# Computational Thinking in Science Teacher Education in Brazil and Worldwide: A Systematic Literature Review

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## ABSTRACT
In a global scenario where Computational Thinking (CT) is increasingly recognized as an essential skill, its integration into basic education curricula stands out as an educational priority. This article conducts a systematic review focused on the role of CT in the training of teachers in Science Education, using the methodology of Systematic Review and the technique of Science Mapping to identify scientific studies. From the analyses, the potential of CT adopting an interdisciplinary perspective that values its application in Science Teaching is highlighted, suggesting that its effective integration can significantly enrich current education and facilitate the approach to practical challenges with a scientific basis.

### Author Keywords
Computer Thinking, Science Education, Systematic Review

### ACM Classification Keywords
Professional Topics; Computer Education; Computational Thinking.

## INTRODUCTION
We live in an era where the challenge for users is to develop their own systems, such as programs and games, or adapt existing ones to their personal needs. In this context, a skill considered crucial for the 21st century emerges: Computational Thinking (CT), defined as "the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a machine or a human can effectively carry out" [32].

It is important to highlight that Brazilian education is guided by the personal and collective development of individuals. Proposals that incorporate CT can enhance this important educational perspective.

According to [29], CT has created "[...] an important and interesting movement among researchers concerned with the integration of digital technologies in education." The emphasis on education arose due to its ability to develop skills applicable to solving problems, from the simplest to the most complex, in various fields of knowledge.

One way to approach CT is through unplugged computing, a pedagogical approach to teaching computing that aims to introduce students to the fundamental concepts of computer science and the way computer scientists think, without using computers. This strategy allows for the implementation of educational activities in remote locations, standing out for its independence from technological resources such as hardware and software [6].

The CT can be structured into four main pillars: breaking down a complex problem into smaller and simpler parts (Decomposition), examining each part separately to find similar known solutions (Pattern Recognition), focusing on the important details while ignoring what is not relevant (Abstraction), and finally, creating simple rules to solve each subproblem (Algorithms) [5].

According to [30] in their studies highlight that CT is multidisciplinary, although the main focus of current implementations is 90% on Mathematics. This indicates a significant and still underexplored potential in other disciplines of the Brazil's National Common Curricular Base (BNCC), such as Natural Sciences, Human Sciences, and Languages. It is suggested that its integration into these areas can enrich the teaching-learning process, foster analytical and creative skills, and prepare learners for the complex challenges of the 21st century.

The present study focuses on investigating CT in science teacher education, expanding the understanding of how this pedagogical approach can be integrated into educational practices. Through a Systematic Literature Review (SLR), we analyzed relevant research to identify the main trends, effective strategies, and challenges in integrating CT into Science Education.

The CT stands out as a relevant topic for studies, having its presence consolidated in BNCC of 2020, as well as in Resolution CNE/CP No. 2 of 2019. This resolution specifies the National Curricular Guidelines aimed at the initial training of Basic Education educators, creating a common foundation for this initial training (BNC-Formation), in addition to the standards on Computing in

Basic Education – Complement to the BNCC described in Resolution Nº. 1 of October 4, 2022.

In classroom pedagogy, we can use CT with teachers and students to solve problems, break them into parts, and create algorithms to solve them. Schools are challenged to explore CT concepts, that is, to use the possibilities of computing processes for people to "think with machines," in order to solve problems and understand how the problem was solved through a sequence of actions [29].

The works [5] [16] [18] [21] underscore the significant impact of the CT concept introduced to [31]. CT is a crucial approach in education, particularly in light of the Computer Science For All movement, launched in January 2016 in the United States, which aims to integrate computing concepts into elementary and high school.

In Brazil, the Center for Innovation in Brazilian Education (CIEB) and the Brazilian Computer Society (SBC) [25] have undertaken various initiatives to implement the fifth competence of the BNCC, which recognizes the fundamental role of technology and establishes that students should understand digital culture, comprehend CT, and be aware of the impacts of technologies on people's lives and society.

According to [26], present a study that investigates the impact of a teacher training course on the educational integration of Digital Information and Communication Technologies (DICTs) on the digital competence of basic education educators. The research, based on the European Framework for Digital Competence (DigCompEdu), highlights that there was a significant improvement in teachers' digital competences after participating in the training course.

This result underscores the importance of integrating Digital Information and Communication Technologies (DICTs) into pedagogical methodologies, aligning with the BNCC guidelines for the Initial Training of Basic Education Teachers.

According to [7], science can offer a context in which CT practices are useful and meaningful, especially in student-centered contexts. However, science teachers often lack experience or did not have contact with CT during their training, thus not utilizing it in their everyday pedagogical practice in the classroom.

Given this scenario, the focus of this work is on integrating the knowledge and perceptions of science teachers into pedagogical activities involving CT to address everyday and contextualized classroom challenges. We recognize that CT has significant potential for interdisciplinary work in education and offers numerous possibilities for exploration in science teaching.

## RESEARCH METHODOLOGY

This study conducts a systematic review inspired by the guidelines proposed [9], as detailed in Figure 1. The investigation follows an exploratory, qualitative, and documentary approach. The study encompasses the evaluation of dissertations and theses available on national academic platforms, as well as the exploration of databases that catalog international scientific publications.

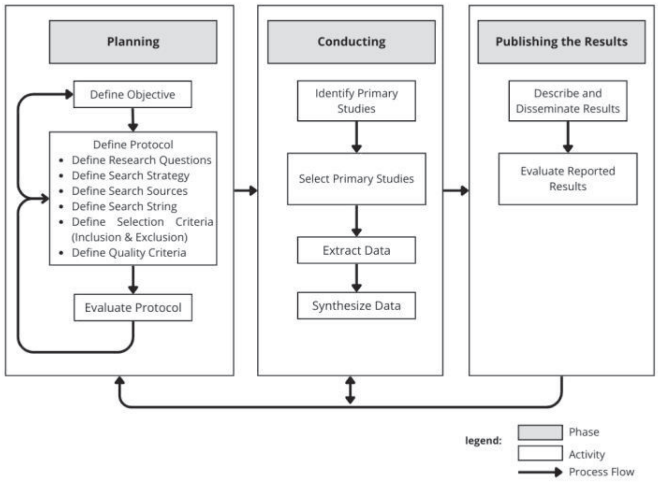


**Figure 1. Phases and Activities of the Systematic Review/Systematic Mapping Process [9]. Image: adapted.**

The systematic review, as defined [15], is a secondary study characterized by a methodological process. The objective is to identify, analyze, and interpret the available evidence pertinent to a specific research question in an unbiased and, to some extent, repeatable manner.

The technique of Science Mapping, as described [7], was employed, which allows, among other aspects, the identification of the most impactful works in any research area. This technique uses open-source tools to provide an overview of the state of development of practices and scientific knowledge in any research topic. The free software RStudio [20] was used, enabling the statistical analysis of the selected articles through algorithms.

In the planning stage, the guiding research questions were determined, namely: a) What tools or activities were adopted in the training of science teachers? b) What content of Computational Thinking and Science are taught in didactic activities? c) What strategies have been developed to integrate Computational Thinking into Science Teacher Education?

The following criteria were established for the selection of relevant studies to be examined in this work, aiming to ensure their pertinence to the research scope. The inclusion criteria adopted were: i) studies focused on teacher training initiatives related to digital technologies; ii) investigations on the role of computational thinking in teacher training; iii) works published between 2019 and 2024; iv) works accessible for download on digital platforms. The exclusion criteria were: i) duplicate works; ii) works without an abstract, keywords, or inaccessible digital file; iii) works not related to the theme.

The temporal criterion starting from 2019 is justified by the implementation of new national or international policies or guidelines relevant to Science Education and Computational Thinking from that year onward [25]. Research prior to 2019 has already been extensively compiled and analyzed in other systematic reviews.

The technique of Science Mapping [4] was employed, which facilitates the identification of high-impact works in various research areas through the use of open-access tools. This method provides a comprehensive view of the development of practices and scientific knowledge around specific investigative themes. For this analysis, techniques from the R language [20] were employed, allowing statistical analyses of the selected articles through an algorithm based on the search string and the established inclusion and exclusion criteria.

The selection of both national and international research was conducted in three distinct phases, adhering strictly to the previously established inclusion and exclusion criteria. The first phase consisted of evaluating studies based solely on their titles. Subsequently, a detailed analysis of the abstracts allowed for further refinement of the selection. The final stage involved the full-text reading of the remaining articles, resulting in the final selection of studies.

To investigate trends in CT within graduate programs, we conducted searches in the main national databases of theses and dissertations, specifically the Coordination of Superior Level Staff Improvement (CAPES) portal and the Brazilian Digital Library of Theses and Dissertations (BDTD). For international works, searches were conducted in the main international databases: Web of Science and Scopus.

### Selection of National Databases in Brazil

The database search was conducted between January and February 2024. Initially, we applied the terms "computational thinking," "science teacher," and "teacher training," resulting in 33 studies identified in BDTD and 5 in the CAPES database. To broaden our scope, we refined our search terms to "computational thinking" and "science education," which initially yielded a total of 175 works.

After a multi-stage filtering process, we selected 4 studies that aligned with our research objectives and met the inclusion criteria, as shown in Table 1. These final 4 works were chosen for their relevance to the intersection of Computational Thinking and Science Teacher Education.

| Bases | Selection by String | 1st Title Selection | 2nd Abstract Selection | 3rd Full-Text Selection |
|---|---|---|---|---|
| CAPES | 44 | 16 | 05 | 00 |
| BDTD | 131 | 58 | 13 | 04 |
| Total | 175 | 74 | 22 | 04 |

**Table 1. Result in the Brazilian National Databases.**

The national studies were chosen for their relevance and thematic proximity to Computational Thinking in Science Teacher Education. The analysis of these works was systematically organized, being divided into specific categories to facilitate the comparison and understanding of the data: ID, title, author, year, institution, program, and type of work. All these details are presented in detail in Table 2, which serves as a comparative base and support for the conclusions and results developed in the context of our work.

| ID | Title | Auhtor(s) | Year | Type |
|---|---|---|---|---|
| N1 | Educational robotics as a mediating tool in continuing education with science teachers in light of activity theory. | Silva, Viviane Barbosa da | 2021 | D |
| N2 | Teaching artificial intelligence: a teacher training proposal in STEAM subjects. | Flores, Diego | 2022 | D |
| N3 | An unplugged pedagogical framework for practicing Computational Thinking skills in elementary education. | Guarda, Graziela Ferreira | 2023 | T |
| N4 | Computational thinking in biophysics teaching in the initial training of Biology teachers: using block programming with Scratch. | Santana, Marcos Paulo da Silva | 2023 | D |

D = Dissertation; T= Thesis.

**Table 2. Brazilian National Theses and Dissertations. The authors of the article translated the titles of the work from Portuguese to English.**

### Selection of International Databases

The searches in international databases were conducted between January and February 2024. Initially, we used the terms "computational thinking," "science teacher," and "teacher training," resulting in only 6 studies found in the Scopus database and 2 in the Web of Science database.

Considering the need to expand this study to analyze more works that address the integration of CT in science teacher training, the search terms were adjusted to the following string: "computational thinking" and "teacher training" and "science".

This process resulted in the identification of a total of 38 studies in the Scopus database and 32 in the Web of Science database. However, with 14 duplicate articles, the final number was 24 unique studies in the Scopus database and 32 in the Web of Science database. After the selection process, which occurred in three stages, the total number of selected studies was 13, as detailed in Table 3.

| Bases | Selection by String | 1st Title Selection | 2nd Abstract Selection | 3rd Full-Text Selection |
|---|---|---|---|---|
| Scopus | 24 | 18 | 09 | 03 |
| Web of Science | 32 | 21 | 16 | 10 |
| Total | 56 | 39 | 28 | 13 |

**Table 3. Result in International Databases, 2024.**

The international studies were systematically organized, being divided into specific categories to facilitate the comparison and understanding of the data: ID, title, authors, year, and database. All these details are presented in detail in Table 4.

| ID | Title | Auhtor(s) | Year | Base |
|---|---|---|---|---|
| I1 | Supporting Future Teachers To Promote Computational Thinking Skills In Teaching Stem-A Case Study | Tripon, C | 2022 | W |
| I2 | Computational Thinking And Teacher Education: Challenges And Didactic Possibilities Using The Scratch Tool | Ferreira do Amaral CC;Yonezawa DM | 2022 | W |
| I3 | Gamified Forms: A Proposal For Teaching Training Based On Computational Thinking | Rodrigues CF; Silveira IF | 2021 | W |
| I4 | Introduction To Computational Thinking: A New High School Curriculum Using Codeworld | Alegre F;Underw J;Moreno J;Alegre M | 2020 | W |
| I5 | First Experiences Of Integrating Computational Thinking Into A Blended Learning In-Service Training Program For Stem Teachers | Knie L;Standl B;Schwarzer S | 2022 | W |
| I6 | Combined Effects Of Block-Based Programming And Physical Computing On Primary Students' Computational Thinking Skills | Kastner-Hauler O;Tengler K;Sabitzer Z | 2022 | W |
| I7 | Tell, Draw And Code - Teachers' Intention To A Narrative Introduction Of Computational Thinking | Tengler K;Kastner-Hauler O;Sabitzer B | 2021 | W |
| I8 | How Might We Raise Interest In Robotics, Coding, Artificial Intelligence, Steam And Sustainable Development In University And On-The-Job Teacher Training? | Henze J;Schatz C;Malik S;Bresges A | 2022 | W |
| I9 | A Computer Science And Robotics Integration Model For Primary School: Evaluation Of A Large-Scale In-Service K-4 Teacher-Training Program | El-Hamamsy L;Chessel-Lazzarotto F;Bruno B;Roy D;Cahlikova T;Chevalier G;Pellet Jp;Lanares Jd;Mondada F | 2021 | W |
| I10 | Exploring Programming Task Creation Of Primary School Teachers In Training | Greifenstein L;Heuer U;Fraser G | 2023 | W |
| I11 | Primary Level Teachers Training In Computer Science Experience In The Argentine Context | Casali A;Monjelat N;San M P;Zanarini D | 2023 | S |
| I12 | Computational Thinking In Elementary School In The Age Of Artificial Intelligence Where Is The Teacher | Abar C;Dos S D S J;De A M | 2021 | S |

S = Scopus; W= Web of Science.

**Table 4. Selected International Articles, 2024.**

## RESULTS AND DISCUSSIONS

From the selection of 4 national and 13 international studies, the analysis aims to answer relevant questions related to the object of study, as well as to identify emerging trends and gaps in the scientific literature. It is observed that there is a predominance of national theses and dissertations focused on fields like mathematics and physics. However, as pointed out [31], CT should benefit all disciplines by promoting problem-solving, not being limited to Computer Science alone.

In this way, an analysis of the selected works was performed to investigate the technological tools and methodologies adopted in science teacher training, the content taught during these trainings, and the strategies used to integrate Computational Thinking into Science Teacher Education.

The same analysis also explored the strategies adopted to promote the development of CT among science teachers, indicating that seven scientific works utilized training courses to integrate CT into the educational context. The results of this analysis, focused on Computational Thinking in Science Teacher Education in Brazil and Worldwide, are presented and discussed in the following sections.

### In the National Context of Brazil

The master's work N1 [24] investigates the integration of CT in the training of science teachers, in Brazil and around the world, through a systematic literature review. The main contribution of this study is the synthesis of technological tools and methodologies used in teacher training to promote CT and the identification of the most effective strategies for integrating these skills in the educational context.

The methodology [24] involved the analysis of articles published since 2019, focusing on the technologies and methodologies adopted, the content taught, and the strategies developed. The positive aspects include the diversity of approaches and the innovative use of technological tools for teaching CT, while the negative aspect is the lack of standardization in assessment methodologies, making it difficult to compare studies.

The master's work N2 [10] presents the STEAM approach, combined with the National Curriculum Base, creating learning situations that provide relevant computational experiences in science and mathematics education. To address this issue, a Didactic Sequence was developed, incorporating knowledge of computer technology, CT skills, and the use of AI to improve teaching skills and the quality of education through technological innovation. This educational product complements teacher training by integrating concepts and practices from AI studies into STEAM education.

Thesis N3 [11], aimed to develop and evaluate a Pedagogical Framework to identify the difficulties and barriers teachers face in learning and applying Computational Thinking (CT), as well as to investigate the feasibility of didactic transposition of CT to the classroom context. To provide this support, a Massive Open Online Course (MOOC) was created, including unplugged activities.

On the other hand, dissertation N4 [23] aimed to describe the process by which students in a Biological Sciences teaching degree can develop skills based on CT, specifically through block programming with Scratch, to represent processes and structures of biological membranes in the Biophysics discipline. This objective was pursued through the implementation of a didactic sequence structured in seven stages, which included the use of Scratch and the fundamentals of CT.

Table 5 presents the guiding questions and, through the analysis of studies, contextualizes national dissertations and theses. The use of tools and methodologies in studies conducted within the country was observed, highlighting the use of tools such as Scratch, Lego Mindstorms, and App Inventor, as well as unplugged activities.

| ID | What technological tools/methodologies were adopted? | What content is taught to teachers during the training? | What strategies have been developed to integrate Computational Thinking into Science Teacher Education? |
|---|---|---|---|
| N1 | Lego Mindstorms | Human body | Didactic Workshop |
| N2 | App Inventor | Artificial Intelligence | Didactic Sequence |
| N3 | Unplugged | Pillars of CT | MOOC Course |
| N4 | Scratch | Biological Membranes | Didactic Sequence |

**Table 5. Questions in Brazilian National Studies, 2024.**

The results emphasize the need for research and interventions focused on promoting development in the natural sciences through the integration of CT. The field of natural sciences brings scientific education to the forefront, and the growing demand for competencies in science, technology, engineering, and mathematics (STEM) in various sectors reinforces the importance of preparing students for future labor market challenges by developing their problem-solving skills and logical reasoning through CT.

As expected, the analysis of the articles' data reveals that the majority highlight the importance of the diversity of tools and methodologies in teacher training. Each approach offers specific benefits, such as the development of practical skills, stimulation of creativity, and promotion of a deep understanding of scientific concepts. Additionally, the variety of content covered demonstrates the broad applicability of computational thinking in different areas of scientific knowledge. The integration of studies such as didactic workshops, didactic sequences, and MOOC courses emphasizes the need for flexible and adaptable educational approaches to meet the diverse needs and contexts of teachers in training.

However, there is still a comprehensive and diverse panorama of formative practices, highlighting the relevance of computational thinking as an essential competence for science teachers. The different tools and methodologies adopted prove effective in promoting innovative and integrated teaching, contributing to the professional development of educators and, consequently, to the improvement of the quality of scientific education.

**In the International Context**

The article I1 [28], validates a training program for future teachers, highlighting the effective integration of CT skills into STEM teaching. Results indicate significant improvement in students' CT skills, despite the limited sample size and lack of participant diversity.

Using an experimental design with control and experimental groups, the study measures the training's impact through the Callysto Computational Thinking Test (CCTt). Emerging questions include adapting CT to other disciplines and the challenges faced by teachers. The research offers valuable insights for pedagogical practices in Science Education, aligning with the goals of promoting a modern and effective education.

The article I2 [3] explores integrating CT in science and mathematics teacher training using Scratch. It highlights Scratch's effectiveness in developing abstraction, algorithmic thinking, decomposition, and pattern recognition skills, fostering a collaborative learning environment. However, challenges include the lack of specific initial CT training for teachers and the need to demystify CT beyond programming. The article provides valuable insights into pedagogical practices, promoting a modern and effective education.

The study developed by Rodrigues and Silveira [22] explores using gamification to develop teachers' computational thinking skills. It argues that gamification makes learning more engaging and effective, supported by qualitative data from questionnaires and interviews. Despite its innovation, the approach faces challenges such as the need for technological resources and infrastructure.

Based on a case study, the research underscores the need to adapt gamified strategies to different educational contexts. It suggests that this approach can enhance Science Education by interactively integrating CT practices.

The article I4 [2] presents a curriculum designed to teach programming and reinforce math skills among ninth graders, with a focus on promoting higher-order thinking. Positive aspects include the innovative use of Haskell in a web-based environment, detailed teacher training, and encouraging preliminary results that show significant improvements in students' programming and computational thinking skills. However, challenges remain, such as the complexity of the course and the need for more extensive data collection. The methodology involves pilot tests, pre- and post-evaluations and qualitative observations.

The article I5 [14] explores implementing CT in STEM teacher training. The program, combining online and face-to-face phases, received high satisfaction from participants, increasing their awareness and confidence in applying CT in the classroom. However, challenges include measuring long-term impact and reliance on self-assessments. The methodology involved pre, post, and follow-up questionnaires with secondary school science teachers in Germany. This work aligns with my study on CT in Science Education, emphasizing practical integration and innovative pedagogical practices to enhance teaching quality.

The study developed by Kastner-Hauler et. al. [13] explore how combining block-based programming and physical computing, using devices like microcontroller, enhances CT skills in primary students. Positive outcomes include significant skill improvements and effective integration of technology. However, the small sample size and short intervention duration are limitations. The methodology involved pre- and post-tests with third and fourth graders, evaluated using the Beginners Computational Thinking test (BCTt).

The article I7 [27], explore how integrating programmable robots with storytelling methods influences teachers' intention to use these technologies. Positive outcomes include increased teacher confidence and student engagement in CT. Challenges include limited resources and measuring long-term impacts. The study used a quasi-experimental pre- and post-test design with primary school teachers. Questions raised include the long-term efficacy of programmable robots and the need for ongoing teacher training.

The article I8 [12], uses STEAM tools and an expanded 5E model to increase teacher and student interest in these areas, aligning with the UN's Sustainable Development Goals (SDGs). Positive aspects include high acceptance of digital tools and promotion of 4C competencies. Challenges included difficulties with hybrid learning during COVID-19 and limited data collection. The methodology involved mixed methods with pre- and post-tests and qualitative interviews.

The 5E [12] model includes five phases: Engage, where students' prior knowledge is activated and curiosity sparked; Explore, allowing hands-on, experiential learning; Explain, where students articulate and discuss their understanding; Elaborate, applying knowledge to new situations to deepen understanding; and Evaluate, involving reflection and feedback on learning. Additionally, the

Exchange phase promotes sharing and reflection on the learning process. The 4C [12] competencies focus on Creativity, encouraging innovative ideas and solutions; Collaboration, emphasizing teamwork and effective communication; Communication, ensuring clear and effective information exchange; and Critical Thinking, developing analytical skills to evaluate information and make informed decisions.

The study developed by El-Hamamsy et. al. [17] presents a model for integrating Computer Science and robotics into primary school curricula, validated by a large-scale pilot study in the Canton of Vaud, Switzerland. Positive aspects include high voluntary adoption rates and improved teacher perceptions of Computer Science. Challenges include logistical limitations and measuring long-term impacts. The methodology involved a quasi-experimental design with pre- and post-tests and qualitative questionnaires.

The article I9 [17], explore how integrating programmable robots with storytelling methods influences teachers' intention to use these technologies. Positive outcomes include increased teacher confidence and student engagement in CT. Challenges include limited resources and measuring long-term impacts. The study used a quasi-experimental pre- and post-test design with primary school teachers. Questions raised include the long-term efficacy of programmable robots and the need for ongoing teacher training.

The article I10 [19], focuses on how improving the creation of programming tasks can promote computational thinking, an essential skill for Science Education. It demonstrates how automated tools like LitterBox can assist teachers in developing more effective and high-quality programming tasks, facilitating the integration of computational thinking into the science curriculum. By enhancing the quality of programming instruction, the article contributes to preparing teachers to teach science concepts through practical and interactive activities.

The study developed by Casali et. al. [8] presents the design, development, and preliminary results of the first specialization in Computer Science for the primary level, approved by the Ministry of Education of Santa Fe province. The "Higher Level Teaching Specialization in Didactics of Computing Science" aims to empower teachers with computational thinking and programming skills for interdisciplinary and inclusive teaching practices. It outlines the course design and student characteristics and provides participant feedback on course delivery and content.

The article I12 [1], emphasizes the importance of continuous teacher training for the implementation of CT in primary education, highlighting its relevance in the era of Artificial Intelligence. Using a qualitative approach and action-research dynamics, the study analyzed the participation of teachers from Brazil, Portugal, Cape Verde, and Angola, demonstrating significant contributions and proposed activities. Despite the need for continuous adaptations due to rapid technological changes, the study concludes that CT can develop abstraction and problem-solving skills across various life areas, not just in computer use.

The research I12 [1] raises questions about the best practices for adapting CT to different school realities and ensuring that continuous teacher training stays updated with technological advancements. This aligns with the broader goal of integrating CT into Science Education, where interdisciplinary pedagogical practices can enhance students' scientific and technological understanding.

Based on the selected articles from the systematic review, a table was developed to synthesize the technological tools and methodologies adopted in science teacher training, the content taught during these trainings, and the strategies used to integrate CT into science teacher education. The Table 6 outlines the types of strategies adopted to promote the development of CT among science teachers, indicating that seven scientific works utilized training courses to integrate CT into the educational context. This table provides an overview of the approaches used and the topics covered, offering a comprehensive understanding of current practices in the field.

| **ID** | **Technological tools/methodologies were adopted?** | **Taught to teachers during the training** | **What strategies have been developed to integrate Computational Thinking into Science Teacher Education?** |
|---|---|---|---|
| I1 | STEM | Sustainable development | Training Course |
| I2 | Scratch | Physics | Training Course |
| I3 | Gamification | Science and Mathematics | Escape Room |
| I4 | CodeWorld | Cells | Training Course |
| I5 | STEM | pH values | Hybrid Training Course |
| I6 | BBC Micro and MakeCode | Programming | Training Course |
| I7 | Tell, Draw & Code | Algorithm | Training Course |
| I8 | STEAM | Creativity, Cooperation, Communication, and Critical Thinking | Training Course |
| I9 | Unplugged | Pillars of | Training Course |

| | | | |
|---|---|---|---|
| | | Computational Thinking | |
| I10 | LitterBox | Organization (Sequence) | Workshop |
| I11 | LightBot | Computational Thinking and Programming | Specialization |
| I12 | LitterBox | Computational Thinking and Programming | Specialization |

**Table 6. Questions in International Studies, 2024.**

It is observed that among the analyzed training courses, the type of study "training course" receives the most investigations. Table 6 highlights the tools and activities used in international studies, showcasing the application of a wide variety of tools supporting the research. There is a rich diversity of digital tools, encompassing both plugged and unplugged technologies (exemplified by flowcharts and mind maps).

From the table, it is observed that the technological tools, methodologies, content, and strategies used in the training of science teachers focus CT. The analysis of these data reflects important trends and relevant insights.

The data analysis highlights the wide variety of technological tools and methodologies used in the training of science teachers. This diversity reflects the need for flexible and adaptable approaches to meet different educational needs and teaching contexts. CT in different areas of knowledge, such as physics, biology, chemistry, and even in socio-emotional skills, demonstrates its importance as a transversal competence.

Moreover, the different types of studies developed, from training courses and workshops to innovative methodologies such as escape rooms and specializations, underline the importance of offering varied and continuous opportunities for the professional development of teachers. These approaches not only enrich educators' learning but also contribute to improving the quality of Science Education, preparing teachers to effectively integrate CT into their pedagogical practices.

The integration of CT in the training of science teachers presents significant potential to transform education. However, it is crucial to address current limitations and explore new research directions that promote accessibility, inclusion, and innovation. By incorporating emerging themes, innovative methodologies, and interdisciplinary approaches, we can better prepare teachers to face the challenges of contemporary and future education.

The word cloud Figure 2, generated from the international articles, as shown in Table 4, using the Systematic Mapping Process methodology [4], offers a comprehensive view of the main trends and prominent themes in the research area.

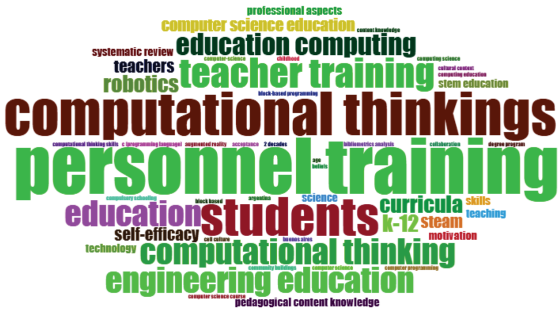


**Figure 2. Generation of the main keywords from international articles in Systematic Mapping Process.**

The most prominent keywords, such as "personnel training," "computational thinking," "teacher training," and "students," indicate a significant focus on the training of teachers and students in the context of computational thinking. This emphasis reflects the growing importance of preparing educators and students to face challenges and seize opportunities provided by computing.

Additionally, terms like "education computing" and "computational thinkings" suggest a critical intersection between traditional education and the new demands of the 21st century, where digital literacy and computational skills are fundamental. The presence of “k-12” and “steam" indicates a concern with integrating these competencies from the early school years, promoting a solid foundation of knowledge that can be expanded throughout the educational trajectory.

The word "robotics" and others related to technology and programming, such as "block-based programming" and "augmented reality," point to the inclusion of emerging technologies in the educational curriculum. This demonstrates an effort to keep contemporary education aligned with technological innovations, preparing students not only to understand but also to create and innovate in the field of technology.

This keyword analysis highlights the essential contribution of these studies to teacher training, curriculum development, and the inclusion of advanced technologies in education. By focusing on these aspects, the research offers valuable insights for educational policymakers, curriculum developers, and educators, encouraging educational practices that promote critical thinking and technological innovation from basic education through higher education.

## CONCLUSIONS

Although CT represents an emerging concept, with definitions still being formulated and debated in the academic community, its importance in the educational environment is evident. The CT approach emphasizes not only the importance of technology and programming but also promotes logical reasoning, problem-solving, and creativity, skills considered essential for success in various fields. In this context, the present research contributes to the investigation of CT in science teacher education, exploring how this concept can enrich pedagogical practice.

Through this Systematic Literature Review (SLR), relevant research was analyzed to identify the main trends of CT in science teacher education. This survey covered studies published in the last five years, aiming to map the tools and methodologies adopted, evaluating their impact on improving science teacher education.

Therefore, this work aims to contribute to the literature by offering an updated overview of the current state of the art, suggesting directions for future research, and proposing new pedagogical possibilities in this field.

From the analysis of the articles, it is observed that there is a low presence of national studies, particularly in the Natural Sciences. According [31], the goal of CT is not to teach people to think like computer scientists, but to use computing as a tool to solve problems in various fields, encouraging the creation and discovery of new solutions. There is a limited number of national dissertations and theses contextualized in teacher training for Science Education, pointing to a still-expanding research area.

It was identified that the predominant teaching strategy is the training course. In practice, it is found that the concepts of physics, cells, sustainability, atmosphere, and Earth's movements have been explored in the literature for science teaching with CT.

Furthermore, it is noted that CT is being implemented in school curricula in basic education in various countries, motivated by the prospect of a positive impact on students' development at an early age.

There is an emerging consensus on the effectiveness of blended learning for teacher training in CT. The works highlight the benefits of combining online courses and training with face-to-face interactions. This approach allows for flexibility and personalized learning while providing opportunities for discussion and practical application, addressing the diverse needs of teachers.

Several studies, notably, converge on the importance of engaging teachers in hands-on learning experiences. Workshops, unplugged activities, and the use of programmable robots offer opportunities for teachers to explore CT concepts, develop teaching materials, and, crucially, experience the role of learners in this new domain. This helps build confidence and reduce anxiety about teaching CT.

The integration of CT in Science Education proves to be an effective strategy for students to develop 21st-century skills. This approach not only prepares students to make innovative contributions in the scientific field, stimulating creative and analytical thinking but also prepares them to deal with complex global challenges of today, such as climate change, public health issues, and the quest for sustainability.

The incorporation of CT in the Natural Sciences goes beyond educational value, establishing itself as a requirement to promote a more just, well-informed society prepared for future challenges.

For future research, it is recommended to expand studies on the development of computational thinking beyond fields like mathematics and physics, directing greater attention to areas that are still underexplored but have great potential for contribution in the educational context.

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