



Research Trends in Computational Thinking: A Systematic Content Analysis of Publications

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Abstract: Computational thinking (CT) is an essential skill for solving complex problems. This study aims to identify and analyze CT frameworks used as instructional techniques across various subjects. This research employs a literature review method. Data were obtained from the ERIC database using the keywords “computational thinking”, “science education.” From more than 600 articles published between 2012 and 2021, 32 articles were selected based on inclusion criteria. The selection process followed systematic stages: identification, screening, eligibility, and inclusion. Data were analyzed using content analysis focusing on publication year, source, subject area, research participants, educational level, and CT frameworks. The results indicate that CT is implemented across multiple educational levels, from preschool to higher education, and is integrated into various subjects. CT approaches are frequently combined with STEM and constructivist approaches to enhance problem-solving skills. Common CT components include decomposition, pattern recognition, abstraction, and algorithmic thinking, along with several variations of other CT components. Overall, CT is an effective approach that can be applied across disciplines to develop problem-solving and critical thinking skills. The integration of CT in learning is recommended to improve the quality of education in the digital era.

Keywords: Computational thinking; STEM Integration; Problem solving

Introduction

Computational thinking is a specialized skill associated with computer science (Chen et al., 2017; Lai et al., 2022; Wong, 2020). However, today almost everyone is expected to have basic computing skills that keep pace with current technological developments (Csizmadia et al., 2019; Yusup et al., 2025). Among these skills, computational thinking is believed to be an important skill to enable future generations (Hunsaker et al., 2020; Merino-Armero et al., 2018; Nouri et al., 2020; Rehmat et al., 2020) but how to apply these skills requires further investigation.

Definitions for computational thinking/CT, which define it as an approach to problem solving, system design, and understanding human behavior based on

computer-based concepts (Ma et al., 2021). Consider CT as a skill that requires the use of computing systems to solve problems in all fields of study (Garneli et al., 2018; Kwon et al., 2021; Rehmat et al., 2020). Thus, most research focuses on CT thinking skills.

Developing CT skills makes it more interesting using coding (Gero et al., 2019; Tran, 2019). by using media results in better CT abilities (Fitri et al., 2024; Fuad et al., 2025) and better understanding of concepts (Novella et al., 2024; Rabiudin et al., 2023; Surbakti et al., 2023) problem-solving abilities increase (Almujaddid et al., 2025; Fitri et al., 2024; Sholihah et al., 2023). In particular, studies on CT have presented a variety of different ideas about the definition and development of CT skills (Ertugrul-Akyol, 2019; Tsai et al., 2021; Yin et al., 2020). These differences revealed in the

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understanding of CT have also been reflected in interventions for the measurement and development of related skills. This also prevents the achievement of an understanding of how CT is developed (Aksit et al., 2020; Garneli et al., 2018; Kwon et al., 2021; Ma et al., 2021), There are even different strategic approaches to CT development used. There is diversity among countries, regions, schools.

This research was conducted as an effort to present a comprehensive literature mapping that not only reviews the definition of computational thinking (Latif et al., 2024; Rabiudin et al., 2023; Sholihah et al., 2023; Sulsilah et al., 2023; Yusup et al., 2025), but also examines the components of CT or CT frameworks, fields of study, and the distribution of research based on educational levels that use CT approaches used globally. Unlike previous research that generally focus on specific aspects, this study integrates various dimensions of CT development in one systematic literature review. Thus, this research is expected to provide a comprehensive overview of trends, research gaps, and future directions of CT development, particularly as a conceptual foundation for learning design and further research.

The main objective of our research is to understand the process of developing CT skills in a literature review. The problem formulation is further clarified below as research questions: a) What are the syntax patterns of computational thinking, b) How is the distribution of articles based on level? c) How is the distribution of computational thinking based on the field of study, d) What is the computational thinking based on subject?

Method

The research method employed in this literature review adopts a modified procedure derived from the Systematic Review and Meta-Analysis (PRISMA) framework proposed by Page et al. (2021). The procedure applied does not strictly follow the standard PRISMA flow diagram; rather, it represents a literature selection process adapted to align with the objectives of the study. The research stages refer to the four main phases of PRISMA, namely identification, screening, eligibility, and inclusion, as shown in Figure 1.

This study used the ERIC journal index search engine (eric.ed.gov). Articles used in the study published between 2012 and 2021 were selected. The keywords used in the article search were "computational thinking, science education." Articles using languages other than English were excluded. Book reviews, editorials, book chapters, and commentaries using languages other than English were also excluded. Based on the index search engine data, 600 articles were obtained, of which 32 articles with the criteria. Data that met the criteria were analyzed using the Computational

Thinking framework and the study of the materials used.

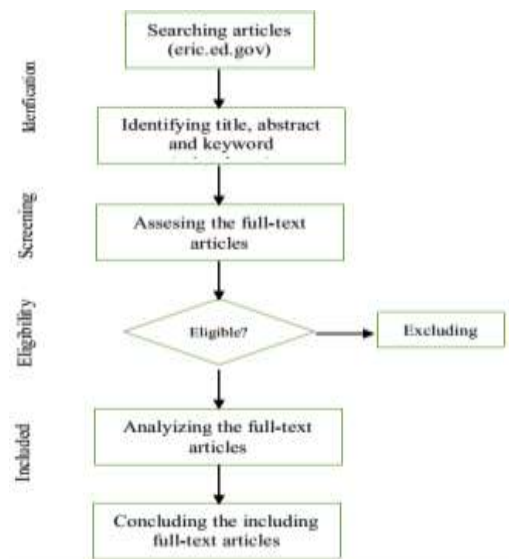


Figure 1. Article selection flow in the research

Result and Discussion

The results of the literature review research include data related to the computational thinking indicators used, educational levels, fields of study, and learning techniques used. The following presents the results of the literature review research.

The component used to measure CT skills vary so they are also related to the subject content used, for example decomposition, pattern recognition, abstraction, and algorithmic thinking (Brigas et al., 2019; Gopinath et al., 2021; Yin et al., 2020). These four components are used in science and robotics learning (Brigas et al., 2019).

In computer learning using CT in this study, three forms of computational thinking were used, namely abstraction, decomposition, algorithmic thinking, evaluation and generalization (Tsai et al., 2021). Pattern formulation and decomposition, alghoritms and logical thinking , data representation (pattern recognition), Abstraction, generalization, debug and simulation (Menolli et al., 2022) and decomposition, abstraction, algorithm design, automation, data collection, data analysis, data representation, simulation, parallelization, generalization (Alfayez et al., 2019). Meanwhile, in robotics learning there are forms, namely decomposition, pattern recognition, abstraction (and modularity), algorithm design (Wu et al., 2021) and there is the addition of modularity to the abstraction indicator (Aristawat et al., 2018) and abstraction, decomposition, generalization, pattern recognition, lghoritmic thinking, flow control and data representation (Piedade et al., 2020).

Table 1. CT Component Used in Research are Related to Material Content

Author	Subject	CT Component
(Ehsan et al., 2021)	Engineering	Abstraction, Algorithms and Procedures, Troubleshooting and Debugging, Pattern recognition, Problem decomposition, Simulation
(Rehmat et al., 2020)	Engineering	Abstraction, Algoritma and procedure, Debugging/ troubleshooting, Problem Decomposition, Pattern Recognition
(Lyon et al., 2021)	Biological engineering	Abstraction, alghoritmik thinking, Evaluating, generalization, decomposition
(Wu et al., 2021)	Robotic	Decomposition, Pattern recognition, Abstraction, Alghoritm design
(Aristawat et al., 2018)	Robotic	Abstraction and modularity, Generalization, Alghoritmik Thinking Decomposition
(Piedade et al., 2020)	Robotic	Abstraction, Decomposition, Generalization, Pattern Recognition, Alghoritmik Thinking, Flow Control, Data representation
(Sung et al., 2021)	Mathematics	Recognition, visual association, description/ analysis, abstraction
(Tran, 2019)	Mathematics	Sequence, Algorithm, Loop, Debug, Condition
(Mensan et al., 2020)	Science	Decomposition, Pattern recognition, Abstarction, Alghoritm design
(Irgens et al., 2020)	Science	Agents, Agent Actions, Biological System, Experimentation, Justification, Quantitative amount, temporak change, Graphs
(Gopinath et al., 2021)	Science	Decomposition, Pattern recognition, Abstarction, Alghoritm design
(Gilchrist et al., 2021)	Science	Data practices, Modeling and simulation practices, Computational, Problem solving Practices, Systems Thinking Practices
(Sirakaya et al., 2020)	Science	Creativity, Alghoritmik Thinking, Cooperativity, Critical Thinking Problem Solving
(Chongo et al., 2020)	Science	Alghoritmik Thinking, Abstraction, Decomposition, Evaluation, Generalization
(Kale et al., 2021)	Science	Decomposition, Pattern Recognition, Abstract, Alghoritm/ Automate, Analysis
(Tan et al., 2021)	Science	Alghoritmik Thinkin, Cooperativity, Creativity, Critical thinking, Problem Solving
(Tonbuloglu et al., 2019)	Science	Creativity, Alghoritmik Thinking, Collaboration, Critical Thinking, Problem Solving
(Garneli et al., 2018)	Science	Abstraction and Problem Decomposition, Parallelism, Logical, Thinking, Flow Control, User Interactivity, Data Representation, Synchronization
(Karakasis et al., 2020)	Science	Alghoritmik Thinking, Decomposition, Pattern Recognition, Abstraction and Generalization
(Sondakh et al., 2020)	Science	Abstraction, Alghoritmik Thinking, Decomposition, Debugging, Evaluation, Generalization
(Brigas et al., 2019)	Science	Pattern Recognition, Alghoritmik Thinking, Decomposition, Abstraction
(Matsumoto et al., 2017)	Natural science	Simulation and Modeling, Analysis data experiment, Coding and programing, Alghorimic reasoning, Statistic and probability
(Tsakeni, 2021)	Natural science	Problem decomposition, Pattern recognition, Generalization and abstraction, Algorithm design
(Adler et al., 2018)	Natural science	Formulation Problem, Logically organization and analyzing data Abstraction, Alghoritmik thinking, Identifying -analyzing and implementation possible solution, Generalizing
(Weintrop et al., 2016)	Natural science	Dekomposisi, Abstraction, Pattern recognition, generating alghoritmik, recognizing and addressing ambiguity in algoritms (evaluation)
(Rich et al., 2020)	Natural science	Abstraction, Decomposition, Debugging, Pattern
(Yin et al., 2020)	Physics	Abstarction, Decomposition, Alghoritm design, Pattern recognition
(Tsai et al., 2021)	Computer	Abstraction, Decomposition, Alghoritmik Thinking, Evaluation and Generalization
(Csizmadia et al., 2019)	Computer	Abstarction, Alghoritmik Thinking, Decomposition, Evaluating, Generalization
(Menolli et al., 2022)	Computer	Pattern formulation and decomposition, Alghoritmik and logical thinking, Data representation (pattern recognoition), Abstraction, Generalization, Debug, Simulation
(Alfayez et al., 2019)	Computer	Decomposition, abstraction, alghoritm Design, Automation, Data Collection, Data Analysis, Data representation, Simulation, Parallelization, Generalization
(Lee et al., 2020)	interdisciplinary	Abstarction, Alghoritmik, Programming/ Development, Data collection and analisi, Modeling and simulation

Meanwhile, in mathematics learning there are 2 forms, namely recognition, visual association, description/analysis, abstraction (Sung et al., 2021) and sequence, algorithm, loop, debug, condition (Tran, 2019)

Meanwhile, for interdisciplinary, namely abstraction, algorithms, programming/development, data collection and analysis, modeling and simulation (Lee et al., 2020). In science learning (science, mathematics, physics) there are various forms of indicators in computational thinking skills that vary.

Classification Based on School Level

Table 2. Classification Based on School Level

Level of Education	Amount	percent (%)
Pre-school	2	6.25
elementary school	6	18.75
High school	15	46.80
College	4	12.50
Teacher	5	15.60

Classification Based on Field of Study

Table 3 Classification Based on Field of Study

Subjects	Amount	Percent (%)
Engineering, Biology	3	9.40
Robotics	3	9.40
Mathematics	2	6.30
Science, Physics	19	59.30
Computer	4	12.50
Interdisciplinary	1	3.10

Classification Based on Subject

Research examining computational thinking has been widely conducted. Based on the analysis of 32 articles, the distribution of studies shows that research subjects include pre-service university students, physics teachers from various universities, and school students ranging from elementary to secondary levels. Data on the distribution of research based on school-level classification are presented in Table 2. The table data show that research related to CT most frequently involves subjects at the senior high school level, elementary school students, and teachers. From these research (Alfayez et al., 2019), it was found that some computer teachers still have a low level of understanding, which occurs due to misconceptions about defining CT as a learning approach, Therefore, it is necessary to introduce CT as a learning approach for teachers (Yin et al., 2020). Furthermore, instruction using a CT approach must ensure that learning is structured according to CT principles (Kale et al., 2021). According to Tsakeni (2021), CT can help learners improve their problem-solving skills, while Weintrop et al. (2016) state that CT can enhance learning outcomes.

Research by Adler et al. (2018) explains that through CT, teachers can learn instructional material more effectively. The implementation of CT in elementary school learning can improve collaboration, perseverance, abstraction, and creativity (Tran, 2019).

Meanwhile, studies by Ehsan et al. (2021) and Wu et al. (2021) show that, in terms of gender, there is no significant difference in computational thinking abilities. However, indicator-level analysis reveals that female students perform better in decomposition, whereas male students demonstrate better performance in algorithm design. In contrast, research by Tsai et al. (2021) indicates that, with the implementation of CT, male students exhibit better decomposition skills compared to female students.

Table 4. Classification by Subject

Integration	Amount	Percent (%)
CT	23	71.90
CT-STEM	6	18.80
CT-STEAM	2	6.20
CT-construktivism	1	3.10

Research by Lyon et al. (2021) shows that the implementation of CT is very important, and therefore it needs to be integrated into the curriculum. CT helps teachers in classroom instruction (Irgens et al., 2020). Learning using STEAM-CT supports science-arts education (Tan et al., 2021), and learning through CT-STEM makes instruction more contextual (Csizmadia et al., 2019).

Learning implemented in elementary schools shows that the use of modules helps students improve their CT skills (Mensan et al., 2020). Meanwhile, research by Garneli et al. (2018) indicates that studies on video game development result in higher CT skills. According to Karakasis et al. (2020), learning with BlocklyScript helps students better understand the basic concepts of CT. Similarly, research by Tonbuloglu et al. (2019) shows that coding-based learning supports the understanding of CT, although there are still difficulties in concretizing concepts that require mathematical equations.

Meanwhile, regarding suitable subject matter for instruction, research by Sung et al. (2021) shows that in a mathematics context, CT becomes more concrete. In addition, visual data science helps facilitate CT learning (Gilchrist et al., 2021). Research by Menolli et al. (2022) indicates that in technology-related subjects, understanding is enhanced when instruction uses a CT approach. One example of technology-based learning is robotics. Piedade et al. (2020) show that robotics learning with a STEAM approach is highly compatible with CT. This is supported by Aristawat et al. (2018), who explain that a CT approach can be applied across various engineering fields involving activities such as assembling, programming, and testing, thereby improving problem-solving skills. This is further reinforced by Sirakaya et al. (2020), who demonstrate that CT is highly suitable when integrated with a STEM approach.

Research by Rich et al. (2020) identifies four important points in CT instruction: (1) presenting CT as a general problem-solving strategy, (2) using CT to structure lessons, (3) highlighting CT through prompts, and (4) using CT to guide teachers' planning. Meanwhile, findings by Sondakh et al. (2020) recommend that higher education institutions adopt CT holistically, as it can enhance problem-solving skills and help prepare high-quality graduates for the future.

Conclusion

The forms of computational thinking skills used to solve problems vary widely. Indicators of computational thinking skills significantly influence the study of the material that is the object of problem-solving studies. Computational thinking skills are not only used for problem solving on computers but also for other fields of study. The study between the article based on Computational thinking syntax, the main findings of the article. The computational thinking approach can be used at the preschool level to higher education and is also a learning approach for teachers. Computational thinking studies can be used in various lessons/multidisciplinary in this study include science, computers, robotics and engineering as well as interdisciplinary. Computational thinking can be integrated with STEM, STEAM and constructivism. And obtained important findings in computational thinking learning. Based on the screening results, 32 articles that met the inclusion criteria were identified. It can be concluded that the components of Computational Thinking (CT) employed in educational practices demonstrate considerable variation. The most commonly identified components include decomposition, pattern recognition, abstraction, and algorithmic thinking. However, additional CT components were also found to be developed and adapted according to specific learning contexts, indicating the flexibility of the CT framework in educational practice. The implementation of CT was identified across multiple educational levels, ranging from early childhood education to higher education, including within the context of teacher professional development. The distribution of studies shows that the majority were conducted at the secondary school level (high school), accounting for more than 46.8% of the total articles analyzed. In terms of disciplinary domains, CT applications span a wide range of fields, including engineering, robotics, mathematics, science, computer science, and interdisciplinary studies. The analysis reveals that science is the most dominant domain, representing 59.3% of the studies. Furthermore, the integration of CT in learning is commonly combined with various approaches, such as CT-STEM, CT-

STEAM, and constructivist-based CT. Among these approaches, the use of CT as a standalone framework is the most prevalent, followed by its integration with STEM. Overall, these findings suggest that CT possesses adaptive characteristics for problem-solving and can be widely implemented across diverse educational contexts, in terms of educational level, disciplinary domain, and instructional approach.

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Author Contributions

Conceptualization, E.D.A and S; validation, B.S and A.R; formal analysis, E.D.A; investigation, E.D.A; resources, E.D.A and B.S; data curation, E.D.A and B.S; writing – original draft preparation, E.D.A and B.S; writing – review and editing, E.D.A, A.R and S; visualization, E.D.A and B.S. All authors have read and agreed to the published version of the manuscript

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Conflicts of Interest

All authors declare that they have no conflict of interest.

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