Computational Thinking and Learning Disabilities: A Systematic Review

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Abstract. *This paper presents a systematic literature review on how computational thinking is approached for individuals with learning disabilities, focusing on dyslexia, autism spectrum disorder, and attention-deficit/hyperactivity disorder. The findings emphasize benefits such as enhanced cognitive skills, increased engagement, autonomy in problem-solving, and improved concept retention. However, gaps remain, including a lack of conceptual clarity around computational thinking; the absence of consensus on assessment methods within the analyzed studies, varying evaluation approaches depending on the teaching strategies used; and a scarcity of studies on specific disabilities like dyscalculia.*

1. Introduction

The term “Computational Thinking” (CT) gained popularity in the scientific community in 2006 when Jeanette Wing published an article analyzing a set of problem-solving skills developed by Computer Science professionals [Wing 2006]. More specific definitions of CT vary based on their focus: some are closely related to programming and computing concepts [Brennan and Resnick 2012, Weintrop et al. 2016], while others emphasize general problem-solving skills [Selby and Woollard 2013, ISTE and CSTA 2011b]. The CT concept has sparked deep engagement with fundamental questions about the nature of Computer Science and its role in problem-solving across various domains of human inquiry [Barr and Stephenson 2011].

The scientific community has not yet formally defined CT, as it remains an emerging and evolving ability. However, in 2009, the Computer Science Teachers Association and the International Society for Technology in Education collaborated to develop support and reference materials promoting CT. One such resource, the *Computational Thinking Leadership Toolkit* [ISTE and CSTA 2011a], provides a framework of vocabulary and skill progression, which serves as a reference in this work. It highlights the following skills: *data collection, analysis, and representation*; *problem decomposition*; *abstraction*; *algorithms and procedures*; *automation*, *simulation*; and *parallelization*. These are the concepts effectively addressed in this work.

While CT is widely recognized for its potential to enhance problem-solving and critical thinking across diverse educational contexts, its application and accessibility for learners with Learning Disabilities (LD) remain important areas of inquiry. This study specifically examines how CT applies to individuals with dyslexia, Autism Spectrum Disorder (ASD) [Gadia 2006], and Attention-Deficit/Hyperactivity Disorder (ADHD) [Maia and Confortin 2015], conditions that impact learning through challenges related to reading, attention, cognitive processing, and social interaction. Understanding how CT can support these learners is essential for fostering inclusive and effective learning environments.

The LD hinder individuals with normal intelligence and no neurological impairments from achieving age-appropriate educational goals. These disorders can only be diagnosed once formal education begins [Araújo et al. 2013]. Accurate diagnosis requires a multidisciplinary team of professionals from fields such as pedagogy, medicine, and psychology [Pestun et al. 2002]. Moreover, early diagnosis is crucial, as it allows individuals to develop strategies for better content absorption. Examples of LD include dyslexia, dyscalculia, and dysgraphia. Among the various LD, this work focuses on dyslexia, considering its impact on reading and language processing.

This work also examines two conditions not specifically classified as LD, but that cause learning difficulties due to their effects on attention, behavior, social interaction, or cognitive abilities ASD and ADHD. Accordingly, this Systematic Literature Review (SLR) explores how CT has been addressed and assessed in the context of dyslexia, ASD, and ADHA, as well as the reported findings. Specifically, it investigates three main research questions:

1. Which CT concepts are addressed in students with LD, and what approaches are used to develop or introduce these concepts?
2. What methods are used to evaluate the effectiveness of these approaches?
3. What outcomes have been reported in the studies?

The rest of this paper is organized as follows: Section 2 reviews related work, positioning the study within the context of CT and LD; Section 3 outlines the methodology used for the SLR; Section 4 presents the findings; and Section 5 concludes the paper with suggestions for future research.

2. Related Work

Although more limited in scope, some studies investigate computing in a broader sense within the context of individuals with special needs. A related work presents an SLR that examines the development of collaborative technologies for children with special needs [Baykal et al. 2020]. The review highlights an increasing interest in the field, particularly in Europe and North America, with a predominant focus on boys with ASD. It also reveals a lack of standardized definitions for collaboration and inconsistencies in evaluation methods, making cross-study comparisons challenging. The authors emphasize the need for clearer theoretical frameworks, more diverse demographic representation, and rigorous assessment criteria in future research.

Furthermore, the review was carried out exclusively in the ACM database and lacks a comprehensive focus on CT, setting it apart from the present study, which addresses this topic in greater depth. Throughout the work, different types of special needs were addressed, ranging from actual diseases, such as cancer, to LD, such as dyslexia. However, although CT is mentioned, the concept is not widely explored in the development of the study.

Another similar work explores the potential of Scratch [Resnick et al. 2009] to develop cognitive and socio-emotional skills in individuals with ASD [Lima et al. 2024]. Scratch is a block-based visual programming language that simplifies the construction of algorithms by allowing blocks to fit together such as puzzle pieces. The study [Lima et al. 2024] analyzed seven works selected based on inclusion and exclusion criteria from national and international databases, emphasizing that Scratch contributes skills development such as memory, imagination, creativity, and social competencies in individuals with ASD. Although the primary focus of the study [Lima et al. 2024] is not the teaching or introducing of CT, there are relevant points of intersection. The use of Scratch involves the construction of algorithms, which indirectly relates to fundamental concepts of CT. Furthermore, the study's target audience includes children with ASD, who are part of the broader spectrum of LD.

Our work, however, differs by broadly addressing the teaching of CT for individuals with various types of LD, rather than limiting the scope to a single condition. By adopting a more inclusive perspective, we seek to understand how CT can be effectively introduced across different learning profiles, considering the diverse challenges faced by these individuals. Additionally, we investigate the teaching of all core areas of CT, including concepts such as abstraction, decomposition, and algorithms, exploring how these elements can be adapted to support different cognitive needs. To achieve this, we analyze diverse pedagogical approaches that go beyond a single tool.

3. Methods

We followed a proposed guideline for SLRs in Software Engineering [Kitchenham 2004], which outlines three main phases: Planning the Review (including identifying the need for a review and developing a review protocol), Conducting the Review (including selecting studies, extracting data, and synthesizing), and Reporting the Review, for which we adhered to PRISMA guidelines. The review protocol was developed based on the research questions presented in the introduction. The selected databases and search engines were chosen to target those specialized in education (ERIC[1]) and computing/STEM (IEEE Xplore[2], ACM[3], and SOL[4]), in addition to the *Portal de Periódicos da CAPES*[5].

To ensure comprehensive coverage of relevant databases, including those from Brazil, and to capture a broader range of studies while staying within the scope of this work, we developed the following search strings using keywords related to "computational thinking", "learning disabilities", and "education":

- *("computational thinking") AND ("learning disabilities" OR "learning disorders" OR "dyslexia" OR "attention-deficit/hyperactivity disorder" OR "ADHD" OR "autism" OR "autism spectrum disorder" OR "ASD") AND ("education" OR "educational strategies")*
- *("pensamento computacional") AND ("transtornos de aprendizagem" OR "dificuldades de aprendizagem" OR "dislexia" OR "transtorno do déficit de atenção*

[1] Available at: https://eric.ed.gov/.
[2] Available at: https://ieeexplore.ieee.org/.
[3] Available at: https://dl.acm.org/.
[4] Available at: https://sol.sbc.org.br/.
[5] Available at: https://www.periodicos.capes.gov.br/.

com hiperatividade" OR "TDAH" OR "autismo" OR "transtorno do espectro autista" OR "TEA") AND ("educação" OR "ensino" OR "estratégias pedagógicas")

We applied specific filters in each database according to the available resources to ensure the relevance and quality of the papers included in this SLR. In the ERIC database, we restricted results to peer-reviewed papers only. In IEEE Xplore, we filtered the results to include only conference papers and journal articles. In the ACM Digital Library, we limited the search to research articles. In SOL, we selected event proceedings and journals published in English and Portuguese. Finally, in the CAPES database, we restricted the search to peer-reviewed papers written in English and Portuguese. There was no limitation on the search period, and the searches were conducted during October 2024.

The studies were selected through an initial screening of titles and abstracts. The screening excluded all papers that met the following criteria:

1. The work did not address CT.
2. The work did not address dyslexia, ASD, or ADHD.
3. The work did not cover CT in the context of LD.
4. CT was mentioned in the context of LD but was not the main focus of the work.
5. The work was duplicated (already analyzed from other search databases).
6. The work was a SLR.
7. The work was not a paper (e.g., report, text, book chapter, poster, etc.).

We sought to retrieve the full papers of all studies that passed the screening phase, or for those whose titles and abstracts were insufficient to determine whether the study should be included. Finally, we reanalyzed the full texts to select the papers to be included in the review. The data extraction process, aimed at answering our research questions, involved coding the selected studies based on their approach to developing or introducing CT skills, the LD addressed, the CT concepts covered, the country, the target audience (ages), and the assessment methods used (such as pre/post-test, surveys, or questionnaires).

4. Results

Our search returned 205 documents; 3 were removed due to duplication, 186 were excluded based on the exclusion criteria during the title and abstract screening, and 5 were excluded in the full-text analysis. Additionally, 2 documents were removed because their full texts were inaccessible. Figure 1 illustrates the search outcomes using the PRISMA [Page et al. 2021] flowchart. Table 1 presents the selected studies along with their respective approaches, targeted LD, countries of origin, CT concepts introduced or developed, intended audiences, and, when applicable, the assessment methods used to evaluate the proposals.

To clarify, in Table 1, "others" in the "CT Concepts" column refers to concepts not covered by this study – those that are not within the scope defined by [ISTE and CSTA 2011a] –, such as logical thinking, synchronization, generalization, and parallelism. Furthermore, the following subsections will provide a more detailed explanation of the table's contents. Finally, to improve the table content visualization, some concepts have been abbreviated: *Decomposition* and *Problem Decomposition* to *Decomp.* and *P. Decomp.*, respectively; *Data Representation* and *Data Collection* to *Data Rep.* and *Data Coll.*, respectively.

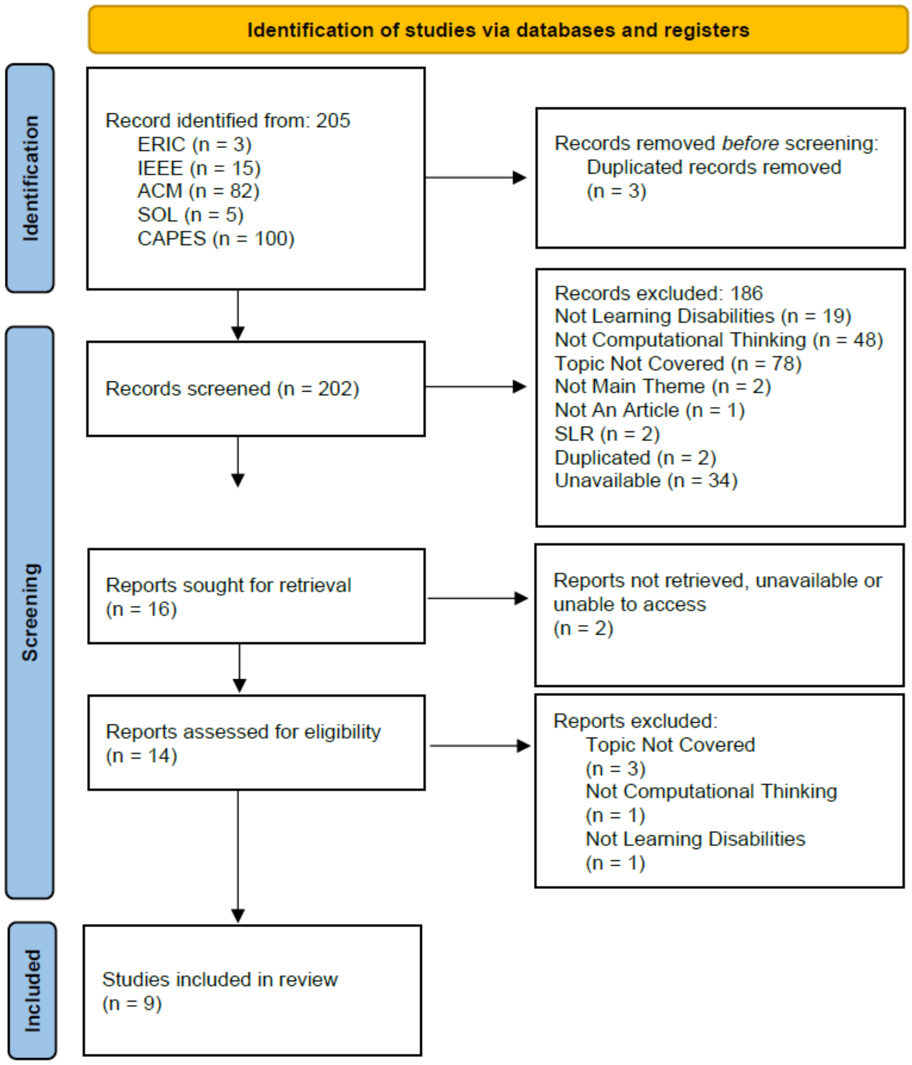

Figure 1. PRISMA flowchart of the review.

Table 1: Studies on CT in the context of LD.

Study	Approach	LD	CT Concepts	Country	Audience	Audience Assessment
[Nadeem et al. 2021]	Visual Programming Languages	Dyslexia	Abstraction Algorithm	Pakistan	K-12 (not specified)	None
[Silva et al. 2020]	Experimental Case Study	Attention-Deficit Disorder	Abstraction Decomp. Others	Brazil	15 years old	Experimental Evaluation
[Elshahawy et al. 2020]	Serious Game	ASD	Algorithm	Egypt	7-14 years old	Focus Groups

Table 1: Studies on CT in the context of LD.

Study	Approach	LD	CT Concepts	Country	Audience	Audience Assessment
[Munoz et al. 2018]	Game Programming	ASD	Abstraction P. Decomp. Data Rep. Algorithm	Chile	11-15 years old	Mainly Quantitative
[Malpartida and Rodrigues 2024]	Serious Game	ASD	Decomp. Abstraction Algorithm Others	Brazil	K-12 (not specified)	None
[Simas and Motta 2019]	Unplugged Game	LD (not specified)	Abstraction Data Coll. Data Analysis Data Rep. Simulation Automation Others	Brazil	12-16 years old	Observation
[Kim et al. 2024]	Robot Programming	ASD and LD (not specified)	Algorithm	South Korea	14-15 years old	Quantitative & Qualitative
[Arslanyilmaz et al. 2024]	Curriculum Proposal	ASD	Algorithm Abstraction Data Rep.	United States	Average age of 13	Focus Groups
[Kert et al. 2022]	Robot Design and Programming	LD (not specified) and ADHD	Algorithm	Turkey	Secondary School Level	Quantitative & Qualitative

4.1. Which CT concepts are addressed in students with LD, and what approaches are used to develop or introduce these concepts?

The reviewed studies covered a variety of CT concepts in the context of students with LD, showing diversity in the competencies targeted and the approaches used. *Algorithms* was the most frequently addressed (seven out of nine studies). It demonstrates the importance of sequential thinking, a fundamental aspect of logical reasoning and problem-solving. However, it is common for CT to be reduced to just programming, with a focus on coding as the end goal, rather than being seen as a means to develop problem-solving and critical thinking skills. Furthermore, the concept of *algorithms* was approached in different ways. For example, some studies focused on ideas such as loops, events, and debugging [Nadeem et al. 2021], while others focused on sequential, conditional, and iterative structures [Elshahawy et al. 2020].

Abstraction also was a frequently addressed concept, appearing in six out of the nine studies. This prevalence suggests that *abstraction* is a key concept in CT, as it allows students to simplify complex problems and focus on essential aspects, which is particularly beneficial for students with cognitive challenges. In addition, *abstraction* proved to be widely applicable in various educational approaches, such as serious games [Malpartida and Rodrigues 2024], visual programming [Nadeem et al. 2021], and game programming [Munoz et al. 2018], making it a core competency in diverse learning contexts. Other competencies, such as *decomposition* and *data-related*, were less frequently addressed (three studies each), as were *simulation* and *automation* (one study) but play a relevant role depending on student profiles and instructional goals. Finally, three of the nine papers also mentioned concepts outside the scope of our evaluation, such as *pattern recognition*, *generalization*, and *synchronization*.

When analyzing the approaches, it can be seen that *game-related* proposals prominently, appear in four studies, often in the context of students with ASD. These games create controlled interactive environments that facilitate skill development while maintaining engagement. *Robot programming* appeared in two studies and was particularly effective in bridging abstract concepts with concrete actions, a strategy that may benefit students who struggle with abstract reasoning. Meanwhile, *visual programming languages*, used in a study with dyslexic students, reduced barriers related to reading and writing by offering simplified graphical coding interfaces. Another observation was the role of *unplugged game* in making CT skills accessible to a broader range of students, particularly those who may have difficulties with digital tools. Although it was addressed in only one study [Silva et al. 2020], its importance cannot be underestimated. By eliminating the need for technological equipment, these activities provided alternative learning pathways, allowing students to focus on the fundamental principles of CT without additional cognitive overload.

4.2. What methods are used to evaluate these approaches?

The assessment methods varied significantly, reflecting an effort to balance qualitative and quantitative evaluations but also emphasizing the lack of standardized methods. Two studies did not conduct evaluations with the target audience. Nadeem et al. (2021), for example, assessed the proposed functionalities in a visual programming environment using prototyping in a tool. However, the authors state that the proposed model will be implemented in the future as a programming environment designed for dyslexic programmers. Malpartida and Rodrigues (2024), on the other hand, did not evaluate the proposal directly with the target audience but rather with two Special Education professionals through a usability evaluation that employed the Cognitive Barriers Walkthrough [Santos et al. 2022], System Usability Scale [Brooke 2013], and Self-Assessment Manikin [Bradley and Lang 1994] methods. After the implementation is completed, the authors report that longitudinal case studies (medium-term) will be conducted with children with ASD.

Although using different assessment methods, two studies worked with focus groups. Elshahawy et al. (2020) proposed the development and evaluation of a serious game to teach CT to children with ASD. The evaluation was conducted with two groups: the first group consisted of eight neurotypical children to validate the graphics and layout, while the second group included four children with ASD to assess engagement and game usability. Likert scales and engagement tests with instructor-assisted observation were used. Arslanyilmaz et al. (2024) investigated the effectiveness of an accessible computing curriculum for students with ASD in learning CT concepts by analyzing computational projects developed by these students. To achieve this, the authors used the Dr. Scratch tool, along with statistical tests such as Multivariate Analysis of Variance (MANOVA) and Analysis of Variance (ANOVA) to compare the experimental and control groups.

One of the studies was evaluated with only one student. Da Silva et al. (2020) conducted an experimental case study to teach CT to a high school student with Attention Deficit Disorder, applying a method divided into three stages: (1) computer discovery, (2) introduction to CT through programming, and (3) learning by doing, using pair programming and challenge-based learning. The study adopted an experimental approach, employing practical tests and questionnaires for assessment, including programming exercises, the student's self-assessment of task difficulty levels, and the identification of the types of exercises that most captured his interest.

Some studies employed similar evaluation methods. Munoz et al. (2018) and Kim et al. (2024) used pre- and post-tests, while Kim et al. (2024) and Kert et al. (2022) incorporated observation as an assessment method. Munoz et al. (2018) adopted a workshop-based approach to digital game programming to develop CT skills in young individuals with ASD. The evaluation was conducted through the analysis of artifacts produced by participants, using an assessment rubric for CT skills implemented in the Dr. Scratch platform, along with a pre- and post-intervention test. The pre-test used to determine participants' proficiency in CT-related skills was the CT Test [Román-González et al. 2017].

Kim et al. (2024) investigated the development of CT skills through programming instruction with robots for students with ASD and Intellectual Disabilities. However, the authors did not specify which diagnoses were included under the latter term. The study was evaluated based on three main methods, each corresponding to one of the CT dimensions proposed by Brennan and Resnick (2012). To this end, direct observation and video analysis (supported by an observation form) were used; a self-recording checklist completed by students to indicate which computational practices they employed; pre- and post-tests (in a Likert scale format) to measure students' interest in programming and robotics; and emotion cards to capture participants' subjective reactions.

Kert et al. (2022) also investigated the impact of robot development on enhancing CT in students with learning difficulties. The study adopted a single-subject experimental design (A-B-A), with systematic observation of skills over 13 weeks. Data collection involved video recordings, Likert scale observation forms, and statistical analysis using the Wilcoxon Signed-Rank test. Finally, Simas and Motta (2019) used an unplugged CT approach in extracurricular activities. In this approach, CT was connected to the curriculum of language and science subjects, reinforcing interdisciplinary learning. The evaluation was based on direct observation of students' behavior during the activities, analyzing their progress in computational and textual skills.

4.3. What outcomes have been reported in the studies?

Despite differences in evaluation methods, a common trend among the studies was the positive impact of CT activities on student learning and engagement. However, the diversity of assessment strategies made direct comparisons difficult. Silva et al. (2020) focused on a single ADHD student, showing substantial improvement in logical reasoning and problem-solving, particularly in mathematics and chemistry. The study emphasized the importance of tailored, interest-driven activities, as the student stayed engaged because the tasks aligned with his interests.

In studies with students with ASD, for example, Munoz et al. (2018) concluded that the students showed improvements in all three dimensions of CT addressed in the study. The research highlighted the importance of individualized teaching strategies while also emphasizing the role of robot-based teaching tools in promoting more accessible and engaging learning. The results of Kim et al. (2024), in turn, showed improvements in skills such as abstraction and logical thinking, as well as promoting communication and collaboration among participants. The pedagogical approach adapted to the needs of students with ASD proved to be promising, and the use of Scratch was beneficial due to its structured interface.

The study of Simas and Motta (2019) reinforces the importance of playful and interdisciplinary methodologies in Computing education, promoting the development of cognitive, linguistic, and logical-mathematical skills. The authors highlight that the initiative enabled advances in students' autonomy and their positive perception of technology, while also emphasizing the need for further research to assess the long-term impact of the methodology. However, it is important to note that, although the study included 28 participants, the authors presented results for only three students, which constitutes a partial analysis.

In summary, while the studies varied in their specific methodologies and targeted skills, common themes emerged: (1) *Abstraction* and *Algorithmic-related* were the most frequently addressed concepts; (2) game-based and interactive methods were particularly effective in engaging students with ASD; and (3) multimodal evaluation approaches provided deeper perceptions into cognitive and emotional aspects of learning.

5. Conclusion

This paper presented an SLR on how CT has been introduced and assessed in the context of individuals with LD, focused on dyslexia, ASD, and ADHD. A set of studies investigating pedagogical strategies employed, CT concepts addressed, and outcomes achieved in diverse populations was analyzed. The results revealed a variety of approaches demonstrating how CT can aid in problem-solving and foster students' autonomy. However, significant gaps were also identified in the literature, both in the field of CT and in the development of activities designed for individuals with LD.

One of the most evident challenges is the lack of conceptual clarity regarding what constitutes CT. Some studies limit CT to programming-related activities, while others take a broader perspective, encompassing concepts such as abstraction, decomposition, and automation. This disparity reflects the absence of consensus within the scientific community, making it difficult to compare results and develop more robust and comprehensive proposals. Additionally, there is a scarcity of studies focused on certain LD, such as dyscalculia. While research on ASD is more prevalent, other conditions receive little to no attention. The difficulty in diagnosing certain conditions may contribute to this gap, underscoring the need for initiatives that promote inclusive pedagogical strategies.

Beyond these gaps, a key challenge is the assessment of CT. Various obstacles hinder effective evaluation, including the lack of a standardized definition and the complexity of measuring cognitive skills that are not directly observable. Many studies rely on qualitative assessment tools, such as observations, or quantitative methods, including pre- and post-tests. One promising approach to improve CT assessment is the use of rubrics, as described in [Ávila and Cavalheiro 2022]. The rubrics provide clear and objective criteria for evaluating students' performance in key CT concepts, such as abstraction, decomposition, pattern recognition, and automation.

In the context of LD, these rubrics could be adapted to reflect specific cognitive and linguist challenges. For example, students with dyslexia can benefit from multisensory stimuli, which combine visual, auditory, and tactile elements to support reading and comprehension. A rubric designed for this profile could include criteria that account for the use of multimodal representations, the reduction of textual complexity, and the integration of interactive and assistive technologies. Digital tools, such as Alfaba, are an example of a tool that can assist dyslexic students in learning processes [Jurgina et al. 2023].

From a practical point of view, these findings have significant implications for educators and policy makers. Since many educators may lack specialized training in CT, it is crucial to provide accessible resources and professional development programs that support the integration of CT concepts into the curriculum. The Appendix on Computing in the Brazilian National Common Curricular Base (BNCC) underscores the need to equip students with digital fluency and problem-solving skills through CT, emphasizing the importance of teacher training initiatives. In addition, schools should foster interdisciplinary approaches, aligning CT education with other subjects as recommended by the BNCC. This integration can improve student engagement and adaptability, ensuring that students with diverse learning needs are included in meaningful learning experiences.

Despite its contributions, this study has limitations. Because the review includes studies addressing three different types of LD and related conditions, it is not possible to draw definitive conclusions about the effectiveness of specific CT approaches for each condition. Future work should consider conducting targeted SLRs focused on individual disorders to better understand the unique challenges and opportunities each presents. Furthermore, the development of condition-specific rubrics and instructional strategies would provide a more tailored and inclusive framework for CT education.

In general, this work reinforces the potential of CT as a powerful tool for the cognitive development of people with LD. However, it also emphasizes the need for future efforts to consolidate clearer definitions, expand the scope of investigations, and develop educational proposals that address the diverse needs of students. By fostering discussions and advancing research in this field, it is hoped that more inclusive and effective educational practices can be developed, ultimately benefiting both educators and students.

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