



**TRENDS OF COMPUTATIONAL THINKING RESEARCH IN SCIENCE AND TECHNOLOGY AREA: A SYSTEMATIC LITERATURE REVIEW**

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**ABSTRACT**

This study aims to map the evolution of research on computational thinking (CT) within the context of science and technology, with a particular focus on science education and physics learning. Through a content analysis of a corpus of scholarly publications from 2015 to 2023, this study seeks to identify annual trends in research on computational thinking and computational thinking skills in the context of science and technology, with a deeper exploration of the context of science education and physics learning. A content analysis guide was employed as the research instrument. In synthesizing the articles, four main aspects were examined: (1) the number of publications per year, (2) research subject areas, (3) research types, and (4) the treatments and variables measured in computational thinking research in science education and physics learning. An analysis of the number of publications, research areas, methodologies, treatments, measured variables, and findings revealed a significant increase in interest in CT in 2022, particularly in the social sciences. Quasi-experimental research emerged as the dominant approach, with a focus on developing and evaluating learning interventions that integrate CT. The use of technology in computational thinking activities to enhance students' computational thinking skills in science education and physics learning was highlighted. The findings of this study have important implications for future research, such as expanding the diversity of research methodologies, delving deeper into CT instruments and data analysis techniques, conducting more in-depth studies on technology products designed to enhance computational thinking skills, and exploring a wider range of learning contexts.

**Keywords:** Computational Thinking, Computational Thinking Skills, Science

**INTRODUCTION**

Technology-based education has become a primary focus in curriculum development worldwide, driven by the increasing demand for 21st-century skills like problem-solving, critical thinking, and technological literacy (Grover & Pea, 2013; Shute, Sun, & Asbell-Clarke, 2017). A particularly noteworthy approach in this context is Computational Thinking (CT), introduced by Wing (2006, 2008) as a problem-solving framework involving computational techniques. CT can be defined as a problem-solving process encompassing problem design, logical structuring and evaluation of data, abstract data representation, algorithmic reasoning for automated solutions, identifying, evaluating, and implementing viable solutions for optimal outcomes, adopting a broad perspective, and applying solutions across various problems (ISTE & CSTA, 2011; Barr & Stephenson, 2011; Ogegbo & Ramnarain, 2021). CT is not merely a



technical skill but a thinking method applicable to various disciplines, especially science and technology (Weintrop et al., 2016). Consequently, numerous studies focus on integrating CT into education, particularly STEM (Science, Technology, Engineering, and Mathematics) fields (Kafai, Proctor, & Fields, 2020).

In the realm of science education, CT can aid students in comprehending abstract and complex concepts through simulation, modeling, and visualization (Barr & Stephenson, 2011; Hsu, Chang, & Hung, 2018; Grover & Pea, 2018; Hamsar et al., 2024). For instance, the application of CT in physics has demonstrated its capability to assist students in grasping concepts such as Newton's laws, electromagnetism, and fluid dynamics (Sengupta et al., 2013), kinematics (Sengupta & Farris, 2012), mechanics (Sengupta et al., 2012), and electricity (Sengupta & Wilensky, 2009; Sengupta & Wilensky, 2011). CT empowers students not only to visualize physics problems but also to develop algorithms that effectively solve them (Jenkins & Wilkerson, 2015; Shute et al., 2017). A study by Grover and Pea (2013) revealed that students exposed to CT were more adept at solving complex science problems compared to their counterparts without such training. Integrating CT into science education can enhance students' critical and creative thinking skills (Grover & Pea, 2013; Shute et al., 2017).

Previous studies have demonstrated that the integration of CT in physics education can enhance students' understanding of complex physics concepts (Fagerlund et al., 2021). Ifriiliya et al. (2022) revealed that the implementation of CT in physics education has the potential to improve learning quality, problem-solving abilities, critical thinking skills, conceptual understanding, and student learning outcomes. However, Ifriiliya et al. (2022) also highlighted several challenges in CT implementation, such as a lack of conceptual understanding, knowledge of technology, and student learning experiences. Sengupta et al. (2013) stated that one of the primary challenges is the limited understanding of teachers regarding how to integrate CT into the science curriculum. Additionally, there is a lack of a comprehensive framework outlining how CT should be integrated into science education at various levels (Yadav et al., 2016; Yadav et al., 2018). On the other hand, Lockwood and Mooney (2018) revealed that the use of CT in science education is still limited, particularly in developing countries, due to a lack of resources and training (Lockwood & Mooney, 2018).

Previous research has primarily evaluated the effectiveness of CT in science education, with results varying depending on the context and approaches used (Bufasi et al., 2022; Addido et al., 2023). For instance, the use of robotics and programming tools in physics classrooms has proven effective in enhancing students' computational thinking skills (Chiazzese et al., 2019; Lapawi & Husnin, 2020). However, not all studies demonstrate the same impact, especially when CT is implemented without adequate guidance or in unsupportive educational contexts (Shute et al., 2017). Therefore, it is essential to investigate and develop effective teaching techniques in physics (Pols et al., 2021; Nisa et al., 2024). The education system needs to prioritize the development of essential skills that students must possess in the 21st century (Bao & Koenig, 2019). Teachers should focus on creating a conducive learning environment that facilitates students' understanding and expression of ideas and scientific methods (Wöhlke & Höttecke, 2022). Improvements in the education system can be achieved through enhanced teaching quality, the implementation of contextual teaching practices (Kim et al., 2019; Nisa et



al., 2024), and the alignment of curriculum materials, assessment, and professional development (Tong et al., 2023).

Research on Computational Thinking in the field of science and physics education focuses on the impact of computational thinking skills on understanding physics concepts among high school students in Albania (Bufasi et al., 2022). Studies have also explored the relationship between computational thinking skills and science process skills in students during collaborative modeling-based learning in high school physics (Herwinarso et al., 2023). Additionally, research has delved into the challenges and strategies employed by high school physics teachers in integrating computational thinking skills into physics teaching using Python (Lane et al., 2023). Other studies have investigated the application of inquiry-based worksheets in physics learning at the high school level to enhance students' critical thinking skills (Pratidhina et al., 2020), and the integration of e-textiles in physics education to explore the impact of integrating computation and physics on students in the context of collecting gravitational data at amusement parks (Tofel-Grehl et al., 2022).

Furthermore, Addido et al. (2023) investigated the effects of using LEGO EV3 robots to teach Newton's second law to 14-18-year-old adolescents in STEM education programs. Du et al. (2023) introduced the OSSCAR platform, an open collaborative platform for developing computational tools used in science education. Syafril et al. (2022) researched the confidence of pre-service science teachers in computational thinking skills, including physics and biology teachers in Indonesia. Xing & Lu (2022) explored the key factors influencing the computational thinking skills of high school students in smart classroom environments.

Based on the previous explanations, this research aims to investigate computational thinking skills in the field of science and technology, with a deeper focus on computational thinking in science education and physics learning. The objective of this study is to identify research trends related to computational thinking in the field of science and technology, particularly in physics learning, and to examine frequently used research designs. Similar studies conducted by Nisa et al. (2024) focused on problem-solving skills, while this research specifically investigates computational thinking and computational thinking skills in the context of science and technology, particularly in physics learning. The implications of this research are highly relevant to educational reform in the digital age, where computational thinking is a crucial component that students must master to meet global challenges in the future. This study will contribute to providing information for teachers and curriculum developers to develop a comprehensive framework and best practices for integrating CT into physics or science education.

## **METHOD**

This study employs a qualitative approach using content analysis. The focus of this research is on the findings of various studies published in scientific journals on computational thinking skills related to science and physics. The research method used is similar to that used by Nisa et al. (2024). The sources of articles used were taken from Scopus-indexed international journals. The articles analyzed in this study were published online between 2015 and 2023. From 6267 articles collected using the keywords "Computational Thinking" OR

Online Journal System : <https://jurnalp4i.com/index.php/science>

"Computational Thinking Skills", 66 articles were found to be relevant to the research topic. The systematic review model used was the PRISMA model with several criteria set by the authors. The articles reviewed were selected based on the following criteria: 1) studies must be indexed by the SCOPUS database, 2) articles must discuss computational thinking or computational thinking skills in the areas of science and technology, 3) articles must be in English, 4) studies must be published as journal articles, 4) not proceedings, 5) not literature reviews, 6) open access, and 7) articles published between 2015 and 2023. The article selection process can be seen in FIGURE 1.

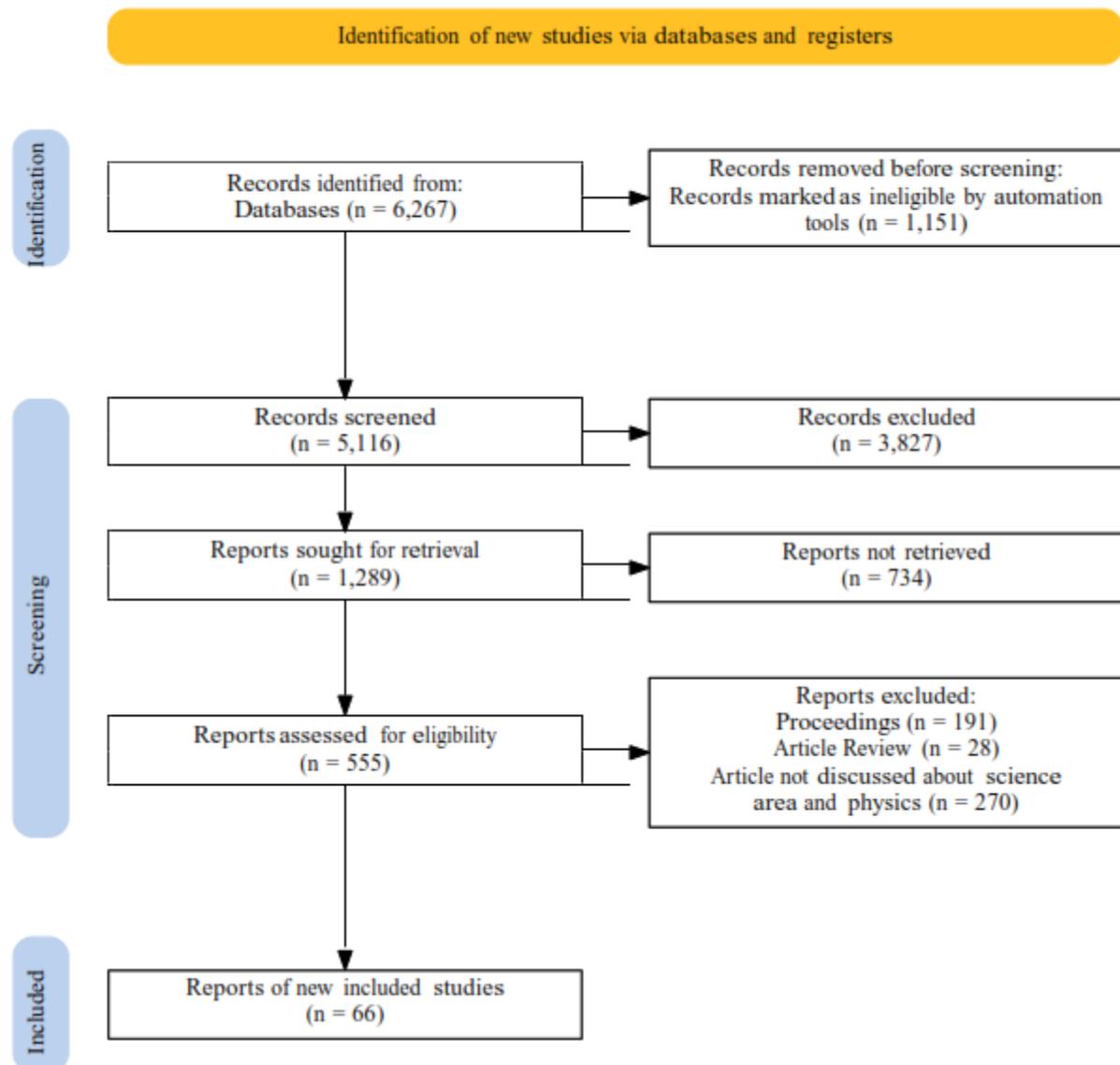


Figure 1. Prism Model Graph

The data from each reviewed article was then analyzed, and several indicators were analyzed according to specific aspects that met the indicators set by the reviewer, including the year of publication of the article, the research subject areas, the research types, and the treatments and variables measured in computational thinking research in science education and physics learning. The relationship between the title and abstract was analyzed using VOSviewer

software, while other indicators were analyzed manually. In addition, the collected data is presented in the form of tables and bar charts.

## RESULT AND DISCUSSION

This section presents the results of the analysis conducted as previously described. The presentation of the analysis includes graphs, tables, and bibliometric network visualizations. A discussion of each analysis is included along with the relevant findings.

### Prism-P

The initial search in the Scopus database identified 6267 documents related to computational thinking or computational thinking skills (keywords used: "Computational Thinking" OR "Computational Thinking Skills"). To narrow down the scope, the search was limited to publications between 2015 and 2023, resulting in 5116 documents. A further screening was conducted based on the following criteria: 1) open access and English language (1289 documents), 2) addition of the keyword: AND "SCIENCE" (555), 3) exclusion of proceedings, review articles, and literature studies, and 4) inclusion of articles discussing computational thinking or computational thinking skills in the field of science and technology. Based on the criteria set by the authors, 66 articles were selected, a sample of which is presented in TABLE 1.

**Table 1. 25 Synthesized Article Samples**

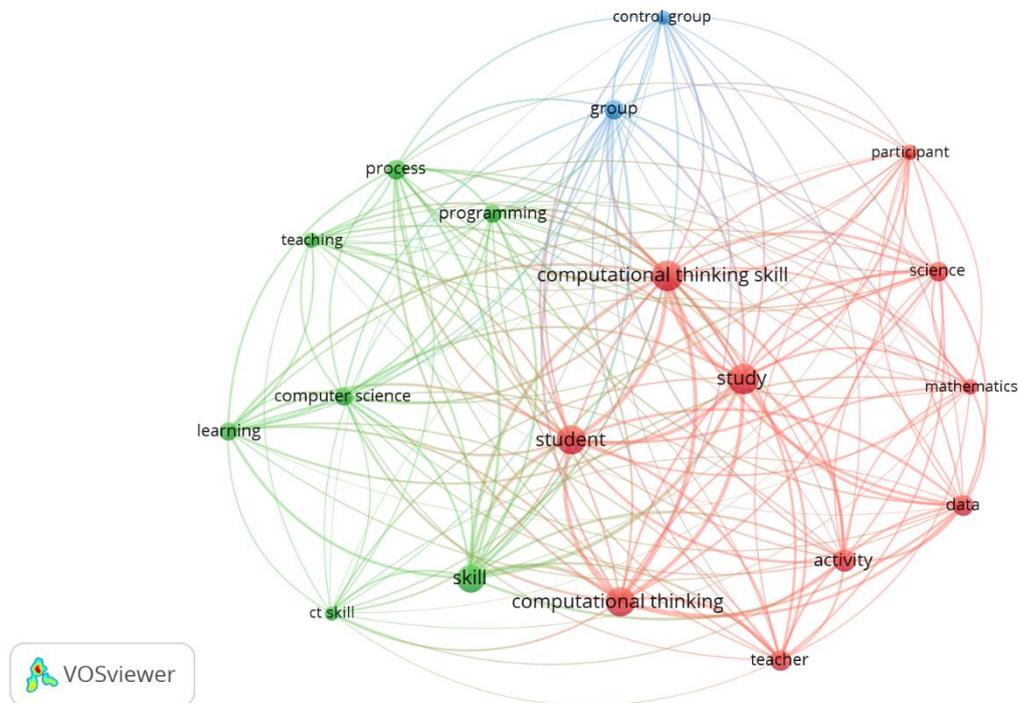
No	Author	Subject Area	Journal
1.	Gough et al., 2023	Biomedical Science	Biochemistry and Molecular Biology Education
2.	Pewkam & Chamrat, 2022	Chemistry, Mathematics, Arts	Informatics in Education
3.	Sun et al., 2021	Computer Science	International Journal of STEM Education
4.	De Souza et al., 2019	Computer Science	IEEE Access
5.	Dorotea et al., 2021	Computer Science	Education sciences
6.	Csapó, 2019	Computer Science	Acta Polytechnica Hungarica
7.	Tengler et al., 2022	Computer Science	Education sciences
8.	Niousha et al., 2023	Computer Science	Education sciences
9.	Csapó et al., 2021	Computer Science	Education and Information Technologies
10.	Moon & Cheon, 2023	Computer Science	International Journal of Information and Education Technology
14.	Altanis et al., 2018	Computer Science	Education sciences



11.	Pratidhina et al., 2020	Physics	Revista Mexicana de Física E
12.	Tofel-Grehl et al., 2022	Physics	Journal of Science Education and Technology
13.	Bufasi et al., 2022	Physics	International Journal of Emerging Technologies in Learning
15.	Lane et al., 2023	Physics	Journal for STEM Education Research
16.	Herwinarso et al., 2023	Physics	Journal of Education and e-Learning Research
17.	Al-Salamat, M.K.M., 2022	Physics	PLoS ONE
18.	Weller et al., 2022	Physics	Physical Review Physics Education Research
19.	Muliyati et al., 2022	Physics	Education and Information Technologies
20.	Bati et al., 2018	Science	Cogent Education
21.	Addido et al., 2023	Science	EURASIA Journal of Mathematics, Science and Technology Education
22.	Syafril et al., 2022	Science	Jurnal Pendidikan IPA Indonesia
23.	Xing & Lu, 2022	Science	Journal of Baltic Science Education
24.	Du et al., 2023	Science	Computer Physics Communications
25.	Lapawi & Husnin, 2020	Science	International Journal of Advanced Computer Science and Applications

Subsequently, VOSviewer was employed to analyze the 66 documents related to Computational Thinking or Computational Thinking Skills in the context of science and technology from the Scopus database. VOSviewer was utilized to visualize keyword maps and correlations among keywords. This map can also be used to identify novel research areas. The results indicated several key parameters or interrelations between variables in Computational Thinking or Computational Thinking Skills and other variables. The colored circles represent

keywords in the titles and abstracts. The size of the circle also indicates the frequency of the research related to the topic. The larger the circle, the more frequently the keyword appears. The mapping results using VOSviewer are presented in FIGURE 2.



**Figure 2. Network Visualization Result About Computational Thinking**

The analysis identified 19 items/keywords related to Computational Thinking or Computational Thinking Skills. These keywords were then selected to represent the research and grouped into three clusters. Based on the mapping in FIGURE 2, the keywords in each cluster are arranged as shown in TABLE 2.

**Table 2. Clusters in Computational Thinking Research**

Cluster	Keyword in Cluster
Cluster 1 (Red)	activity, computational thinking, computational thinking skill, data, mathematics, participant, science, student, study, teacher
Cluster 2 (Green)	computer science, ct skill, learning, process, programming, skill, teaching
Cluster 3 (Blue)	control group, group

Based on the clusters identified in TABLE 2, the most significant keywords are: 1) computational thinking skill, 2) study, 3) student, 4) computational thinking, and 5) skill. The keyword 'computational thinking skill' has the highest link strength (link strength = 350) as it is the primary focus of the selected studies. The analysis reveals that the terms 'computational thinking skill' and 'computational thinking' are strongly associated with the following issues (in cluster 1): 1) student, 2) study, 3) teacher, 4) science, 5) mathematics, 6) teacher, 7) data, and 8) activity. The literature presents several examples where researchers have been interested in



exploring the relationship between these highly related terms along with computational thinking skill, such as in relation to science education (Bati et al., 2018; Syafril et al., 2022; Addido et al., 2023; Xing & Lu, 2022; Du et al., 2023; Lapawi & Husnin, 2020) and physics learning (Pratidhina et al., 2020; Herwinarso et al., 2023; Mulyati et al., 2022; Bufasi et al., 2022; Lane et al., 2023; Tofel-Grehl et al., 2022; Weller et al., 2022).

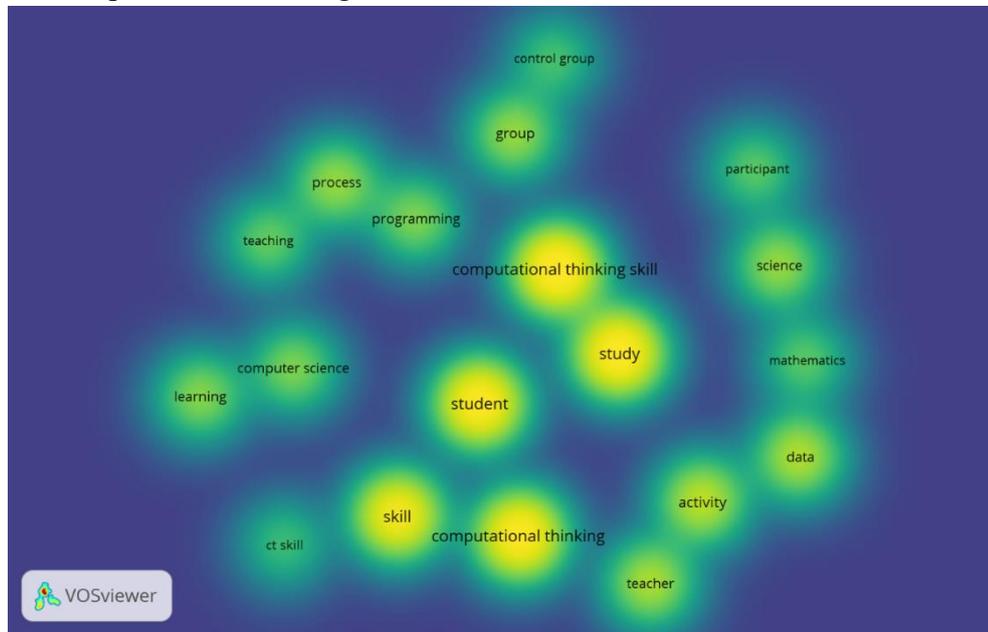
Furthermore, the keyword 'skill' (link strength = 290) has the highest strength in cluster 2. This is because most studies on Computational Thinking evaluate or aim to improve students' computational thinking skills. The term 'skill' is closely related to terms such as 'learning', 'process', and 'teaching'. This is clear because to improve students' skills, especially computational thinking skills, it can be done through the teaching and learning process. Therefore, appropriate learning processes that can facilitate students with computational thinking activities are needed to enhance these skills. Several studies have shown ways to improve students' computational thinking skills. Research conducted by Mulyati et al. (2022) demonstrated that the development of worksheets using the ADDIE method can enhance students' computational thinking skills. Lapawi & Husnin (2020) showed that the use of a computational thinking-based module with Scratch can improve students' computational thinking skills.

Another study by Tofel-Grehl et al. (2022) demonstrated that the need for computational content in physics education is crucial. The findings showed that the use of e-textiles by teachers to integrate physics and computation can expand and deepen student learning by providing computational thinking skills within the structure of scientific inquiry in physics. Weller et al. (2022) argued that physics classes with computational activities integrated into the curriculum, such as the use of computational modeling activities with Glowscript VPython, are well-suited for investigating computational thinking. This aligns with the research by Bufasi et al. (2022), which showed that the implementation of computational thinking activities not only enhances students' knowledge of physics concepts but also improves visual thinking, allowing students to cognitively understand problems more effectively.

The use of technology in learning has a positive impact on improving computational thinking skills. Altanis et al. (2018) present an innovative game-based teaching approach that proposes a series of steps for the systematic design and rapid development of touchless motion-based games, i.e., games based on natural user interaction technologies such as the Microsoft Kinect camera. Findings from an evaluation study in two secondary schools show that this approach can increase student motivation, strengthen their computational thinking, enhance their understanding of geometry principles, and improve their social skills. The use of technology facilitated Pratidhina et al. (2020) in providing remote learning during the COVID-19 pandemic. Through online video demonstrations, discussions using mathematical approaches and visualizations with spreadsheets, remote learning activities allowed students to develop science process skills, mathematical and computational thinking skills, and conceptual understanding of Fraunhofer diffraction.

The mapping results using VOSviewer presented in FIGURE 3 show that there are six largest density visualizations, namely computational thinking skill, computational thinking, study, student, and skill, all of which are interconnected. If the word computational thinking

skill is highlighted, then this word will be connected to the other four words. In the world of education, the word student is related to the research subject, the word study is related to the learning process, and the word skill is related to the skills that students must master in learning, in this case, computational thinking skills.

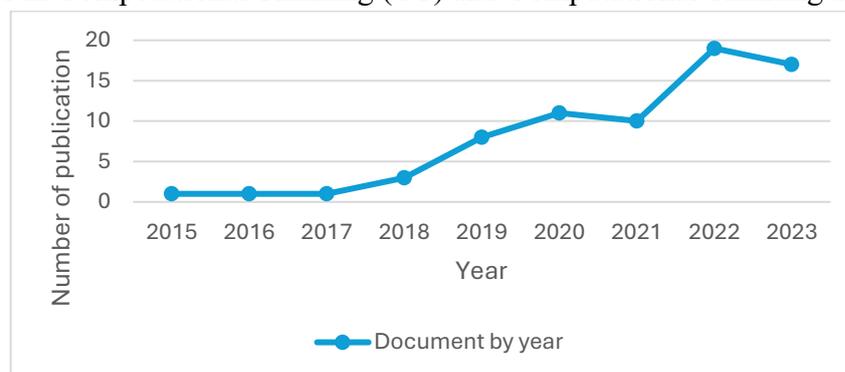


**Figure 3. Density Visualization Result About Computational Thinking**

Furthermore, a more in-depth re-examination of the articles can provide a more detailed analysis based on the publication year, research subject area, the research types, and the treatments and variables measured in computational thinking research in science education and physics learning. The process of analyzing computational thinking skills is as follows.

### Number of Publications

Figure 4 presents the total number of articles published between 2015 and 2023. The number of publications on this topic remained relatively stable from 2015 to 2018, varying between 1 and 3. However, starting from 2019, there was a steady increase in the number of publications, reaching a peak of 19 in 2022. This indicates a growing interest among researchers and publishers in Computational Thinking (CT) and Computational Thinking Skills (CTs).



**Figure 4. Number of publication by year (2015 – 2016)**

From the 66 synthesized articles, the top five authors with publications on Computational Thinking and Computational Thinking Skills in the field of science and technology were identified in the Scopus database. TABLE 3 shows that Sabitzer, B. is the most prolific author in research on this topic.

### Treatments and The Measured Variable

A further analysis was conducted to identify the treatments and variables measured in computational thinking research within the context of science education and physics learning. The results of this analysis are presented in Table 9.

**Table 9. Treatments and Measured Variables in CT Research in Science Education and Physics Learning**

No	Author	Subject Area	Treatments	The Measured Variable
1.	Pratidhina et al., 2020	Physics	The use of Tracker software and spreadsheets	A substitute for physics lab activities involving Fraunhofer diffraction in remote learning
2.	Tofel-Grehl et al., 2022	Physics	The use of inquiry-based learning with e-textiles to analyze physics data	Student engagement in computational practices and scientific thinking skills
3.	Bufasi et al., 2022	Physics	Computational thinking activities using VPython simulations	Students' understanding of physics concepts and computational thinking skills
4.	Lane et al., 2023	Physics	Workshop on Python integration in physics teaching	Teachers' capacity to integrate computational thinking and Python programming skills into physics teaching
5.	Herwinarso et al., 2023	Physics	Collaborative model-based learning	Computational thinking skills and science process skills
17.	Al-Salamat, M.K.M., 2022	Physics	Scientific and engineering practices aligned with NGSS (Next Generation Science Standards)	Practices such as asking questions and identifying problems, obtaining and communicating information, planning and conducting investigations, as well



				as using mathematics and computational thinking
18.	Weller et al., 2022	Physics	The use of computational modeling activities with Glowscript VPython	Student engagement in computational thinking practices
19.	Muliyati et al., 2022	Physics	Development of worksheets using the ADDIE method	Students' computational thinking skills
20.	Bati et al., 2018	Science	STEAM-based learning program	Students' computational thinking skills
21.	Addido et al., 2023	Science	The use of LEGO EV3 robots	Students' understanding of physics concepts (Newton's laws) and computational thinking skills
22.	Syafril et al., 2022	Science	A survey to measure the confidence of prospective science teachers in their computational thinking skills	The confidence of prospective science teachers in computational thinking skills
23.	Xing & Lu, 2022	Science	A survey of 420 middle school students in China to measure the factors affecting students' computational thinking skills in a smart classroom environment	Attitudes towards the internet, self-efficacy in using the internet, internet usage, and computational thinking skills
24.	Du et al., 2023	Science	Open collaborative platform for developing computational tools (OSSCAR).	The effectiveness of using computational tools to enhance the understanding of physics concepts and the use of computational thinking in teaching
25.	Lapawi & Husnin, 2020	Science	Computational thinking-based module using Scratch	Students' computational thinking skills

Table 9 shows that the majority of research related to CT in science education and physics learning utilizes technology in teaching to enhance students' computational thinking skills



(Pratidhina et al., 2020; Tofel-Grehl et al., 2022; Bufasi et al., 2022; Weller et al., 2022; Addido et al., 2023; Du et al., 2023; Lapawi & Husnin, 2020). These studies consistently demonstrate that interventions involving technology, such as robotics, VPython simulations, Scratch, the OSSCAR platform, and collaborative modeling, have a positive impact on students' computational thinking skills, aligning with Chookhampaeng et al.'s (2023) statement that the best way to foster computational thinking skills is through technology-based and collaborative training. Additionally, according to Ogegbo & Ramnarain (2022), educators should leverage effective technological tools to enhance the teaching of scientific concepts through deductive and inductive reasoning within a computational thinking framework.

## CONCLUSION

This study analyzes previous research on computational thinking skills in the context of science and technology published between 2015 and 2023. A deeper analysis is conducted in the fields of science education and physics learning that integrate CT. Several recommendations are proposed, namely: (1) expanding qualitative research to understand the development of computational thinking skills, particularly in the context of science and physics learning; (2) reviewing the development of technology-based learning products specifically designed to enhance students' computational thinking skills; and (3) further examining CT instruments and data analysis techniques

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