiry, as presented in Table 4 and Figure 3.

Table 4. Learning Approaches and Outcomes

No.	Authors	Approach	Learning Outcomes
1.	Panupong & Worapun (2023)	STEM	Improving science achievement, computational thinking skills, and student satisfaction with learning experiences
2.	Agustiningrum & Demboh, 2024	Design Besed Research (DBR)	Improving independent learning and computational thinking skills
3.	Cabrera et al. (2024)	STEM	Computational thinking skills
4.	Tan et al. (2021)	STEAM	Critical thinking, problem solving, and computational thinking skills
5.	Galoyan et al. (2022)	STEM	Computational thinking skills
6.	Yang et al. (2021)	STEM	Students' STEM skills and computational thinking

No.	Authors	Approach	Learning Outcomes
7.	Pratidhina et al. (2023)	Modeling-based learning	Students' scientific process skills and computational thinking
8.	Samad et al. (2023)	Engineering Design Process (EDP)	Students' computational thinking
9.	Lore et al. (2023)	Authentic Investigation	Students' understanding of science content and computational thinking
10.	Arık & Topçu (2022)	Model-based Explanations (MbEs)	Improving students' understanding of computational concepts and thinking.
11.	Prajuabwan & Worapun (2023)	STEM	Achievement in science, computational thinking skills, and student satisfaction

Based on Table 4, it can be seen that the STEM approach is more widely implemented in learning to improve CT skills. As explained in the research conducted by Panupong & Worapun (2023) on the STEM approach to students' CT skills. The research results indicate a significant difference between pre-test and post-test student learning achievements related to concepts, with an average pre-test score of 11.87 and an average post-test score of 21.77. Meanwhile, the research results of Agustiningrum & Demboh (2024) using the Design-Based Research (DBR) approach focused on improving self-directed learning skills through integration and practice, critical thinking (CT), and self-directed learning (SLR).

The overall results of this study highlight the great potential of integrating CT with various approaches, especially through unplugged methods, in revolutionizing science pedagogy. Students' ability to create clear and organized representations of how biological systems are interconnected without relying on technology, as described by Arık & Topçu (2022), demonstrates that the foundations of computational thinking can be stronger when students learn through simple activities that do not depend on complex digital tools. Furthermore, the success of STEM approaches as the primary method, as demonstrated by the research conducted by Prajubawan & Wittaya (2023) in enhancing motivation and learning outcomes, indicates that shifting the paradigm from traditional teaching to more integrated and problem-solving-centered approaches is key to preparing students for 21st-century challenges.

Therefore, the development and implementation of a science curriculum emphasizing MbEs, CT unplugged, EDP, modeling, authentic inquiry, and the STEM framework should be seriously considered to optimize students' learning experiences and equip them with essential skills for scientific reasoning and innovation.

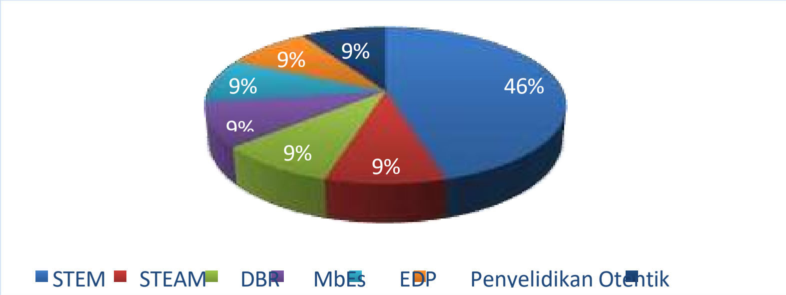

Figure 3. Distribution Diagram of the Approach

CONCLUSION

Computational Thinking (CT) implementation were found in elementary and high school levels. Additionally, the CT has been integrated in various learning strategy such as STEM approach, STEAM approach, DBR approach, PjBL, EDP, MBEs, Model-based Learning, and Authentiq inquiry.

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