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Computational Thinking, Plug and Unplug Theory: A Review of the Literature

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Abstract: The purpose of this study was to ensure that computational thinking (CT) is viewed as a critical skill necessary to adapt to the future. However, educators, especially teachers and researchers, have not made it clear how it should be taught. In this study, we conducted a meta-review of studies published in academic journals from 2018 to 2023 and divided them into application courses, adopted learning strategies, participants, teaching tools, programming, impact, creativity and course categories for CT education. The review results depicting that the promotion of CT in education has made great strides over the past decade. In addition to the increasing number of CT courses in each country, the subjects, research topics and materials have also become more diverse in recent years. It was also noted that CT applies primarily to program design and computer science activities, with some research being related to other subjects. On the other hand, most studies employ project-based learning, problem-based learning, collaborative learning, and game-based learning for CT activities. This means that activities such as aesthetic experiences, design-based learning, and storytelling are employed relatively infrequently. In addition, students' cognitive abilities vary by age, so CT skill development methods and content standards should vary accordingly. Furthermore, most studies reported on CT performance and prospects of learners, but little training of learners' information social skills. Research trends and potential research topics in CT are therefore suggested as a reference for researchers, educators, and policy makers.

Keywords: Computational thinking, Plug and unplug theory, Technology

Introduction

The concept of Computational thinking (CT) was initially introduced by Paper (1990), and since then, it has been a topic of discussion among several scholars regarding its definition, education, and assessment (Grover & Pea, 2013). CT as a learning approach is still very much a trend at the moment, in this article we will look at a systematic literature review on taxonomy, the use of subject divisions, levels and tools, assessment and learning strategies. According to Wing (2006), CT is not just a programming skill limited to computer scientists, but an everyday skill necessary for everyone. Wing (2010) also defined operational thinking as the problem-solving process, enabling successful execution of message processing agents and resolution of problems. Computers can assist us in problem-solving through two key steps: firstly, analyzing the steps required to solve the problem, and then utilizing technical expertise to operate the computer for problem-solving. For instance, one must have a

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grasp of mathematical formulas and explain the problem, and then apply basic methods or formulas to solve the problem using computer computation. Similarly, when designing animations, the animator must first plan the storyline and shooting techniques before creating the computer animation using software and hardware. These two examples illustrate that computational thinking (CT) is the thought process that individuals must engage in before operating computers and machines.

As an illustration, the United States has established curriculum frameworks to promote computational thinking abilities in K-12 education and instill a favorable disposition towards computer science among young students (Santos et al., 2018). In this regard, Code Hour, Code Week, and Scratch Day are some of the initiatives that foster the development of computational thinking and promote its integration in the curriculum (Eguíluz, Garaizar & Guenaga, 2018; Hava & Koyunlu Unlu, 2021). It means that CT has used by many countries for their curriculum.

Literature Review

Computational Thinking

Computational thinking is a skill that has become essential in our daily lives, and it is no longer limited to computer engineers. It is important for everyone to have a positive attitude towards, comprehend, and apply this skill in their routine (Wing, 2006). The capabilities and constraints of CT are based on computational processing, whether it is the human mind or computers that are utilized to process the problem. In addition to the 3Rs (reading, writing, and arithmetic), children in their early learning phase should be educated on how to implement CT and perform logical analysis (Wing, 2006). CT comprises four operational skills, namely simplification, integration, transformation, and simulation. To make a problem easier to understand, CT applies fundamental computer science concepts to resolve issues, design systems, and transform them into a thinking mode that humans can comprehend (Wing, 2006).

CT encompasses the processes and techniques used to operate a system and focuses on how individuals use computers to solve problems (Wing, 2008). CT is not concerned with computer hardware or imitating the computer's thinking mode. Furthermore, Wing (2008) argues that CT is not only crucial for problem-solving, but also for identifying and developing problems. CT is not solely dependent on machines, as individuals can use machines to produce CT processes (Wing, 2008). Therefore, Wing (2008) suggests that CT is no longer limited to learners in computer science but is also essential for learners in other domains. Educators must create and promote facilities for learning computational thinking. Computational thinking is acknowledged as a skill that students must acquire in the twenty-first century to comprehend the information technology-dominated world and actively participate in it (Wu et al., 2019; Zhang & Nouri, 2019).

Taxonomies of CT

According to Wing (2006), CT can be classified into 11 thinking processes, including abstraction, algorithm design, decomposition, pattern recognition, and data representation. We also added the other steps of computational thinking that we found in the past studies, as shown in Table 1.

Application Any Subject Area

CT can be integrated with a variety of disciplines, yet some instructors still rely on programming languages to impart its principles (Lye & Koh, 2014; Zhong et al., 2016). While many educators contend that programming languages are the most straightforward and fitting approach to teaching CT, this narrow view may limit the potential of logical thinking to a select few subjects and learners (Wing, 2006, 2008). In truth, CT has been extensively employed in diverse fields, such as mathematics (Benakli et al.,, 2017; Snodgrass et al., 2016; de Freitas, 2016), biology (Dodig-Crnkovic, 2011; Libeskind-Hadas & Bush, 2013; Navlakha & Bar-Joseph, 2011; Rubinstein & Chor, 2014), computer science (Repenning, 2012; Shell & Soh, 2013; Repenning et al., 2015; Grover et al., 2015), language (Evia, Sharp, & Pérez-Quiñones, 2015), and programming (Bers et al., 2014; Kazimoglu et al., 2012, p. 316; Wolz et al., 2011).

Computational thinking it’s just a not for computer using only, but many subject matter, CT helping for hot to learn and teach some subject areas. Numerous contemporary scientific predicaments necessitate the cooperation of experts from diverse scientific domains. Novel scientific disciplines, such as biostatistics, physical chemistry, and theoretical physics, have even emerged. Nevertheless, the educational curriculum segregates subjects in distinct categories. In Slovakia, science subjects are also partitioned into physics, chemistry, and biology. Both mathematics and science education aspire to facilitate students in comprehending the marvels of the surrounding world. They utilize comparable approaches to problem-solving and scientific investigation, which encompass logical reasoning, hypothesis formulation, observation, analysis, and experimentation. Even tertiary-level students lack experience in resolving practical issues, and consequently, they struggle to interpret the findings they acquire (Bobo ˇnová, 2019).

Table 1. Computational thinking steps

Num	Thinking steps	Definition	Resource
1	Abstraction	Identifying and extracting relevant information to define main ideas.	(Barr & Stephenson, 2011; Grover & Pea, 2013; Wing, 2006)
2	Algorithm	Design Creating an ordered series of instructions for solving similar problems or for performing a task	(Barr & Stephenson, 2011; Grover & Pea, 2013)
3	Automation	Having computers or machines do repetitive tasks.	(Fletcher & Lu, 2009; Forrest & Mitchell, 2016; Kafai & Burke, 2013)
4	Data Analysis	Making sense of data by finding patterns or developing insights.	(Angeli et al., 2016; Atmatzidou & Demetriadis, 2016; Basu et al., 2017; Cesar et al., 2017; Choi et al.,2016; Magana & Silva Coutinho, 2017)
5	Data Collection	Gathering information	(Barr & Stephens, 2011; CSTA, 2011)
6	Data Representation	Depicting and organizing data in appropriate graphs, charts, words, or images.	(Benakli et al., 2017; Gynnild, 2014; Manson & Olsen, 2010; Stefan, Gutlerner et al., 2015; Weintrop et al., 2016)
7	Decomposition	Breaking down data, processes, or problems into smaller, manageable parts.	(Kilpeläinen, 2010)
8	Parallelization	Simultaneous processing of smaller tasks from a larger task to more efficiently reach a common goal.	(Barr & Stephenson, 2011)
9	Pattern Generalization	Creating models, rules, principles, or theories of observed patterns to test predicted outcomes.	(ISTE & CSTA, 2011)
10	Pattern Recognition	Observing patterns, trends, and regularities in data	
11	Simulation	Developing a model to imitate real-world processes.	(Barr & Stephenson, 2011; Grover & Pea, 2013; Wing, 2006)
12	Transformation	Conversion of collection information.	(Wing, 2006)
13	Conditional logic	Finding the associated pattern between different events.	(Grover & Pea, 2013)
14	Connection to other fields	Finding the relationships between information.	(CSTA, 2011)
15	Visualization	Visual content is easier to understand	
16	Debug & error detection	. Find your own mistakes and fix them	(Atmatzidou & Demetriadis, 2016; Berland & Lee, 2012; Yadav et al.,, 2014)
17	Efficiency & performance	Analyze the efficiency of the final results in order to achieve a more perfect goal.	(Grover & Pea, 2013)
18	Modeling	Solve the current problems through the model architecture or develop a new system.	(Barr & Stephenson, 2011; ISTE & CSTA, 2011)
19	Problem solving	The final step of logical thinking	(Kim & Kim, 2016; Ngan & Law, 2015)

In other hand acquiring mathematical proficiency alone is no longer sufficient in the 21st century. Critical thinking, creativity, and technology literacy are also essential skills. One of the recommended teaching methods for active learning in mathematics is collaborative problem solving. Studies have shown that this approach yields better results in standardized mathematics tests compared to traditional transmissive methods, especially when the problems are related to real-life situations faced by students and involve the use of technology. Collaborative problem solving also enhances students' appreciation for mathematics and science, which can positively impact their academic performance and career choices in the future.

Moreover, it is anticipated that computing will comprise half of the STEAM-related occupations in the coming years. Although children and adolescents frequently use smartphones and tablets, they are primarily used for amusement rather than educational purposes. Conversely, mathematicians regard the efficient utilization of technological resources as a "valuable aspect of the mathematics practice. Similarly, scientists share this perspective. As a result, there has been significant growth and experimentation in the creation of resources designed to cultivate computational thinking (L’ubomíra Valoviˇcová et al., 2020).

However, not all approaches are appropriate for problem-centered learning. Utilized opaque objects as the central concept for tasks that promote computational thinking, which generated a strong response (Cápay & Magdin 2011; L’ubomíra Valoviˇcová et al., 2020). Created an exercise that allowed students to learn about the physical principles of an ultrasonic sensor, linking knowledge from physics and computer science (Burbaite et al., 2018). This enabled students to acquire conceptual knowledge in physics while designing algorithms. Another instance of an interdisciplinary approach is found in Lytle et al.'s 2019. work, which focused on an agent-based simulation with an emphasis on students' perceived ownership of their created programs. Students who utilized the use-modify-create approach felt more confident and considered the code they developed during the guided portion, with minor adjustments, to be more familiar than the transmissive approach used by the control group.

Several studies have indicated that a design-based approach can enhance students' computational thinking and self-efficacy in using computers while also increasing their awareness of the various tasks that can be accomplished with a computer. Relationship between students’ computational thinking skills and (creativity, algorithmic thinking, cooperative thinking, and critical thinking) and their STEM career interest Hava & Koyunlu -Unlu, 2021). So that many learning strategies can be based with CT to teach the concept of measuring connects mathematics and physics, and the problem-based orientation of the analyzed activity supported the interdisciplinary learning of participating students.

Learning and Teaching Strategies

As per the literature review on CT, it is evident that the advancement of operational thinking is not limited to computer programming but can also be implemented in mathematics and biology to enhance students' logical concepts, CT, and problem-solving abilities.

Table 2. Categories of the 16 learning strategies in the CT learning activities adopted in this study.

Num	Strategy	Explanation
1	problem-based learning	The definition of problem-based learning is helping students toset their own learning goals through a problem scene. Students will explore the learning solution by themselves, and report their own learning conclusions and feedback to the team. Problem-based learning is not only used to solve problems, but also to enhance students' understanding of new knowledge through appropriate questions (Wood, 2003)
2	collaborative learning (teamwork)	Group learning is divided into: collaborative learning and cooperative learning. In cooperative learning, partners splitthe work,solve subtasksindividually, andthenassemble the partialresults into the final output. Incollaborative learning, group members are required to complete the task together, negotiate, and share meanings relevant to the problem-solving task (Dillenbourg, 1999; Roschelle & Teasley, 1995).
3	project-based learning	Project-based learning (PBL) is a model that organizes learning around projects. Projects are complex tasks, based on challenging questions or problems, that involve students in design, problem-solving, decision making, or investigative activities; PBL gives students the opportunity to work relatively autonomously over extended periods of time, and culminates in realistic products or presentations (Jones et al., 1997)
4	game-based learning	Game Based Learning (GBL) is similar to Problem Based Learning (PBL), wherein specific problem scenarios are placed within a play

		framework (Barrows & Tamblyn, 1980). GBL can provide a Student-Centered e-Learning (SCeL) approach (Motschnig-Pitrik & Holzinger, 2002). Moreover, games include many characteristics of problem solving, e.g. an unknown outcome, multiple paths to a goal, construction of a problem context, collaboration in the case of multiple players, and they add the elements of competition and chance
5	scaffolding	Scaffolding provides the framework of learning to help the students learn the new knowledge at the beginning. The purpose of scaffolding is to train the students to solve problems independently.
6	problem solving system	To find the solution to problems through logical or special methods, and to understand the goals of the problem and apply the appropriate abilities and methods to solve the problem
7	storytelling	Pesola (1991, p.340) suggested that storytelling is "one of the most powerful tools for surrounding the young learner with language.'' According to Isbell (2002), many stories that work well with children include repetitive phrases, unique words, and enticing descriptions. These characteristics encourage students to join in actively to repeat, chant, sing, or even retell the story. Much of the language children learn reflects the language and behavior of the adult models they interact with and listen to (Strickland & Morrow, 1989). ''Listening to stories draws attention to the sounds of language and helps children develop a sensitivity to the way language works'' (Isbell, 2002, p. 27).
8	systematic computational strategies	Systematic computational learning theory provides a formal framework in which to precisely formulate and address questions regarding the performance of different learning algorithms so that careful comparisons of both the predictive power and the computational efficiency of alternative learning algorithms can be made.
9	aesthetic experience	Aesthetic experience provides the means through which meanings that are ineffable, but full of feeling, can be expressed and understood, helping us to tolerate ambiguity, to discern subtle relationships, and to focus on details (Kokkos, 2010).
10	concept-based learning	Concepts are a way to organize and make sense of learning. The students try to define the attributive differences among different concepts. Other researchers have made use of concept-based models or graphic organizers. The model described here relies heavily on including attributes that can be generalized to multiple instances. The other concept depends on the definition of the concept of exclusion featuring a collection of example facts (Boudah et al., 2000; Erickson, 1998; Kameenui & Carnine, 1998).
11	HCI teaching	Human-Computer Interaction teaching (HCI teaching) is suitable for all grades of college students to learn natural science, and is also a common online teaching method (McCoy & Ketterlin-Geller, 2004).
12	design-based learning	Design-based learning is integrated design thinking and processes in the curriculum, which can be applied to many subjects. It asks students to set up their own goals and to create ideas to achieve them
13	embodied learning	Theories of embodied cognition argue that mental modal simulations in the brain, body, environment and situated actions are composed of central representations in cognition. Based on embodied cognition, body movements of performing natural science experiments can provide learners with external perceptions for better knowledge construction.
14	teacher-centered lecture	Students put all the focus on the teacher, and concentrate on lectures without collaborative learning activities. Students will not miss the key points through the teacher guiding all of the activities.
15	Critical computational literacy	A concept of "computational literacy" helps us better understand the social, technical, and cultural dynamics of programming. Critical computational literacy emphasizes how to use the computational method, and what can be done.
16	Universal Design for Learning	The basis of Universal Design for Learning (UDL) is grounded in emerging insights about brain development, learning, and digital media (Hitchcock, Meyer, Rose, & Jackson, 2002). It arouses the learners' interest through multiple methods of communication and expression.

In addition, strategies for learning or teaching not only in the school, but also it can be applying in higher education too. Depends or they want to use it or need analyzing firstly. So this study making some suggestion for using CT for teaching and learning based on Figure 1 below:

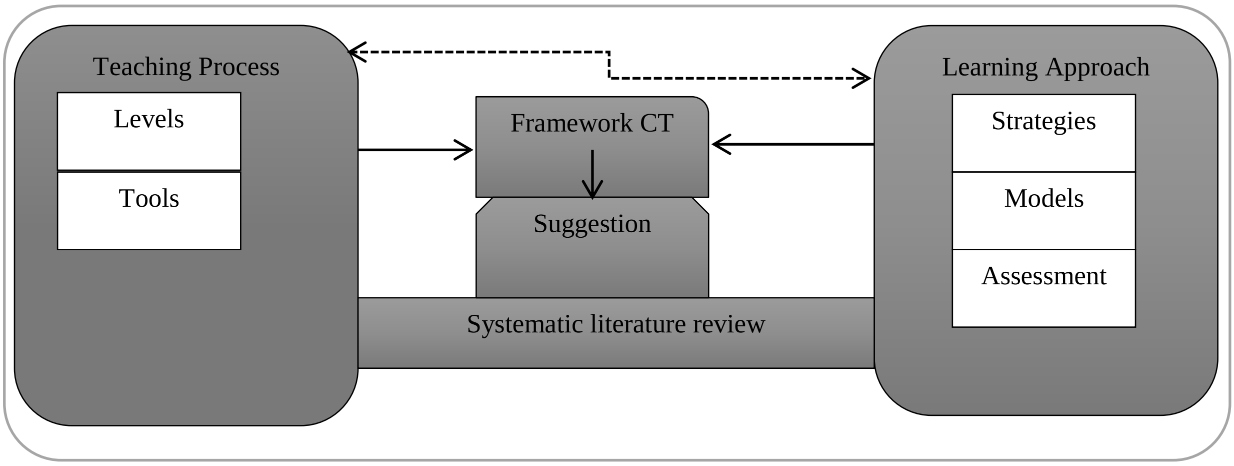

Figure 1. Conceptual framework of CT teaching and learning

The objective of this investigation is to create a basic structure for introspective reasoning and application in the realm of scientific education by recognizing the instructional and evaluative techniques that aid in revolutionary learning worldwide. The inquiries for research are categorized into two sections as stated below:

RQ 1: What is the dispersion of research based on the qualities of the material?
RQ 2: What are the prevalent themes and methods employed in literature to encourage computational thinking's application in science education for suggestions?

Method

The SCOPUS, SCI and SSCI database was utilized as the primary source for this research. Initially, we conducted a search using the term "computational thinking" to retrieve relevant papers, abstracts, and keywords. In the subsequent step, we narrowed down our search period to include articles published from January 1, 2006 for basics and 2018-2023 for primary resources. Upon establishing the time frame for publication, the search yielded a total of 1112 CT-related articles within the specified dates.

Subsequently, we narrowed down the article type to published academic journal papers, academic journal papers (in press), and books, resulting in a total of 262 journal papers or books. To further refine our analysis, we eliminated non-SCI and non-SSCI journal articles, leaving us with 120 articles for further examination. To ensure accuracy, two seasoned researchers scrutinized and classified the papers using our coding scheme. In cases where there were conflicting codes, the researchers were required to deliberate and reach a consensus. Then finally 52 selected articles for this systematic literature review for suggestions.

Data Distribution

Figure 1. depict the publishing scenario of CT papers from January 2006 until 2023. The earliest manuscript, authored by Wing (2006), elucidated the meaning of computational thinking to aid readers in comprehending CT. The quantity of CT articles escalated steadily from 2006 to 2023, with the original solitary paper expanding to 21 in 2018 and 44 in 2023. As shown in Figure 1, a total of 52 papers were published throughout the aforementioned period. This outcome is logical since CT is a novel benchmark for educators to formulate learning activities. Initially, academics defined CT and endeavored to promote it until it gradually progressed to implementation in the classroom. Furthermore, they shared concerns regarding integrating CT into courses and presented solutions for future research to design courses and activities. In addition, the number of CT papers doubled from 2018, indicating that it has gradually captured the attention of scholars and educators, and is a new topic that cannot be ignored in the future.

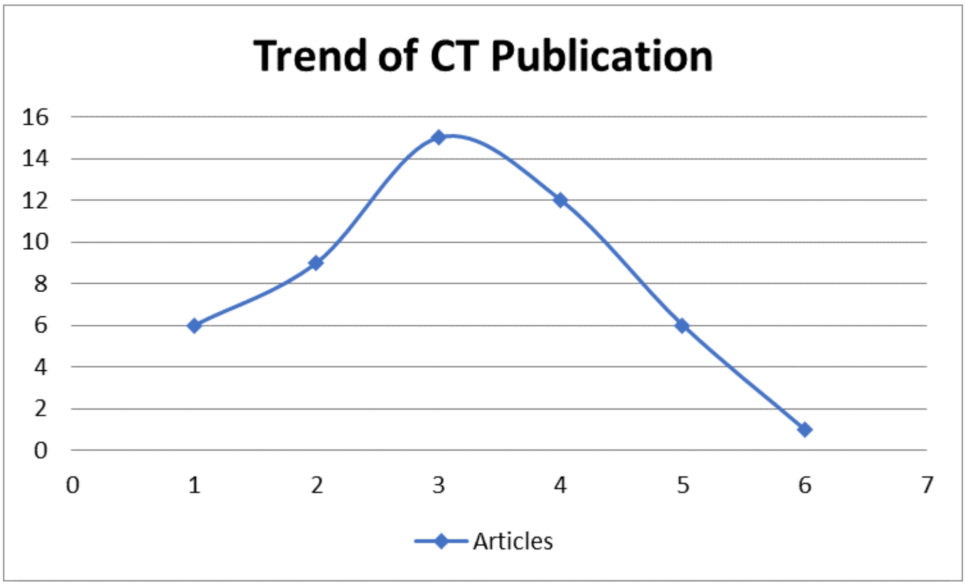

Figure2. Trend of CT publication

Coding Systems

The coding system was altered from the one created by Hwang and Wu (2014) and Hsu et al. (2018,) which consisted of variables such as nationality, writer, periodical, training program, educational approach, and participants (Hwang & Tsai, 2011; Hwang & Wu, 2014; Hsu et al, 2018). Furthermore, we compiled pertinent educational material information, which included teaching resources, programming dialects, and course classifications (formal or informal). The ensuing sections elaborate on the coding system for each aspect.

Identity

The fundamental details regarding the released documents are deliberated, encompassing writers, origin, participant and periodicals. The aim is to comprehend which nations have published CT studies with greater frequency. The data compilation project also comprised of publications and evaluations of literature.

Application Used

The CT field contains programming, information engineering, computer application software, mathematics, biology, medicine, society, business management, language, music, computer science, journalism, robotics, science and technology, epidemiology, physics, STEM, social ecosystems, and algorithms.

Learning Strategy

The category of 16 learning strategies was composed based on the previous studies in each country, and counted in project-based learning, problem-based learning, teacher-centered lectures, collaborative learning, game-based learning, aesthetic experience, concept-based learning, systematic computational strategies, scaffolding, problem-solving systems, storytelling, embodied learning, universal design for learning, HCI teaching, design-based learning, and critical computational literacy.

Teaching Tools that are often Used in CT Courses

The teaching tools that are repeatedly used in CT courses embrace programming software, games, mobile games, board games, experiments, Arduino, robots, Game Maker, video, IRS (Clickers) and e-books; however, in order to coordinate with the course, and considering suitability for different ages, the programming language categories include LoGo, LEGO, ViMap (based on Logo), MATLAB, ALICE, TurtleArt (similar to Scratch),

Scratch, Scratch4SL (Scratch for Second Life), Code.org (similar to Scratch), AgentCubes (making 2D/3Dgames), Scalable Game Design, Java, C, and C++. Apart from the plug model, CT learning can be done in an unplugged way, taking into account the concept of computation.

Results and Discussion

Research Question 1: What is the dispersion of research based on the qualities of the material?

Identity of Articles

In this investigation, we solely recorded the origin details of the leading author in the CT document. Furthermore, the meta-evaluation approach employed was based on the principles of a systematic review, as proposed by Wang et al. (2017) and Hsu et al. (2018). Based on the findings of the present meta-evaluation, various nations have initiated the development of CT instructional design. The distribution status of the leading five countries is visible in Figure 2. As a result of the study's selection pool, the top four are the United States, Turkey, Spain, and the United Kingdom. Additionally, this meta-evaluation examined the organizations that published more than two CT research papers, including the country and indexing depict of figure 3 and table 3 below:

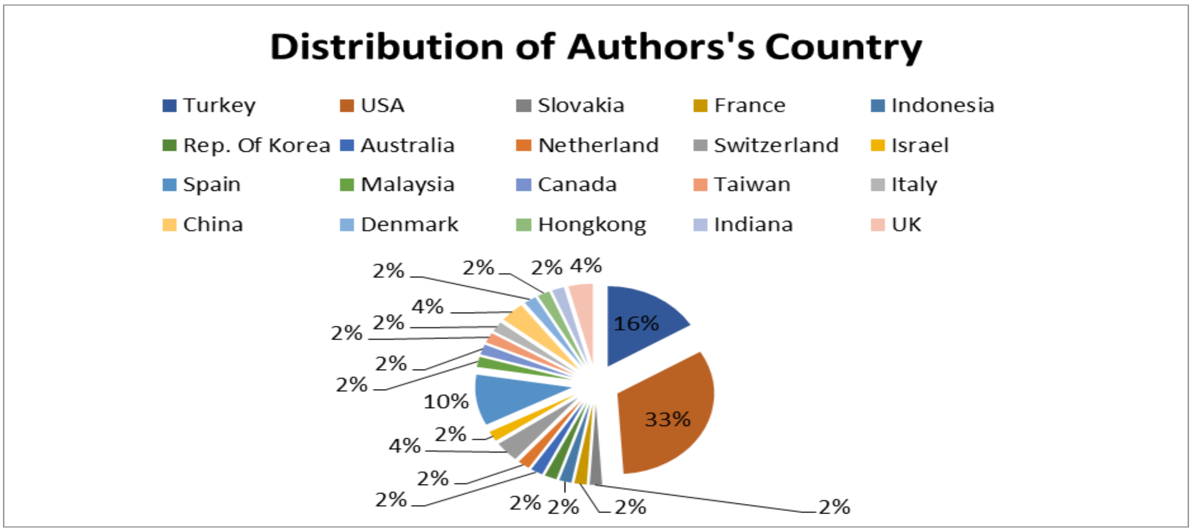

Figure3 . Distribution of Authors's Country

Furthermore, a SLR is carried out to evaluate the input of each nation. Figure 4 illustrates the allotment of writers of articles by nation. Turkey and United States of America (USA) are at the top of the list of publications in CT topics. Spain is in the third position with 5 writers, followed by UK with 2 writers. Moreover, China and Switzerland each have 2 writers.

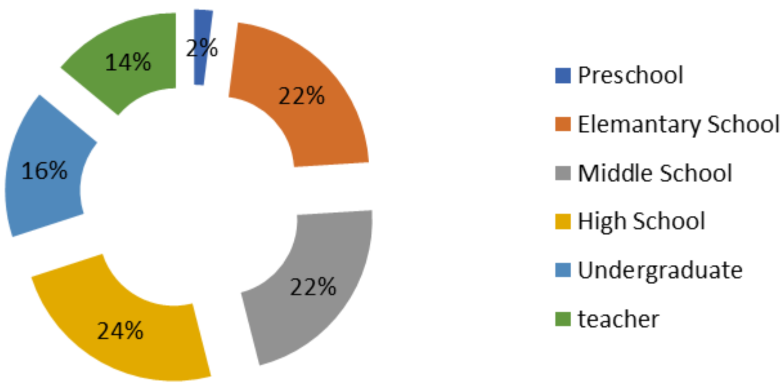

Figure 4. Levels of participants

Table 3. Journal metrics and ındexing ınformation

No	Journal	F	%	Indexed by (H Index/SJR 2023)	WoS (H Index/JIF for SSCI or JCI for ESCI 2021)
1	Journal of Science Education and Technology	18	36,735	Scopus (Q1/1.15)	WoS (SSCI/1.47)
2	Mathematics MDPI	1	2,041	Scopus (Q2/0.54)	WoS (SCIE/2.15)
3	Computers and Education	5	10,204	Scopus (Q1/3.68)	WoS (SSCI/3.75)
4	Heliyon	3	6,122	Scopus (Q1/0.61)	WoS (SCIE/0.72)
5	Information Discovery and Delivery	1	2,041	Scopus (Q2/0.54)	WoS (ESCI/0.52)
6	Journal of Educatioanal Computing Research	1	2,041	Scopus (Q1/1.67)	WoS (SSCI/2.20)
7	Journal of Educational and Technology System	1	2,041	ERIC	
8	Frontiers in Education	1	2,041	Scopus (Q2/0.66)	WoS (ESCI/0.89)
9	Journal of Digital Learning and Teacher Education	1	2,041	Scopus (Q1/0.87)	
10	Technology, Knowledge and Learning	2	4,082	Scopus (Q1/1.11)	WoS (ESCI/1.93)
11	TechTrends	1	2,041	Scopus (Q1/0.8)	WoS (ESCI/1.18)
12	International Journal of STEM Education	1	2,041	Scopus (Q1/1.67)	WoS (SCIE/2.46)
13	International Journal of Child-Computer Interaction	2	4,082	Scopus (Q1/1.07)	
14	Education and Information Technologies	3	6,122	Scopus (Q1/1.25)	WoS (SSCI/1.90)
15	Asia-Pacific Edu Res	1	2,041	Scopus (Q1/0.99)	WoS (SSCI/1.25)
16	Interactive Learning Environments	1	2,041	Scopus (Q1/1.17)	WoS (SSCI/1.93)
17	Comput Appl Eng Educ.	1	2,041	Scopus (Q1/0.65)	WoS (SCIE/0.64)
18	Education Tech Research Dev	2	4,082	Scopus (Q1/1.52)	WoS (SSCI/2.83)
19	Science and Education	1	2,041	Scopus (Q1/01.31)	WoS (SSCI/1.77)
20	Instructional science	2	4,082	Scopus (Q1/0.93)	WoS (ESCI/1.05)
Total		49	100		

RQ 2: What are the prevalent themes and methods employed in literature to encourage computational thinking's application in science education for suggestions?

Application Used

Afterwards, we examined the areas where CT was utilized. As depicted in Fig. 5, the highest percentage of papers, totaling 31, implemented CT in programming subjects. This was followed by 26 papers in the field of computer science, 11 in mathematics, and 9 in biology. Additionally, there were 28 papers pertaining to preliminary single-case design or recommendations for instructional design utilizing CT, which did not belong to a specific subject category and were thus excluded from this section of data classification. Furthermore, there were 30 papers that employed more than two subjects in their study. Therefore, it can be concluded that CT was predominantly used in programming design and computer science courses, but some scholars also integrated it into diverse subjects like biology, mathematics, language, and music. These findings demonstrate that CT is not only crucial for computer-related subjects, but also for enhancing computing skills in mathematics and fostering problem-solving abilities in any subject material. the used of CT can be integrated or combined with various learning strategies, this is done as an effort to improve. Various learning strategies can be seen in the table below:

Table4. Strategie and learning models used.

Strategies and learning models	
C2STEM	Digital Story Telling
CCPS	Evaluation and developing
Coding Apps	Inquiry
Comparasion	Integrating
Computational physics Course	Intructional intervention
computer simulation	Modeling
Contructing Models	NGSS
correlation	Problem Solving
CPS	programming app
CT	SRA
CT Course	STEAM
Ct engineering	STEM
CT test	STEM and ACTMA evaluation
CT with reflective	STEM and CTIEs
CTAE	STEM and SEM
Design based learnig	Validating and reability

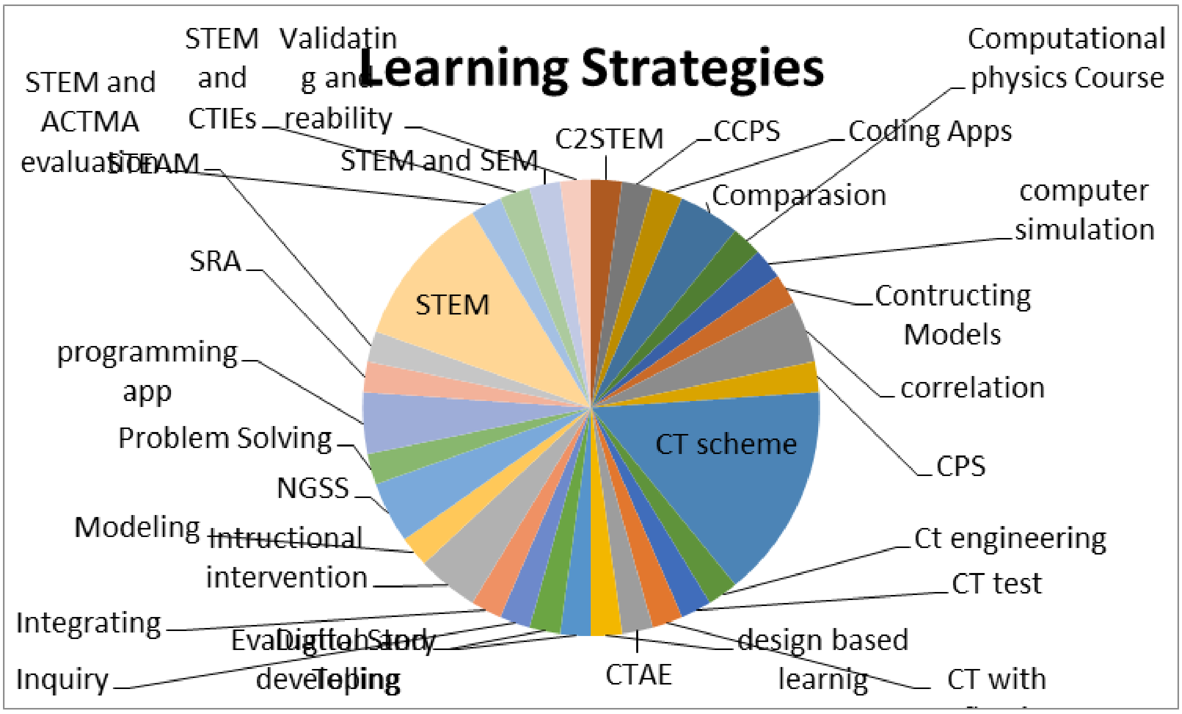

Figure 5. Learning strategies

CT can be used as a result variable by influencing the dependent variable, both of which can meet the needs of educators, with CT indicators that are adjusted to needs, some articles only use at least two variables, depicting or table . below:

Table5. Variable

Variable	
As dependent	44.90%
As Independent	55.10%

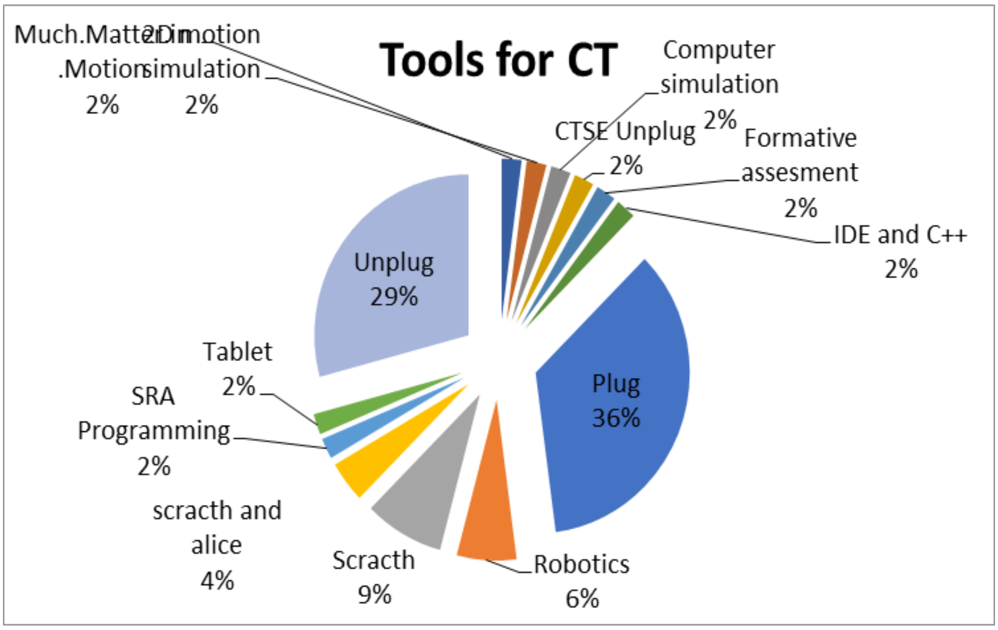

Figure 6. Tools for CT

Conclusion

This research involved a review and analysis of CT articles published in academic journals between 2006 and 2023. The data was classified and discussed, and it was discovered that the number of CT articles has significantly increased in recent years. Scholars from various countries, such as Balanskat & Engelhardt (2014), Falkner et al. (2014), Sysło & Kwiatkowska (2015), Heintz et al. (2016), and Hsu et al. (2018), have provided positive feedback on CT, emphasizing its importance in achieving future educational goals. Statistical analysis revealed that CT activities were mainly incorporated into program design, computer science, biology, and robot design courses. Thus far, numerous CT activities have been integrated into various subjects in a way that aligns with the CT concepts proposed by Wing (2006). According to Wing, CT is a skill that can be applied in everyday life, rather than being exclusively used by computer engineers. It is a skill that deserves a positive attitude in daily life and should be known and engaged in. Therefore, CT is a subject that requires in-depth research in the future, and its impact on children's academic performance is also worth discussing.

The discussion also touched upon the utilization of CT and learning techniques. Studies have primarily focused on Project-based Learning, Problem-based Learning, Cooperative Learning, and Game-based Learning. Over the past decade, numerous scholars have acknowledged the advantages of CT in enhancing children's learning. Therefore, further research should explore diverse learning methods such as Scaffolding Learning Strategy, Storytelling Learning, and Aesthetic Experience to facilitate learners in various aspects, such as subject development and advanced skills training, including critical thinking and problem-solving abilities. And also how the CT as a dependent and independent variable depict the same value of research in importing things.

a. Educate teaching staff on CT. To ensure a comprehensive introduction and development of CT courses, primary teaching staff must receive comprehensive training and establish accurate concepts to effectively carry out and enhance their CT teaching.

b. Evaluate students' learning progress effectively. As different learning strategies and subjects are applied at different ages, formal and informal courses require distinct scoring guidelines. Such evaluations can assist in future teaching activity design and modification of teaching strategies.

c. Be aware of students' learning status. Teachers must consider students' learning status to guide them through CT training courses, as well as provide appropriate assistance or feedback for different students.

The objective of this investigation is to assess and scrutinize the advancements and transformations in CT research pertaining to its application in teaching and learning, during the period of 2018 to 2023. The virtual and tangible worlds are increasingly converging due to the rapid development of technological skills and computerized information. This digitalization and computation of computers have become fundamental aspects of contemporary society. To enable students to comprehend and integrate into the information society, it is imperative to not only foster their creativity and enhance their digital literacy, but also augment their CT competency, acquire knowledge of recent technological skills, and utilize them optimally to adapt to the fast-paced changes in the information society. Consequently, it is crucial to investigate the means of designing CT teaching and research, and integrating suitable learning tactics with the subjects at hand. Furthermore, from this research SLR, STEM is the most of learning and teaching strategies and formative assessment for CT.

Recommendations

As cognitive abilities vary among students of different ages, CT ability cultivation methods, content criteria, and learning strategies should vary accordingly. CT training courses should be designed for different age groups using appropriate strategies. Utilize cross-domain teaching methods to enable students to manage and analyze materials from various domains through computing. This will deepen their understanding of cross-domain knowledge, allow them to experience the roles played by cross-domain knowledge and computing in solving complex real-world problems, and foster their interest in science, technology, engineering, and mathematics. CT is still widely applied in schools; therefore, it is recommended to be applied at the university levels, apart from that, the problems used must be more complex and have rich context problems. Using plug and unplug theory separating and should be used simultaneously and will be a force for maximum results

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM Journal belongs to the authors.

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