Integration of Computational Thinking in Elementary and Secondary School in Latin America: A Systematic Literature Review

Integración del Pensamiento Computacional en la educación primaria y secundaria en Latinoamérica: una revisión sistemática de literatura

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Abstract
Computational Thinking (CT) has been consolidated as a line of international research. However, in Latin America, there are limited studies that examine its development and integration in primary and secondary education. This study aimed to analyze the integration of CT in primary and secondary education in Latin America, based on a systematic literature review of studies published between 2006 and 2020. The results were grouped into two main categories: conceptualizations of CT and strategies for CT integration. Conceptualizations can be divided into two groups: those linked to computer science and those in which CT is conceived as a methodological resource. Regarding the strategies, it was found that educational robotics and block programming languages are the most used in the region.
Keywords: computational thinking, conceptualizations, strategies, primary and secondary education.

Resumen
El Pensamiento Computacional (PC) se ha consolidado como una línea de investigación internacional, sin embargo, en Latinoamérica son limitados los estudios que examinan su desarrollo e integración en la educación primaria y secundaria. El objetivo de este estudio fue analizar la integración del PC en la educación primaria y secundaria en Latinoamérica, a partir de una revisión sistemática de literatura de los

DOI: http://dx.doi.org/10.6018/red.485321

estudios publicados entre 2006 y 2020. Los resultados se agruparon en dos categorías principales: las conceptualizaciones del PC y las estrategias usadas para la integración del PC. Se encontró que las conceptualizaciones se dividen en dos grupos: unas ligadas a las ciencias de la computación y otras en las que se entiende el PC como un recurso metodológico. Frente a las estrategias, se encontró que las más usadas en la región son la robótica educativa y la programación en lenguajes con bloques.
Keywords: pensamiento computacional, conceptualizaciones, estrategias, educación primaria y secundaria.

Introduction

Currently, skills related to Computational Thinking (CT) are considered fundamental to be developed in the 21st-century society (Zhang and Nouri, 2019). They are a topic of interest for research, development of innovations, and interventions in *STEM* (Science, Technology, Engineering, and Mathematics) classes (Grover and Pea, 2018). CT has been identified as a powerful resource to solve problems in creative ways (Carmona- Mesa et al. 2021) and one of its most cited definitions refers to a thinking process where proposed solutions are represented in a form that can be treated efficiently by an information-processing agent (Wing, 2011).

The integration of activities that foster CT in the school system has a wide potential to improve students' cognitive skills (Huerta and Velásquez, 2021). According to Cansu and Cansu (2019), these activities promote students' strategies to understand, interpret and transform their reality. Although these activities tend to be developed through the creation of computational algorithms and other aspects related to computer science, CT involves a set of general, current useful skills not limited to computer science (Wing, 2006).

With the studies of Papert (1980), a movement that promoted the development of computer skills in students at different school levels began. However, it was from the studies of Wing (2006; 2008; 2011) that the expression 'Computational Thinking' was adopted and its integration into school curricula in the United States was promoted. Since then, studies on CT and its integration in education have constantly increased around the world. For example, Tang et al. (2020) report that between 2006 and 2012, the average per-year number of articles published on this topic was 36.1, while between 2013 and 2018, it was 80.1. For their part, Roig-Vila and Moreno-Isac (2020) highlight that, in the field of education, between 2008 and 2018, there was also a significant increase in the publication of CT articles: from 1, in 2008, to 49, in 2018.

Although Wing's definition has become popular in the field, debates regarding the operational definitions of CT in education remain open (Bocconi et al., 2016; Zhang and Nouri, 2019; Roig-Vila and Moreno-Isac, 2020). Thus, in the international literature there is no consensus about this type of thinking, nor about its scope and forms of integration in everyday school life; some of the diverse CT perspectives include the study of algorithms (Stephens and Kadijevich, 2019), problem-solving skills (Denning, 2009), and thinking like computer professionals (Wing, 2006).

Stephens and Kadijevich (2019), propose that the area of study of algorithms can be enriched from concepts of computer science and mathematics, one of them being CT, which they define as algorithmic thinking supported by an automation process; in this sense, these authors develop a perspective of CT highly supported by mathematics. Denning (2009) argues that CT can be understood as a set of skills for solving everyday problems while questioning Wing's (2006) understanding that CT refers to thinking like a computer scientist, as this may suggest that CT is only relevant to the field of computer science.

The diversity of perspectives, approaches, and purposes of CT suggests several challenges, not only for research but also for its integration into curriculum design in primary and secondary education (Grover and Pea, 2013), as well as in universities (Villa- Ochoa and Castrillón-Yepes, 2020). Likewise, there is still a need for articulation between teaching and research, for the development of innovations and interventions based on research results, and for the training of teachers who participate in these designs and use them in their classrooms (Carmona-Mesa et al., 2022; Zampieri and Javaroni, 2020; Hsu et al., 2018; Lockwood and Mooney, 2018; Bocconi et al., 2016).

In Latin America, initiatives have been developed to promote CT integration in primary and secondary education; for example, organizations such as Microsoft are interested in expanding opportunities for young people in the region in terms of employment, entrepreneurship, and re-admission into education, in addition to supporting ministries of education in the construction of educational policies in schools (Jara and Hepp, 2016). Jara and Hepp highlight that several organizations support processes that incorporate CT through programming but emphasize the need for other organizations to join this type of project, in addition to highlighting the challenge faced by the region in terms of designing relevant curricula to integrate CT and offer adequate training for teachers in this area. By the, Villa-Ochoa and Castrillón-Yepes (2020) highlight two research needs in the region; on the one hand, the need to develop more studies referring to CT in areas other than computing; on the other hand, the challenge of developing both theoretical and methodological works that make it possible to integrate the diverse CT skills in interdisciplinary problems. In this regard, Quiroz-Vallejo (2020) also argues that it is necessary to develop projects that offer in-depth analyses of the impact of CT at the primary and secondary education levels.

In their reviews, Curasma and Curasma (2020) and Huerta and Velásquez (2021), contribute to the research of CT in primary and secondary education in Latin America. The former through a study focused on educational policies, teaching methodologies, languages, didactical resources, and assessment techniques; the latter, through the analysis of CT as a generic skill for solving real problems in different fields of knowledge. However, there is still a need to identify the conceptualizations of CT that predominate in the region and, accordingly, the ways of integrating them into different curricular subjects within educational institutions. In this sense, the objective of this article is to analyze the integration of CT in primary and secondary education in Latin America through a systematic literature review.

The rest of this article is organized as follows: the methodology section describes the research questions and the characteristics of the process of selection of the articles to be reviewed. The results section presents the analysis of the information extracted from the selected articles: the integration of CT as a methodological resource and as a component of computer science, as well as the strategies used for its inclusion. Finally, in the discussion and conclusions sections, the results obtained from the review process are interpreted, and future work opportunities for the region in terms of CT integration in primary and secondary education are stated.

Methodology

To analyze the integration of CT in primary and secondary education in Latin America, a systematic literature review was conducted (Wohlin et al., 2012). For this, two dimensions were delimited: CT conceptualizations and implementation strategies. The review phases presented by Wohlin et al. (2012) were followed. The questions that guided the review are:

- What conceptualizations of Computational Thinking are presented in primary and secondary education studies in Latin America?
- What kind of strategies are used in primary and secondary education to promote Computational Thinking in Latin America?

Based on these questions, a review protocol was developed from a search equation in English and Spanish (Table 1) and was implemented in the databases Scopus, Eric, Scielo, Dialnet, Redalyc, IEEE Xplore, and ACM. These databases were selected for being reliable data sources, with impact both in Latin America and internationally and some of them being specialized in the subject of interest.

Table 1. *Search equations*

Spanish	English
(“pensamiento computacional”) AND (“educación básica” OR “primaria” OR “secundaria” OR “bachillerato” OR “educación media” OR “K-*”)	(“computational thinking”) AND (“basic education” OR “elementary school” OR “K-*” OR “high school” OR “middle school” OR “secondary education” OR “primary education” OR “compulsory education”)

Authors' elaboration

In the Scielo and Redalyc databases, there were variations in the results when iterating the term K-*, by K-9 and K-12, producing increased results; in Scielo two more results were obtained in the search in Spanish and Redalyc, 5 more results were obtained in the search in the same language. The criteria for inclusion/exclusion of documents included: peer review, CT conceptualization, methodology or strategy for the development of CT in Latin America, publication between 2006 to 2020, inclusive, among others. The publication dates were chosen considering that, since 2006, studies on computational thinking began to expand in different regions of the world. Table 2 describes in full the inclusion and exclusion criteria for the document search. Table 3 shows the results of the review by database and language.

Table 2. *Inclusion and exclusion criteria*

Inclusion Criteria	Exclusion criteria
Peer-reviewed articles or book chapters.	Proceedings of academic events, theses, and grey literature.
Documents focused on primary or secondary education levels (6-18 years old).	Documents focused on levels of education other than elementary, secondary, or K-12.
Empirical studies in elementary and secondary or K-12 education.	Essays, theoretical studies, or literature reviews.
Studies whose empirical work is developed in Latin America.	Studies that were developed in countries outside Latin America.
Studies that describe CT conceptualizations and methodologies or strategies for integrating computational thinking in primary and secondary education.	Documents in which the methodology, courses, or CT conceptualizations are not explicit
Documents written in English, Spanish, or Portuguese.	Documents that are written in languages other than English, Spanish or Portuguese.
Documents published between 2006 and 2020.	Documents published before 2006 or after 2020

Authors' elaboration

The search in the databases was carried out on March the 29th of 2021 and resulted in 5320 documents. Duplicates were eliminated (twelve documents) and reading of titles, abstracts, and keywords was made; inclusion and exclusion criteria were applied, resulting in 76 documents. Then, a first reading of the selected documents was made and inclusion and exclusion criteria were applied again, resulting in 28 documents for in-depth analysis.

Each of the 28 documents was reviewed in detail to identify and code descriptive information, explicit or implicit CT conceptualizations, and integration strategies in primary and secondary education. In particular, the main exclusion criterion in the selection of the studies was that of geographic location. Although this criterion was not included as a keyword in the search equations, it was found that most of the documents were not from this region. Table 3 describes the selection process by database and language.

Table 3. *Results by database and language*

Database	***Search in English***		***Search in Spanish***	
	Number of found documents	*Selected from the first round*	*Number of found documents*	*Selected from the first round*
Scopus	*99*	*5*	*1*	*0*
Eric	*1447*	*5*	*584*	*3*
Dialnet	*46*	*7*	*67*	*13*
Scielo	*1*	*1*	*3*	*1*
IEEE Xplore	*197*	*23*	*0*	*0*
Redalyc	*3530*	*7*	*29*	*6*
ACM	*1935*	*12*	*1*	*0*

Authors' elaboration

In addition to the descriptive information, two categories corresponding to the research questions were organized for the analysis, namely: CT conceptualizations and promotion strategies in primary and secondary education.

CT Conceptualizations is a study topic relevant for CT integration into curricula at different educational levels. According to Fessakis et al. (2018), implementation experiences provide feedback that allows generating a critical review of the integration of CT in primary and secondary education. On the other hand, although this has been widely analyzed internationally (Shute et al., 2017; Bocconi et al., 2016), in Latin America, there are still elements to be explored in this regard. The category of CT conceptualizations refers to implicit and explicit interpretations of the subject present in the reviewed literature. CT conceptualizations are analyzed when used as a methodological resource to develop skills in subjects and courses in educational institutions and when used as a component of computer science. For this purpose, CT definitions, skills, and concepts and their relationships with computer science and other areas (e.g., mathematical, and analytical thinking) were codified.

Strategies for integrating CT include different teaching resources, programming languages, robotics, board games, among others, used in different CT integration experiences that contribute to students learning of different CT-related skills (Xu, 2018). Knowledge of these strategies is useful since it offers important information about instructional tendencies and their perception by teachers and students (Kale et al., 2018). Moreover, these strategies provide relevant information for the design of environments that promote the learning of competencies and skills in school contexts.

To assess inter-rater reliability concerning study selection, two of the authors independently coded a sample of 10 of the 76 initial articles based on the inclusion and exclusion criteria described in Table 2. Inter-author reliability was measured through Cohen's kappa coefficient and resulted in k = 0.74, which, according to McHugh (2012), represents substantial inter-author agreement. Table 4 shows the detailed process that was followed to calculate the inter-rater reliability; p_0 is the relative agreement observed between the authors, *yes* indicates that the rater includes the document using the established criteria and *no* indicates that the rater does not include the document; pe is the hypothetical probability of casual agreement and k is the Cohen's kappa coefficient.

Table 4. *Inter-rater reliability*

	Author 1		**Author 2**		**Result**
p_0	Yes $8/10$	No $2/10$	Yes $7/10$	No $3/10$	0.9
The probability that the two authors evaluate **yes** coincidentally.	$\frac{8}{10} = 0.8$		$\frac{7}{10} = 0.7$		$0.8 * 0.7 = 0.56$
The probability that the authors evaluate **no** coincidentally.	$\frac{2}{10} = 0.2$		$\frac{3}{10} = 0.3$		$0.3 * 0.2 = 0.06$
p_e	$0.56 + 0.06$				0.62
k	$k = \frac{p_0 - p_e}{1 - p_e} = \frac{0.9 - 0.62}{1 - 0.62}$				0.74

Authors' Elaboration

Results

The results of this review are presented in two sections: the first one includes the descriptive information of the reviewed studies and the second one presents the categories of analysis stated in the methodology (CT conceptualizations and strategies).

Distribution of articles by country, year of publication, knowledge area, and study duration

This section presents information related to the Latin American country in which the research reviewed was identified, the duration of the CT studies, the areas of knowledge in which its integration into school systems is prioritized, and the years of publication.

DOI: http://dx.doi.org/10.6018/red.485321

Countries

The experiences reported in the reviewed documents were distributed among nine Latin American countries, Brazil being the leader with thirteen publications, followed by Mexico and Colombia with three each; the Dominican Republic, Uruguay, and Argentina presented two reports of experiences about CT integration in primary and secondary education; Chile, Peru, and Ecuador contributed with one publication each. Figure 1 presents this information graphically.

Duration of the studies

The CT integration studies reported in this review presented different periods. This section considers the amount of time that the implementation of CT-related activities lasted in the different investigations and relates them to the methodologies used in the different studies. Table 5 relates the duration of the experiences with the type of study.

Results regarding the duration of the experiences and their relationship with the types of study allow us to conclude that the experiences for CT integration have been mostly qualitative, case studies being the most used alternative. Quantitative research focused on experimental and quasi-experimental designs, while only one paper reported the use of mixed methods through a case study.

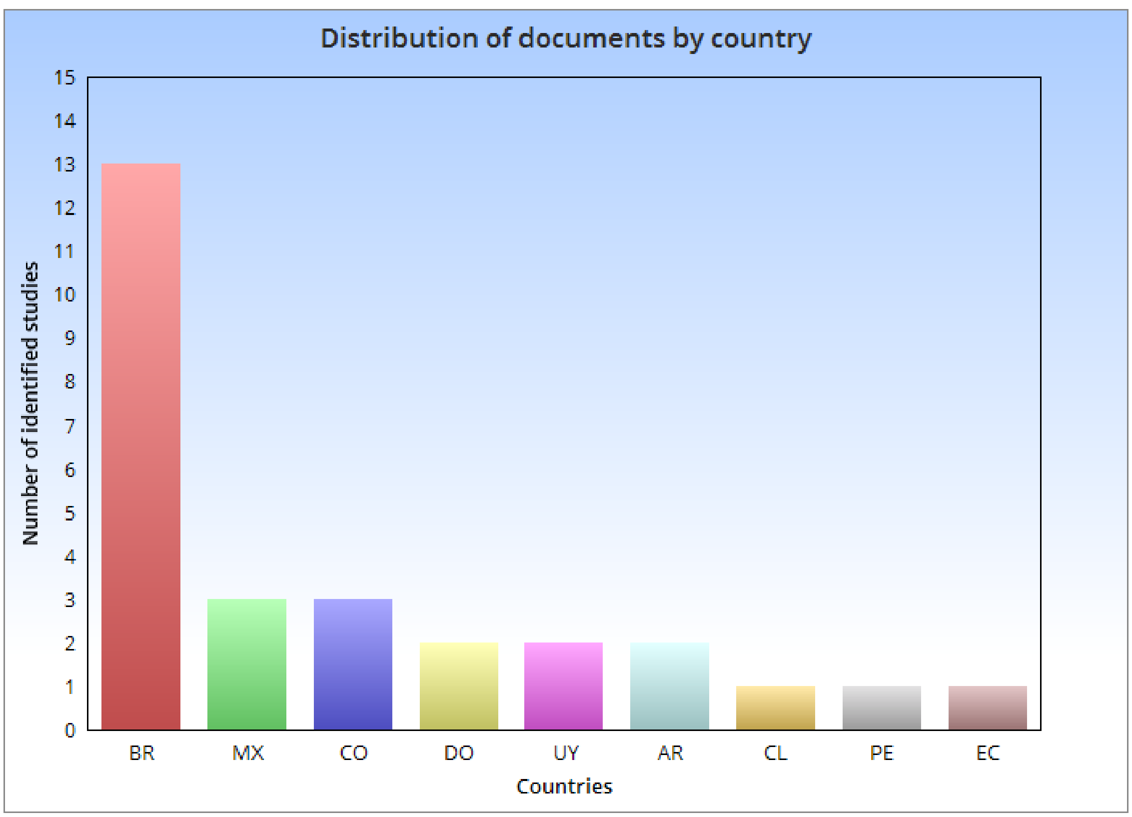

Figure 1. *Distribution of documents by country.* Authors' elaboration

Table 5. *Types of study and its duration*

	Less than two months	Three to six months	Six months to one year	More than one year
Qualitative	7	4	3	5
Quantitative	4	2	0	2
Mixed	1	0	0	0

Authors' elaboration

The number of experiences for CT integration in the classroom with a duration of fewer than six months represents 64% (eighteen out of twenty-eight) of the total number of studies reviewed. In addition, most of the studies focus on in-depth research on specific cases with small groups of students. In this sense, long-term strategies and continuous integration into different school curricula are still limited due to the lack of long-term research with broad population scope which allows deducing general guidelines to support CT integration in educational plans.

Prioritized areas of the school system

Regarding the disciplines in which experiences to integrate CT is developed, the results show that computer science/technology (nineteen studies) and mathematics (seven studies) have the highest frequency. In the area of computer science/technology, mainly activities related to the creation of computational algorithms in programming languages, in which code writing is necessary, such as Python or C++, were observed; only one of the studies integrated an unplugged strategy through a board game. In mathematics, problem-solving activities using CT skills were a predominant means for the study of mathematical content, and, to a lesser extent, designs for the study of algorithms and the use of mathematics to solve problems or understand computational contexts were implemented.

On the other hand, two experiences integrated CT in humanities classes, in which video game design and storytelling were the focus of teaching for the development of knowledge of both history and CT. With these findings, it is evident that, at present, the integration of CT is mainly present in areas related to computer science, despite its importance in other disciplinary fields is recognized (Villa- Ochoa and Castrillón-Yepes, 2020). In this sense, the integration of CT in subjects other than those related to computer science continues to be a challenge in the region.

***Year of publication*.**

Concerning the year of publication of the studies, although the review contemplated 15 years in its inclusion criteria -between 2006 and 2020-, no studies were found for the first 8 years. Results were only found from 2013, the year from which the trend of publication of experiences for CT integration in primary and secondary education began to increase in the region in a sustained manner. Figure 2 shows the growth trend of the reviewed publications from 2013 to 2020.

This section describes the distribution of the reviewed articles according to the countries where the experiences were recorded, the time of implementation, the types of study, the prioritized areas for the implementation of CT experiences, and the publication years. In this sense, it is identified that most of the studies are qualitative and with a duration of fewer than six months. In addition, priority is given to the areas of technology/computer science for CT integration in primary and secondary education. These findings make it possible to identify potential routes for action to promote research on the subject in the region; for example, it is relevant to develop more long-term studies.

The use of CT as a methodological resource to support interdisciplinary processes or teaching in disciplines other than computer science/technology emerges as an unexplored possibility that can be promoted in the region. On the other hand, the use of CT as a methodological resource to support interdisciplinarity and teaching processes in disciplines other than computer science/technology emerges as a little-explored possibility that can be expanded in the region. The following section presents the results of two more categories of analysis of the information: CT conceptualizations and integration strategies.

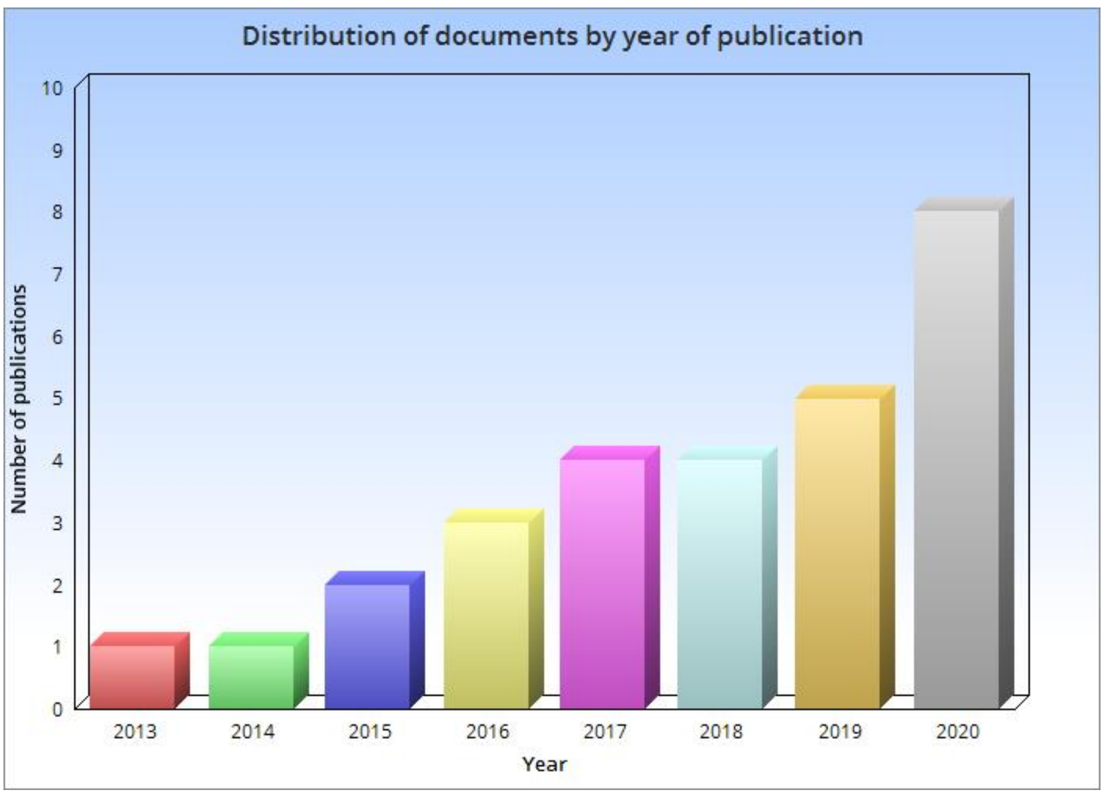

Figure 2. *Distribution of documents by year of publication, between 2013 and 2020.*

Authors' elaboration

Conceptualizations and strategies

Regarding the categories of analysis (CT conceptualizations and strategies), Table 6 presents a summary of the results reported by the review, along with some of the relevant studies in each subcategory. In addition, the table presents a relationship between CT conceptualizations and strategies used to implement them. In terms of conceptualizations, two important subcategories were identified: conceptualizations for the use of CT as a methodological resource, that is, as a means for teaching different disciplines, and conceptualizations of CT as a set of skills specific to computer science, used only in that discipline. Consequently, the table also shows the strategies for CT integration reported in the literature review and the type of CT conceptualization they tend to be included in.

Table 6. *Relationship between CT conceptualizations and integration strategies*

	CT Conceptualizations	**Strategies for CT integration**
Methodological resource in different disciplines	• Complex problem-solving approach / skill set (de Jesus and Silveira, 2020; Manrique- Losada et al., 2020; von Wangenheim et al., 2017; Costa et al., 2017). • Collaborative work skills (Basogain and Olmedo, 2020; de Souza et al., 2014). • CT as a resource to foster interdisciplinarity (Corzo et al., 2020; Curasma et al., 2019; von Wangenheim et al., 2017; Costa et al., 2017).	• CT Integration through Educational Robotics (Curasma et al., 2019; Souza et al., 2019; Rosales et al., 2017; Garcia, 2015). • CT integration through the creation of digital games (da Silva et al., 2020; Barbosa and Maltempi, 2019; Kaminski and Boscarioli, 2018; von Wangenheim et al., 2017).
Computer Science	• Creation of programs or algorithms (da Silva et al., 2020; Kaminski and Boscarioli, 2018). • Application of new computational methods for problem solving (de Jesus and Silveira, 2020; Manrique-Losada et al., 2020; Curasma et al., 2019; von Wangenheim et al., 2019). • Reformulation of problems to be solved with computational strategies (Schneider et al., 2020; da Silva et al., 2020; Barbosa and Maltempi, 2019; Araujo et al., 2018; González et al., 2018; Basogain et al., 2016; Enriquez et al., 2016).	• CT integration through the programming of computational algorithms (da Silva et al., 2020; González et al., 2018; Araujo et al., 2018). • CT integration through unplugged activities (von Wangenheim et al., 2019).

Authors' elaboration

CT Conceptualizations

The category CT conceptualizations refer to implicit and explicit interpretations reflected in the reviewed research on the subject. In this sense, the results grouped in this category provide information regarding the influence that the different perspectives of CT have on the design and development of predominant educational experiences in the region. This category was divided into two subcategories for analysis: conceptualizations of CT as a methodological resource and conceptualizations of CT for computer science.

CT as a methodological resource.

The development of CT as a methodological resource refers to a conception of this kind of thinking as a vehicle or means to solve tasks in other disciplines or to find mutual relationships. This is a key subject since it permits recognizing the scope and uses of CT in computer science and other school subjects. In this sense, this category describes experiences regarding CT integration aiming to contribute to the development of skills such as problem-solving, collaborative work, as well as the potential of CT as a methodological resource that promotes interdisciplinarity.

The results of the review show that CT, when used as a methodological resource, is mostly used as an approach or a set of skills for solving complex problems. When CT is conceptualized in this way, skills such as critical thinking, innovation, abstraction, and the use of systemic processes to optimize problem-solving are promoted. For example, de Jesus and Silveira (2020) use the CT as a methodological resource to automate solutions to problems proposed to students through the creation of digital games. Additionally, it is common for the studies that adopt this CT conception, to implement their experiences in the first years of schooling. This is the case of the experience developed by von Wangenheim et al. (2017), which focused on the integration of CT in a transversal way in a history course for children between 8 and 14. Likewise, Costa et al. (2017) report a study in mathematics classes through a mathematical problem-solving approach adapted to strengthen CT-related skills.

On the other hand, there are CT conceptualizations that consider this topic as a resource for the development of collaborative work skills, such as tolerance and respect among teammates. For example, de Souza et al. (2014) reported experiences in which, using team programming, students reported communicating better with each other, since they acquired greater assertive communication skills. Likewise, works such as those of Basogain and Olmedo (2020) show the possibility of using CT to promote competencies related to the construction of citizenship, through online collaborative learning in primary schools in Uruguay.

As mentioned above, mathematics is the second area in which more studies related to CT were found. In this field, some reported studies conceptualize CT for use in mathematics education through systemic processes that combine computational and mathematical algorithms. In this regard, Barbosa and Maltempi (2019) describe an experience that focused on supporting students with difficulties in understanding first-degree equations, through the design of a digital game in Scratch. Educational robotics and CT were also used to complement mathematics classes in secondary education with positive results, showing that students' end-of-year grades improved and, in general, their understanding of mathematical concepts was deeper and greater in scope than before the experience (Souza et al., 2019; Rodrigues et al., 2016). On the other hand, Basogain et al. (2016), although without integrating CT directly in mathematics courses, reported that this topic and its understanding from systemic processes, contributed directly to the development of mathematical skills in primary education, such as understanding and communicating problems in an organized way and based on logic.

Other experiences report that some CT conceptualizations tend to consider CT as a bridge between different disciplines. In this sense, Curasma et al. (2019) propose that the skills derived from CT integration are fundamental for different areas at the same time, such as computer science, mathematics, social sciences, and humanities. For this reason, CT is implicitly considered as a methodological resource that promotes interdisciplinary processes. In this regard, an outstanding experience relates the history and computer science integrating them in a cross-disciplinary way by promoting CT through the creation of digital games with historical content (von Wangenheim et al. 2017). For their part, Costa et al. (2017) propose that individual elements of CT can be fostered across different disciplines, so it is not necessary to make space in curricula for new subjects focused solely on CT. They think that such an approach has the potential to promote interdisciplinary processes, specifically between mathematics and computer science.

Following the same trend, studies such as those of Azevedo and Maltempi (2020) show how some elements of computer science can contribute to the teaching of mathematics through the design of digital games and robotic devices with Scratch by secondary school students. These authors show that the experience of CT integration in interdisciplinary ways favors important students' skills such as real problem solving, systematization of concepts to be used in concrete situations, and creative work; in this sense, the CT conceptualization as an approach to the resolution of complex problems is implicitly followed. In the same line of ideas, Corzo et al. (2020) integrated CT in basic education in an interdisciplinary way, linking mathematics and computer science, through the STEAM approach. Their results show that this strategy makes it possible to achieve the learning objectives proposed in mathematics curricula and expands students' ability to understand and use digital technologies.

In summary, CT as a methodological resource was presented in different scenarios in which it played the role of a vehicle to obtain an end. This conceptualization contributed to developing content in disciplines other than computer science/technology and has a high potential as a resource to develop interdisciplinary processes in which CT is a means to strengthen skills for problem-solving and collaborative work among peers. In addition, this conceptualization stands out for the diversity of alternatives it offers to approach different situations in the school system, such as the need for reinforcement in some classes or the design of joint projects between different subjects. So, this CT perspective allows to transcend both computer science and other disciplines and support some of the challenges that the educational systems of the region have, such as the integration of digital technologies and the development of skills currently demanded by society.

CT as a component of Computer Science

As evidenced in the previous section, CT can be used to complement educative processes in different disciplines of school curricula. However, its contributions tend to be centered mainly on computer science. In this sense, this category includes studies in which CT is a goal or an end to be achieved through the development of skills directly related to computer science. Likewise, in the conceptualizations of CT as a component of computer science, it is considered as an alternative for the development of new computational methods to solve or reformulate problems related to computational strategies.

The reviewed experiences in which CT is a component of computer science, use computer programming to foster skills such as abstraction, decomposition, algorithm recognition, and automation to strengthen students' computer skills. For example, in the work of da Silva et al. (2020), CT was integrated to strengthen the creation of computational algorithms and computer programming, and peer assessment strategies allowed students to analyze elements such as the efficiency of their peers' codes and algorithms. Kaminski and Boscarioli (2018) integrated CT with a similar aim, albeit through the creation of virtual learning objects by students.

On the other hand, the conceptualization of CT as a component of computer science is also evident through the application of new computational methods in problem-solving. For example, the automation of solutions for similar problems is a fundamental skill when integrating CT (de Jesus and Silveira, 2020; Manrique-Losada et al., 2020). In this sense, to materialize this skill, students should adopt a role like that of a computer scientist in the way they approach problems and create computational content. In this way, there are points of convergence between this way of understanding CT and the approach of Wing (2006), who proposes that one of the characteristics for the development of CT is to think like a computer scientist.

In contrast to what has been mentioned so far, alternatives such as the creation of virtual maps through mobile devices using augmented reality are reported in the reviewed documents (Esteves et al., 2019). In this case, students had the possibility of programming a character that moved on a virtual map, generating a programming toy that introduced different subjects in computer science classes. On the other hand, von Wangenheim et al. (2019) developed and implemented a board game in which it was possible to integrate, in an introductory way, concepts of computer science such as algorithms and some elements of programming. For their part, Curasma et al. (2019) proposed that the development of skills focused on finding new computational methods to solve problems in primary and secondary education is an opportunity that could enhance the economic development of the region, given that the development of this type of strategies makes it possible to increase labor capacity in ICT and prepare students for the wide variety of future jobs related to computer science.

The reviewed studies also allowed us to visualize that CT, as a component of computer science, was integrated to reformulate problems for their solution through computer science strategies. The results show that, under this approach, the development of abstraction, planning, generalization, execution, and pattern recognition skills is encouraged through different programming languages such as Scratch (Barbosa and Maltempi, 2019; Basogain et al., 2016).

In this sense, concepts such as variables, assignments, and relational operators were recurrent for the reformulation of problems in these languages.

In addition, multiple experiences have supported the use of programming languages with other resources, such as educational robotics or the Internet of Things. For example, Enriquez et al. (2016) implemented an experience with robotics for teaching programming in the Java language and found that this resource was useful in two ways: it fostered the motivation of students and their performance in the use of basic programming control structures. Schneider et al. (2020) made use of the Internet of Things and problems related to *Smart Human Cities* for teaching computer skills and reported that this experience promoted significant learning in the students, who could focus on a real problem in their environment that is important for their future and used computing resources to contribute to its solution.

In this section, the conceptualization of CT as a component of computer science was presented. Two approaches to this conceptualization are recognized. The first one considers CT as an alternative for the development of new computational methods for problem-solving, in which skills such as abstraction, decomposition of problems into small parts, recognition of computational algorithms, and automation are promoted; in this approach, CT is conceived as an element to strengthen students' computational abilities. The second approach uses CT for the reformulation of problems using computational strategies, in which students take the role of content creators and use their computational knowledge in different problems.

Acknowledgment of the lack of a clear conceptualization

The previous two sections presented two types of conceptualizations of CT that are either explicitly or implicitly reflected in the reviewed literature. However, some of the studies reported that, although important works have shed light on conceptualizations for integrating CT in the school system at the international level (e.g., Weintrop et al., 2016; Perković et al., 2010), there is still a need to broaden the discussions to consider the particularities of Latin American education systems. For example, Souza et al. (2019) recognize the potential for the development of interdisciplinary processes through CT as a methodological resource; however, they reported that the different ways of understanding CT that coexist in the literature need to be nuanced for their adequate integration in school systems. Meanwhile, Basogain et al. (2016) highlighted the need to enrich these conceptualizations in the region from the materialization of proposals that address the educational needs of Latin America.

Although CT is a subject with the potential to contribute to educational processes in Latin America and could help close the gaps between developing and developed countries, supporting the development of the skills needed for the jobs of the future (Curasma et al. 2019), its integration presents significant challenges. In particular, the results of this review of conceptualizations identify the challenge of building consensus around different understandings of the issue. The following section describes the strategies used for CT integration in the different reviewed studies.

Strategies

The results of this study show that CT integration in primary and secondary education is mainly realized through programming in different scenarios such as robotics (11), creation of digital games in block programming languages (9), and problem-solving in code programming languages (8). In addition, to a much lesser extent, there are also strategies for unplugged CT integration (1) through unplugged experiences.

CT integration through educational robotics

In the articles reviewed, robotics as a strategy was the most frequent for CT integration. The devices worked with were mainly robots based on Arduino boards and Lego Mindstorm NTX robots. An example of this is the study by Curasma et al. (2019), who through robots with Arduino Uno boards, implemented a CT integration and evaluation experience with middle school students. The author highlights as an important feature of this strategy, the fact that students can test their ideas about hardware and software interaction quickly and see results immediately. Other experiences agree with these results, such as that of Souza et al. (2019), who in their findings show how educational robotics favors students' perception of theoretical concepts of computer science, through a practical approach that effectively stimulates skills related to CT and mathematics.

Studies such as those of García (2015), address educational robotics and its use as a strategy for CT development in a broader way, presenting some approaches experimented in Uruguay, using the imagination, design, construction, and programming of robots created by students. Its results show that this strategy sustains the development of the CT beyond programming and transcends the future professional paths of the students. In this way, coding is presented as an issue that is not exclusively about programming but various ways of communication. In this sense, Rosales et al. (2017) developed their programming environment, called RITA en RED (Rita on the Web), with the aim of teaching programming through robot combat experiences. Its objective, in addition to promoting technical skills involved in robot programming, was the development of creativity, critical thinking, communication, and collaboration between peers.

In general, the contributions of robotic strategies for CT integration reported in the reviewed studies can be summarized in three aspects: the first one is the specific CT skills that these strategies contribute to abstraction, pattern generalization, problem decomposition, and systematic debugging and detection of errors; the second important contribution of educational robotics for the integration of CT is the possibility it offers for the rapid comprehension of concepts because it is an alternative in which changes take effect immediately, generating fast feedback for students; and finally, the third contribution is based on the fact that the use of educational robotics fosters communication and collaboration among peers.

These results highlight the potential of educational robotics for the development of CT-related skills, given that students can interact with both software and hardware elements at the same time, in addition to analyzing how one influences the other, learning different CT skills such as abstraction or pattern recognition. On the other hand, the use of educational robotics to integrate

CT showed positive results regarding the development of communication skills among peers and the perceptions of computer science.

CT integration through computational problem-solving using programming languages

The creation of computational algorithms in different languages to solve computational problems has been a widely used strategy for CT integration in primary and secondary education. In this strategy, the experiences considered different ways of working with algorithms, such as peer programming or challenge-based programming; in addition, the languages used tended to use lines of code, compared to the educational robotics strategy, in which mostly block programming languages were used.

Peer programming was a strategy used in the work of da Silva et al. (2020), in which students write code and the instructor stands next to them to supervise, exchange impressions, and discuss the efficiency of the written code and the possibility of improving it. For their part, González et al. (2018) designed and executed strategies for teaching the C++ language through the promotion of skills such as systems thinking and abstraction; in this research, a first moment of the class was devoted to basic programming concepts and the rest was dedicated to exploring and work on solving situations proposed by the instructors, who made feedback sessions with peer programming when requested. On the other hand, one of the experiences reviewed used Screen Turtle (Araujo et al., 2018), a learning environment inspired by the work of Seymour Papert, introducing students to programming through the creation of geometric figures with simple commands and programming concepts such as loops, functions, structures, and parameters; the results of this study show that this type of programming with simple commands had a positive impact on student's motivation.

The results related to CT integration through programming show the potential of teamwork in these processes, which a priori seem to be activities designed to be carried out only individually; in addition, it shows the potential of programming languages of low level of complexity to introduce students to CT related skills, both in computer science and in different areas of the school system. In this sense, the contributions of CT integration through the solution of computational problems with programming languages are synthesized in two fundamental aspects: the first aspect is related to the CT skills that allow developing the command of programming languages, such as abstraction and systemic thinking processes; in this process, the role of pair programming was fundamental to make continuous improvements to the solutions offered by students' teams. The second aspect has to do with the basic elements of programming such as loops, functions, structures, and parameters, whose learning is enhanced through languages with simple commands and contributes to students' motivation while solving the proposed problems.

CT integration through digital games

The creation of digital games through block programming languages was another of the strategies used in many of the experiences reviewed in this study. Scratch was the most used resource for content creation since it enables the easy development of animations, interactive games, and other elements. In particular, the work of Kaminski and Boscarioli (2018) is noteworthy. In their study, primary education students use Scratch to support the educational processes of their peers at earlier levels of schooling; the results of this study showed that this strategy allowed the development of both CT skills and interdisciplinary processes between programming and the disciplines that students taught to their peers. In these processes, there was a high degree of commitment by the students who had the role of creators of educational content. On the other hand, von Wangenheim et al. (2017) also used Scratch to develop digital games with an educational purpose related to history. Their results show that such games help students increase their level of engagement with the discipline of humanities, in addition to increasing the levels of teamwork of students through peer-to-peer game programming.

Relating CT integration in mathematics classes, studies such as those of Barbosa and Maltempi (2019) presented the development of a game in Scratch to reinforce basic concepts of first-degree equations; among the results of this strategy, in addition to the comprehension of mathematical concepts, students acquired abstraction, automation, simulation, and generalization skills, typical of CT. In the experience reported by da Silva et al. (2020), students also developed a game in Scratch, in which it was necessary to apply mathematical concepts, such as the quadratic function, to build the algorithm of movement of the characters in the game. These results show that, while integrating CT through strategies such as the development of digital games, it is possible to find situations in which different disciplinary knowledge makes sense and can be integrated with elements of digital technologies and CT skills.

Digital games as a strategy for CT integration in primary and secondary education were characterized using the block programming language Scratch, which has been widely used internationally for combining ease of use with unlimited programming opportunities. In other words, Scratch is a programming language that is easy to learn, but with a high potential to become more complex as students acquire new skills. Under these conditions, the reviewed studies allow recognizing the development of CT skills such as automation and process simulation. Moreover, some of the studies that used this game creation strategy (e.g., Kaminski and Boscarioli, 2018; von Wangenheim et al., 2019) report that it makes it possible to develop interdisciplinary processes given that the story of such games can be developed in terms of different themes.

CT integration through unplugged activities

Unplugged CT refers to activities that have the potential to foster CT skills without including the use of computers or electronic devices, and although its relevance and importance are reported in the literature (Zapata-Ros, 2019), the results of this review found only one experience in which this strategy is used to integrate CT in middle school education. The study presents the strategy called Splashcode, a board game that aims to support processes of understanding of algorithms (von Wangenheim et al., 2019); its results showed that the game has a positive impact both on the motivation to learn concepts and skills related to CT and on concrete issues, such as the decomposition of problems, the recognition of the concept of algorithm and its use to solve tasks. According to these results, academic and educational communities in Latin America could build new unplugged CT activities that foster the integration of CT in scenarios where there is no stable access to the Internet or electronic devices.

Finally, an important need is identified in the region: the creation of strategies, whether based on the programming of different types -including unplugged-, that allow for the assessment of student learning and the development of their CT skills. This suggests the need to enrich the literature in the region on appropriate assessment strategies for all educational levels to generate resources for both teachers and researchers that make it possible to trace a complete trajectory of students' CT development throughout their academic lives.

Discussion

The international literature identifies multiple reviews that directly contribute to conceptualizations and strategies for the implementation of CT in primary and secondary education. For example, Shute et al. (2017) describe CT as a conceptual basis needed to solve problems effectively and efficiently with solutions that can be reused in different contexts. Similarly, Barr and Stephenson (2011) mention that CT is an approach to problem-solving in a way in which it can be implemented on computers and puts students in the role of resource creators. These conceptualizations have become useful tools for CT integration in computer science classes in places such as the United States or European countries.

There are international studies, especially literature reviews, that have been concerned with the integration of CT across disciplines other than computer science. In this regard, works such as those by Perez (2018) and Weintrop et al. (2016) report specific issues to consider while integrating CT in mathematics and science classes. Meanwhile, Perković et al. (2010) developed a framework for CT across disciplines such as arts and literature. In Latin America, the integration of CT in primary and secondary education is a consolidating topic of broad interest to researchers and teachers; CT conceptualizations and concrete strategies to be integrated into the educational reality of the region, have an increasingly relevant role.

Most of the experiences reported in this review are framed within the areas of computer science or informatics and are mainly part of short-range research or pilot tests for the promotion of the subject. In other words, in most of the experiences reviewed in this study, CT is not yet a formal element included in school curricula. Concerning the predominance of computer science and informatics, these results confirm the review by Shute et al. (2017). However, the still incipient insertion of CT in curricula is a particularity of the region. In contrast, in countries such as the United States and members of the European Union, CT is currently an important part of school curricula (Bocconi et al., 2016).

The above arguments allow to delimit two opportunities for strengthening the subject in the region: first, a broad potential for research on experiences for CT development in disciplines other than computer science is identified to establish possibilities and limits of this subject through different areas of knowledge (Grover & Pea, 2013; Villa-Ochoa & Castrillón-Yepes, 2020). A second opportunity to strengthen CT integration in Latin America is related to the implementation of long-term experiences that offer in-depth analyses of the impact of CT integration in primary and secondary education (Quiroz-Vallejo, 2020); these more in-depth analyses would have the potential to contribute to curriculum designs that formally integrate CT in the region's classrooms (Curasma and Curasma, 2020).

The potential for the development and integration of CT in diverse disciplines generates the challenge of transcending its use as a vehicle to achieve objectives specific to computer science subjects. In this sense, the comprehension of coding is fundamental, as its nature goes beyond writing computer programs to solve specific problems. On the contrary, the activity of coding can be understood as ranging from the process of developing mathematical calculations to the prediction of the consequences that specific actions can have on a system (Coll, 2018). Under this view, in addition to being a methodological resource, CT allows students to develop skills and attitudes derived from computer science but adapted to face problems beyond coding or algorithm construction. Therefore, beyond the analysis of the programs built by students, the analysis of the involved thought process and the management of cognitive and metacognitive tools for program construction becomes relevant (Zapata-Ros, 2018).

In Latin America, the conceptualizations evidenced in CT integration in primary and secondary education are still a subject of discussion and there is no consensus in this regard among the academic community in the region (Souza et al., 2019; Basogain et al., 2016); in particular, gaps in integration are recognized both in computer science/technology subjects and in different disciplines. In the case of computer science/technology, although these disciplines are the ones in which the subject of CT has been most applied and from which it has been deployed to other fields of knowledge, there are criticisms regarding the way problems are reformulated (Cansu and Cansu, 2019). For example, Hemmendinger (2010) argues that reformulation of difficult problems is a typical element of all domains of complex problem solving; philosophy has thought recursively since long ago and mathematics has already integrated elements of abstraction, as do all sciences that use models. These criticisms reveal a need for identity elements proper to the subject matter that provide a clear essence to the CT academic community. In this regard, this review shows that possibly the differentiating factor of CT for primary and secondary education has to do with the simultaneous inclusion of different CT elements and the connection they have with digital technologies and training needs for future labor markets (Tabesh, 2017).

On the other hand, regarding the conceptualization of CT across different disciplines of school curricula, some points favor its integration, such as its possible connections with mathematics in aspects such as modeling, problem-solving, data analysis, and statistics (Sneider et al., 2014). Furthermore, the data and systems thinking practices proposed by Weintrop et al. (2016) share similar aspects with CT integration efforts in mathematics and science classrooms. Within this context, mathematics and computer science were constituted in this review as the two disciplines with the most evidence of interdisciplinary integration. in these fields, students build connections with CT to solve complex problems and learning processes are differentiated (Gao et al., 2020). However, in the experiences that integrated CT in disciplines such as the social sciences or humanities, the tendency was marked towards the use of CT as a vehicle to achieve specific learning in these disciplines, leaving out key elements of computer science with the potential to be integrated.

Following the above discussion, the need to expand research and educational experiences in the region that integrate CT and disciplines such as natural sciences, humanities, and social sciences is recognized, given that the number of documents found was relatively low. in addition, it is also important to identify limitations that arise while developing interdisciplinary connections. These subjects are in line with the problems that the region has historically faced regarding the integration of digital technologies in educational systems, This process, although characterized by the latent concern to close gaps in technological equipment, has encountered problems in the lack of digital literacy of teachers and students, which leads to the instrumental use of technology (Artopoulos and Kozak, 2012) and, consequently, to a low disciplinary integration in computer science and technology classes. Figure 3. summarizes the conceptualizations of CT identified in the review.

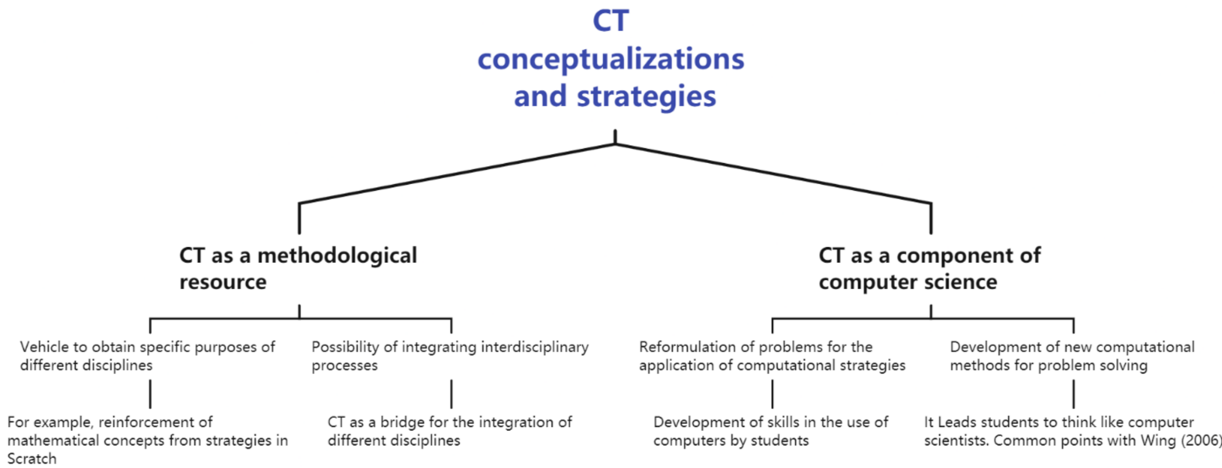

Figure 3. *CT conceptualizations identified in the review*

Authors' elaboration

Some of the mentioned CT conceptualizations are in correspondence with the definitions of CT for mathematics and science classes in primary and secondary education proposed by Weintrop et al. (2016); these authors propose a series of practices related to CT, including the practices of computational problem solving and of systemic thinking. In the frame of CT integration as a methodological resource, such practices are included in the subcategory of CT as a systemic process, given that, in general, their objectives aim to solve problems through the understanding of the relationships between the characteristics of the problem, the possible solutions and the investigation of the problematic situation as a complex system (Souza et al., 2019; Rodrigues et al., 2016). On the other hand, the experiences categorized in CT integration as an object of study are framed in the practice of computational problem solving, since one of its characteristics is the reformulation of problems to be solved with computational strategies and the direct use of programming (Scheneider et al., 2020; Enriquez et al., 2016).

While the reviewed works present commonalities with some of the international trends of CT integration, some frameworks are not considered and present an opportunity for future research. For example, in the case of mathematics, CT can be explored as an element that contributes to tolerate ambiguity, as Perez (2018) puts it in his framework for CT and mathematics. Ambiguity contributes to students learning in mathematics classes, since it gives them the possibility to clarify by their means what they know and what they ignore, considering multiple approaches to situations and improving their collaborative work skills. In the case of natural sciences, the way

CT can affect students' understanding and experimentation, presents an opportunity for future research (Denning, 2017). On the other hand, it is necessary to identify approaches for CT integration in disciplines other than computer science, natural sciences, and mathematics, given that very few studies integrate CT in these areas in the region.

In the results of this review, regarding the strategies used for CT integration, it was found that educational robotics is the most used strategy in the analyzed experiences. The use of strategies related to robotics has been reported as having broad potential, given that they enable students to have tangible experiences (Shute et al., 2017); accordingly, the main argument why robotics was integrated into the reviewed experiences is the possibility of immediate interaction between software and hardware. These findings contrast with international reviews such as that of Hsu et al. (2017), in which these types of strategies were only used in few cases. Thus, although educational robotics is consolidating in Latin America as a strategy worth considering, due to its potential for CT integration in primary and secondary education, it is also necessary to recognize the limitations of resources and infrastructure in the region, which could limit the integration of CT under this modality.

On the other hand, the use of different programming languages, both for the solution of problems in different disciplines, as well as for the solution of computational problems and the creation of digital games, continues to consolidate as one of the most used strategies for CT integration at all educational levels. In this sense, it is observed that the need for training in programming is a fundamental issue for integrating CT in primary and secondary education. These results are consistent with Villa-Ochoa and Castrillón- Yepes (2020), who found the same trend in higher education. In addition, the use of block programming languages is the most frequent; especially Scratch, which is more used than other similar software because it is a versatile resource that enables the development of different types of programs such as games, *storytelling,* among others. Moreover, Scratch has been a subject of study both theoretically (Brennan and Resnick, 2012) and empirically (Zhang and Nouri, 2019), so its use for CT integration has been widely validated in the academic community.

It is important to highlight that the use of unplugged CT integration strategies was conspicuous by its absence in the review. Only one study, developed by von Wangenheim et al. (2019), developed a strategy in this category. In this sense, an opportunity is identified to expand on research that reports different resources for CT integration without the use of electronic devices, a need that is heightened when considering that in Latin America there are still regions that do not have access to either computer or the Internet constantly. Finally, there is a need in the region to generate different resources that make it possible to assess both computer-based learning on the part of students, as well as learning fostered by the CT in other disciplines. This need is confirmed by Tang et al. (2020), who report the importance of constructing assessment strategies that are aligned with different existing CT conceptualizations.

Conclusions

The objective of this review was to analyze CT integration in primary and secondary education in Latin America. For this purpose, two categories were considered: conceptualizations of CT and strategies for its integration. The results of this study contribute to the discussions on CT in education by identifying strategies that explore the integration of CT in relatively short periods. In this sense, there is a latent need to expand research of longer duration that makes it possible to generate in-depth analyses of the contributions and challenges of integrating CT into school curricula in the long term, both in computer science and informatics and through other areas of the curricula.

Discussions regarding CT conceptualizations for primary and secondary education should be broadened in the region. Although it is currently evident that the regional research trends are in line with some important international research, it is necessary to broaden the perspectives of the subject in the region by considering specific regional problems such as Internet access and digital technology infrastructure. In this regard, although different strategies for CT integration through electronic devices have been explored, unplugged CT was only found in one of the studies reviewed. It is necessary to explore this modality of CT in the region because it makes it possible to expand coverage for curricula integration in regions where there is still no stable Internet connectivity or adequate access to devices such as cell phones and computers. Finally, for future CT research, it should be more deeply analyzed the implications of CT integration as a methodological resource in different disciplines and the implications of its long-term use.

Acknowledgments

The authors like to express thanks to Siemens Stiftung and Siemens Caring Hands for funding the project "Fostering STEM education through computational thinking", which is part of the initiative STEM Education for Innovation in Latin America.

Received: June 29, 2021
Accepted: May 30, 2021
Published: November 30, 2021

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Funding

This research was funded by Siemens Stiftung and Siemens Carinhands in the framework of the STEM Education for Innovation in Latin America initiative.

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