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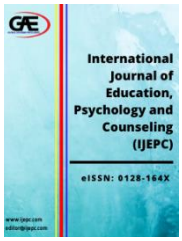

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THEORY ON COMPUTATIONAL THINKING IN EDUCATION: A SYSTEMATIC REVIEW

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Abstract:

Computational Thinking (CT) has become integral to modern education, fostering problem-solving skills essential for navigating a technology-driven world. This Systematic Literature Review (SLR) explores the theoretical landscape underpinning the integration of CT in education. Despite the growing prominence of CT in education, a systematic understanding of the underlying theories remains elusive. This SLR aims to fill this gap by conducting a rigorous analysis of existing literature, discerning patterns and trends in the theoretical frameworks shaping the incorporation of CT into educational contexts. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology guides this review. Advanced searching techniques are employed to enhance the precision and inclusiveness of the literature search. The search is executed across Scopus and Web of Science (WoS) databases, ensuring a comprehensive exploration of the available literature. The findings reveal a rich landscape of theoretical perspectives on CT in education. Expert validation emerges as a crucial aspect, and our analysis categorizes it into two prominent key themes: (1) Learning theory on CT and (2) Theory for analysis and validation of CT Instrument. This systematic review contributes a nuanced understanding of the theoretical foundations governing CT in education. By categorizing expert validations into learning theories and instrumental frameworks, this study informs educators,

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researchers, and policymakers on the diverse theoretical landscape. These insights lay the groundwork for future research endeavors and pedagogical innovations, enriching the ongoing dialogue on the role of CT in shaping the educational landscape.

Keywords:

Computational Thinking, Computational Thinking Skills, Education, Theory

Introduction

In the dynamic realm of education, the integration of Computational Thinking (CT) has become a pivotal pedagogical paradigm. CT, denoting the cognitive processes and problem-solving strategies employed by computer scientists, has transcended its disciplinary origins to constitute a fundamental skill set applicable across diverse academic domains (Arenare, 2021; Chongo et al., 2021; Durak et al., 2019; Kaup, 2022; Kjällander et al., 2021; Matsumoto & Cao, 2017; Yilmaz & Karaoglan Yilmaz, 2023). Coined by Jeannette Wing in 2006, the term CT serves as a conceptual framework describing an essential skill set for effectively addressing complex problems and designing systems (Wing, 2006). Wing argued that CT entails a synthesis of algorithmic problem-solving, abstraction, and logical reasoning, extending beyond its roots in computer science to become a cross-disciplinary cognitive tool (Wing, 2008, 2017). Within the academic sphere, the incorporation of CT is deemed imperative for fostering analytical and critical thinking skills, preparing students to navigate the increasingly digitized educational landscape (Jiang & Li, 2021; Kamha & Chookhampaeng, 2023; Lee et al., 2023; W. Li et al., 2023; Moraiti et al., 2022; Saidin et al., 2021; Thabvithorn & Samat, 2022). Therefore, positioned as a foundational element in the intellectual toolkit of 21st-century learners, the integration of CT responds to the demands of the digital age.

Regarding the research related to CT theory, Agbo et al. (2021) conducted a study on theories or frameworks that specifically address CT in the higher education context. The search for relevant literature was performed on April 19, 2021. The results of this study indicated that scholars predominantly investigate constructionism and constructivism as the primary learning theories utilized in the implementation of CT within higher education institutions. The research by Ali and Yahya (2020) analyzed the principles of learning theory in relation to CT. This was achieved by a comprehensive analysis of studies conducted throughout the timeframe between 2015 and 2020, employing a systematic review methodology. The research findings indicate a predominant presence of constructivist learning theory in studies on CT in K-12 and high school education.

Therefore, the primary goal of this systematic review is to meticulously analyze a range of theories that advocate for the integration of CT in educational settings between 2021 and 2023. The study extensively explores the learning theory that directs the implementation of CT and clarifies the theoretical underpinnings guiding the analysis and validation of CT instruments. Furthermore, through thorough synthesis, the results aim to offer a nuanced understanding, pinpoint theoretical gaps, and lay the groundwork for future research and advancements in educational practices.

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Literature Review

Learning theories are crucial in shaping the educational strategies employed to develop CT skills. Constructionism is a learning theory significantly influenced and developed by Seymour Papert, a mathematician and educational theorist (Ackermann, 2001; Papert, 1994; Parmaxi & Zaphiris, 2014; Wooster & Papert, 1982). In the context of CT, this theory encourages learners to engage in hands-on activities, such as programming projects, problem-based learning, or problem-solving tasks to foster a deep understanding of abstract concepts (Aminah et al., 2023; Funk et al., 2022; Molina-Ayuso et al., 2022; Pou et al., 2022; Saad & Zainudin, 2022). Constructivism is an educational theory highlighting the active involvement of learners in forming their own comprehension of knowledge. It asserts that learning is a mental construction process in which individuals actively create their knowledge through engagement with their surroundings, contemplation of experiences, and assimilation of new information into existing cognitive frameworks (Aylward & Cronjé, 2022; Bryce, 1993; Petchtone, 2014). In essence, learners construct their own understanding rather than passively receiving information (Jonassen et al., 1998; Md. Mahmood Alam, 2016; Pham, 2011). Hence, when exposed to real-world problems and encouraged to explore solutions collaboratively, students can internalize CT principles.

The study by Choi (2019) evaluated a constructivism-based instructional model for college students' Java programming classes, demonstrating positive impacts on CT, programming skills, and problem-solving abilities. Another study revealed a link between methodology, incorporating CT, neuroeducation, constructivism, and active methodologies, significantly improving basic mathematical operations in early school education (Cristina et al., 2022). At the same time, another study introduced a mapping tool for computer science education, combining existing definitions with a new constructionism matrix, focusing on learners' autonomy, indicating a relationship between learning context and constructionism in activities (Csizmadia et al., 2019). In a different study, Mayne and Bath (2023) examined and explored the use of educational technologies like Makey, Micro:bit, Ozobots, and Minecraft Education Edition for teaching CT to young learners.

Classical Test Theory (CTT) as well as Item Response Theory (IRT) are both pivotal in the educational measurement and evaluation of assessments. This includes those designed to measure CT. CTT is a foundational framework in educational measurement, focusing on the reliability and validity of test scores (Bichi, 2016; El-Hamamsy, Zapata-Cáceres, Barroso et al., 2022; Himelfarb, 2019). It assesses reliability through test-retest, internal consistency, and inter-rater reliability and considers measurement error in each test score. Meanwhile, IRT is a modern test theory that focuses on the properties of individual test items, using probabilistic models to link the likelihood of a specific response to an item with the respondent's underlying trait or ability (Ackerman et al., 2022; Giacomelli et al., 2021; Kong & Lai, 2022). It is utilized in Computerized Adaptive Testing (CAT) and assesses Differential Item Functioning (DIF) to ensure test fairness.

Several studies have reported the positive effect of using CTT and IRT in testing the validity and reliability of CT assessment tools. For example, the study by Zhang and Wong (2023) introduced the Computational Thinking Test for Lower Primary (CTtLP), designed for students aged 6-10. It underwent content validation through expert reviews and cognitive interviews, followed by a large-scale field test (N = 1225) analyzed utilizing CTT as well as IRT. Accordingly, the results confirmed the test's validity, reliability, and utility in diagnosing CT

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acquisition in young students. Another study developed a tool to foster interest in Computationally Intensive Science (CIS) careers among middle school students in Indonesia, validated through CTT and IRT, highlighting significant predictors and the impact of online modelling activities (Rachmatullah & Wiebe, 2023b). With the same objective, El-Hamamsy, Zapata-Cáceres, Marcelino et al. (2022) have conducted a study that compares two CT assessments, the Beginners' CT Test (BCTt) for grades 1-6 and the cCTt for grades 3 and 4. Data from 575 students in grades 3 and 4 were analysed using CTT and IRT. The result suggested that the CCTt is preferred for students in grades 3 and 4 due to the ability to discriminate between students, while the BCTt is better for identifying lower-ability students.

Material And Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology, which serves as a standardized framework for undertaking Systematic Literature Reviews (SLRs), is utilized in this analysis. The publication guidelines serve a crucial function in guiding authors as they evaluate and scrutinize the precision and rigor of a review through the provision of essential and germane information. The PRISMA framework, as illustrated in Figure 1 and delineated by Moher et al. (2009), not only underscores the evaluation of randomized studies but also functions as an indispensable component in reports of systematic analyses encompassing a wide range of study designs. Regarding the instruments utilized, the rigorous databases Scopus and Web of Science (WoS) were employed to assess the research methodology. This section provides a comprehensive outline of the four major sub-sections: identification, screening, eligibility, and data abstraction and analysis.

Identification

The process of choosing appropriate papers for this report comprises three main stages within the systematic review procedure. The initial stage involves the identification of keywords and the search for associated terms through the utilization of thesaurus, dictionaries, encyclopedias, and prior scholarly investigations. Subsequently, following the determination of pertinent keywords, search strings were generated for the Scopus and WoS databases, as depicted in Table 1. During the initial stage of the systematic review procedure, a total of 780 papers were successfully retrieved from the databases utilized in this research endeavor.

Table 1: The Search String

Scopus	TITLE-ABS-KEY ("computational thinking" AND theory) AND (LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2023)) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (PUBSTAGE, "final"))
WOS	"computational thinking" AND theory (Topic) and 2023 or 2022 or 2021 (Publication Years) and Article (Document Types) and English (Languages)

Screening

In this stage, the removal of any duplicate papers within the compiled list of searched documents is undertaken. The preliminary screening phase resulted in the exclusion of 576 publications, followed by a subsequent phase involving the examination of 204 papers utilizing distinct exclusion and inclusion criteria as delineated in Table 2. The primary criterion applied was the nature of the literature, specifically focusing on research papers as the primary source of practical recommendations. This category also encompassed reviews, meta-analyses, meta-

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synthesis, book series, books, chapters as well as conference proceedings not encompassed in the most recent study. Moreover, the review was confined to publications in the English language. It is imperative to underscore that the strategy exclusively concentrated on the years 2021 to 2023. Ultimately, 65 publications were excluded relying on duplication criteria.

Eligibility

In this stage, denoted as the eligibility assessment, a compilation of 139 articles was assembled. Rigorous scrutiny was applied to each article's titles and substantive content during this phase to ascertain their alignment with the inclusion criteria and congruence with the specific research objectives of the present investigation. Consequently, 109 reports were excluded from consideration due to their divergence from the scope of the study, insufficient thematic relevance in the titles, and abstracts that lacked substantive correlation with the study's objectives, grounded in empirical evidence. Subsequently, a total of 30 articles emerged as eligible for comprehensive review, as detailed in Table 2.

Table 2: The Selection Criterion Is Searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2021 - 2023	< 2021
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press

Data Abstraction and Analysis

This research employs integrative analysis as a pivotal assessment strategy, embracing a spectrum of research designs, including qualitative, quantitative as well as mixed methods. The primary aim is to identify pertinent topics and subtopics, commencing with data collection as the foundational step in theme development. Figure 2 illustrates the meticulous examination of 30 publications, wherein the authors systematically analyzed assertions and content pertinent to the study's topics. Following this, a comprehensive evaluation of significant studies on CT ensues, covering methodologies and research findings. Collaborative endeavors among researchers facilitate the extraction of contextually grounded themes, meticulously documented in a log, capturing analyses, perspectives, queries, and other insights crucial for data interpretation. For coherence, a comparative analysis of results is conducted, addressing any inconsistencies in theme design through internal discussions. In cases of conceptual disparities, authors engage in collaborative discourse. The derived themes undergo refinement to ensure consistency. Moreover, to fortify the findings' validity, independent examinations by two experts in instructional design and CT are conducted, ensuring domain validity. The iterative process involves adjustments based on the authors' discretion, incorporating feedback and comments gleaned from expert evaluations.

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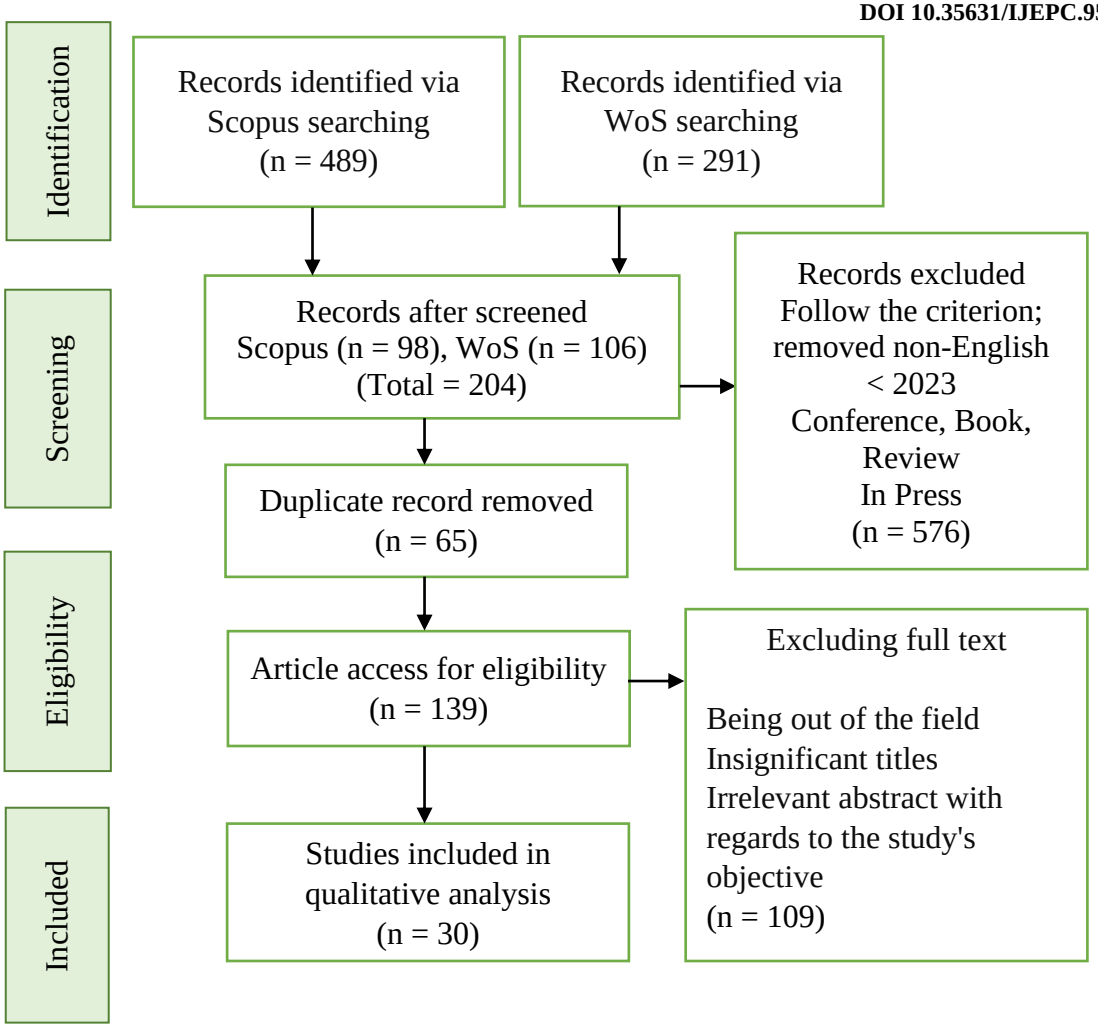

Figure 1: Flow Diagram of The Proposed Searching Study

Source: Moher et al. (2009)

Result and Finding

CT is crucial for developing problem-solving skills, breaking down complex challenges, and fostering logical reasoning abilities, essential for navigating a technology-driven environment. Employing a systematic search approach, a total of 30 articles were identified and subjected to thorough analysis. All articles were classified relying on two main themes, which are (1) Learning theory on CT (20 articles) and (2) Theory for analysis and validation of CT Instruments (10 articles).

Learning Theory on CT

The initial theme examines learning theories pertaining to CT, specifically focusing on the processes by which students acquire and utilize computational concepts in their educational endeavors. Implementing CT in many educational environments necessitates the integration of multiple theories, including Constructionism, Bandura's Social Cognitive Theory, Piaget's Four Stages Theory, Self-Determination Theory, and the Decomposed Theory of Planned Behavior. The study discovered that constructivism and constructionism are the most widely adopted learning theories in implementing CT in education. Table 3 summarizes the result of Theme 1 Learning theory on CT.

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Table 3: Theme 1 Learning Theory on CT

Authors and Source title	Title	Result and Findings	Theory	Participants
Muchsini B.; Siswandari; Gunarhadi; Wiranto (2023) Cogent Education (2023)	Promoting college students' computational thinking: the use of constructionism-based accounting spreadsheets designing activities	The study suggested that constructionism-based accounting spreadsheet designing activities can improve college students' CT by addressing errors and deficiencies in spreadsheet design.	Constructionism	College students (n = 38)
Zhang J.-H.; Meng B.; Zou L.-C.; Zhu Y.; Hwang G.-J. (2021) Interactive Learning Environments (2021)	Progressive flowchart development scaffolding to improve university students' computational thinking and programming self-efficacy	The experimental group exhibited improved academic achievement, programming self-efficacy, and CT skills through a progressive thinking training approach with flowcharts.	Scaffolding Instruction	University students (n = 49)
Huang Y.-C.; Lii P. (2023) Sustainability (Switzerland) (2023)	Evaluating Kindergarten Parents' Acceptance of Unplugged Programming Language Courses: An Extension of Theory of Planned Behavior	The study revealed that expectation and compensation significantly influence attitude, subjective norm, as well as perceived behavioral control, positively affecting family acceptance of unplugged programming language programs.	Planned Behavior	Parents of children aged 5–6 years old (n = 489)
Zhong H.-X.; Lai C.-F.; Chang J.-H.; Chiu P.-S. (2023) International Journal of Technology and Design Education (2023)	Developing creative material in STEM courses using integrated engineering design based on APOS theory	The study indicated that our course significantly enhanced students' creativity, especially among males, aligning with previous research findings and providing suggestions for improving learning materials.	Action-Process-Object-Schema (APOS)	College students (n = 40)
Rachmatullah A.; Wiebe E.N. (2023a)	Changes and Sources of Changes of Middle School Teachers' Self-efficacy for	The study discovered that teachers' self-efficacy in teaching science and CT in a computationally rich	Bandura's Social Cognitive Theory (Constructivism)	Middle school science teachers (in-service n = 7

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Journal of Science Teacher Education (2023)	Teaching Science in A Computationally Rich Environment: A Mixed-Methods Study	environment increased over time, influenced by computer programming experience, student interests, and teaching repetition and field experience.		and pre-service n = 4)
Markandan N.; Osman K.; Halim L. (2022) Frontiers in Psychology (2022)	Integrating Computational Thinking and Empowering Metacognitive Awareness in STEM Education	The ME-CoT learning module exhibited strong stability reliability (r = 0.974) and offered advantages like active and fun learning for students.	Robert Gagne's Information Processing Theory, Metacognitive Theory, Vygotsky's Social Constructivism Theory, Constructionism Theory	Secondary students (n = 29)
Welch L.E.; Shumway J.F.; Clarke-Midura J.; Lee V.R. (2022) Education Sciences (2022)	Exploring Measurement through Coding: Children's Conceptions of a Dynamic Linear Unit with Robot Coding Toys	The study explored how social context, gesturing, and verbal descriptions influence children's understanding of dynamic linear units, highlighting challenges in developing constructed conceptions and reconciling preconceptions in early elementary education.	Artifact-Centric Activity Theory	Kindergarten students ages 5–6 (n = 4)
Fagerlund J.; Leino K.; Kiuru N.; Niilo-Rämä M. (2022) Frontiers in Education (2022)	Finnish teachers' and students' programming motivation and their role in teaching and learning computational thinking	Teachers' motivation varies based on experience, subject, and gender, with boys generally more motivated. Increased motivation and positive CT experiences are crucial for higher test scores.	Self-Determination Theory	Grade 8 teachers (n = 1,853) and students (n = 2,546)
Budiyanto C.W.; Fenyvesi K.; Lathifah A.; Yuana R.A. (2022) European Journal of	Computational Thinking Development: Benefiting from Educational Robotics in STEM Teaching	The research highlighted the connection between CT principles and STEM learning phases, emphasizing the role of educational robotics in enhancing previous	Constructivism	Pre-service teacher (n = 8)

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Educational Research (2022)		literature on learning experiences.		
Muchsini B.; Siswandari; Gunarhadi; Wiranto (2022) Pegem Egitim ve Ogretim Dergisi (2022)	Behavioral Dimensions of College Students' Intention to Implement Computational Thinking in Designing Spreadsheets for Accounting	The study revealed that attitudes, subjective norms, and perceived behavioral control significantly predict college students' intention to implement CT in spreadsheet learning, providing empirical evidence.	Decomposed Theory of Planned Behavior' Taylor & Tod	College students (n = 148)
Gonda D.; Ďuriš V.; Tirpáková A.; Pavlovičová G. (2022) Mathematics (2022)	Teaching Algorithms to Develop the Algorithmic Thinking of Informatics Students	The experiment's statistical analysis confirmed that using an algorithm for decision-making in teaching motivated students to learn algorithms with comprehension.	Algorithmic Graph Theory	Higher education students (n = 74)
Zhan Z.; He W.; Yi X.; Ma S. (2022) Journal of Educational Computing Research (2022)	Effect of Unplugged Programming Teaching Aids on Children's Computational Thinking and Classroom Interaction: with Respect to Piaget's Four Stages Theory	The study revealed that children aged 6-8 with ego-centered cognitive style struggle with problem-solving, but the treatment group exhibited higher CT scores and increased classroom interaction.	Piaget's Four Stages Theory (Constructivism)	Primary students aged 6–8 (n = 48)
Gao X.; Hew K.F. (2022) Journal of Educational Computing Research (2022)	Toward a 5E-Based Flipped Classroom Model for Teaching Computational Thinking in Elementary School: Effects on Student Computational Thinking and Problem-Solving Performance	The study revealed that the 5E-based FCM significantly enhanced students' comprehension of CT concepts and computational problem-solving abilities and exhibited positive student perception towards the FCM.	5E Model (Constructivism)	Elementary students (n = 247)
Weber A.M.; Bastian M.; Barkela V.; Mühling A.; Leuchter M. (2022)	Fostering pre-service teachers' expectancies and values toward computational thinking	Seminar attendees demonstrated higher expectancies, values, and emotional costs towards CT and programming, demonstrating the benefits of low-	Expectancy-Value Theory	Primary school and special education pre-service teachers (n = 311)

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Frontiers in Psychology (2022)		threshold tasks in preparing future classroom teachers.		
Akkaya A.; Akpinar Y. (2022) Computer Science Education (2022)	Experiential serious-game design for development of knowledge of object-oriented programming and computational thinking skills	Students with and without programming experience significantly improved their understanding of OOP concepts, with weak correlations discovered between creative problem-solving, attitudes towards digital game-based learning, and learning.	Experiential Learning Theory	Non-engineering higher education students (n = 61)
Xing (2021) Interactive Learning Environments (2021)	Large-scale path modeling of remixing to computational thinking	The study revealed that while remixing can enhance CT, excessive community exposure and excessive remixing can hinder its development.	Social Cognitive Theory (Constructivism)	Students aged 8-16 (n = more than 100,000)
Jocius R.; O'Byrne W.I.; Albert J.; Joshi D.; Robinson R.; Andrews A. (2021) Educational Technology and Society (2021)	Infusing Computational Thinking into STEM Teaching: From Professional Development to Classroom Practice	The study highlighted the use of CT infusion in secondary classrooms, highlighting the importance of scaffolding, collaborative contexts, and the challenges faced by teachers in adapting their lessons.	Technological Pedagogical Content Knowledge (TPACK) And TPACK-CT	Middle and high school teachers (n = 24)
Pürbudak A.; Usta E. (2021) Participatory Educational Research (2021)	Collaborative group activities in the context of learning styles on web 2.0 environments: An experimental study	The study discovered significant differences in students' academic achievement, online cooperative attitude, computer thinking levels, and learning styles, with discriminating learning styles achieving the highest success.	Kolb Learning Style	6th grade students (n = 83)
Jiang B.; Zhao W.; Gu X.; Yin C. (2021) Educational Technology Research and	Understanding the relationship between computational thinking and computational participation: a case	The study discovered a low to moderate correlation between CT level in projects and popularity but no effect on learners' participation,	Social Cognitive Theory (Constructivism)	(n = 105,720)

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Development (2021)	study from Scratch online community	suggesting instructors should focus on basic CT skills.		
Butler D.; Leahy M. (2021) British Journal of Educational Technology (2021)	Developing pre-service teachers' understanding of computational thinking: A constructionist approach	Pre-service teachers emphasized the importance of manipulating objects to develop CT and demonstrated high pedagogical knowledge, demonstrating their understanding of designing challenges for children's classroom experiences.	Constructionism	Pre-service teachers (n = 51)

Theory For Analysis and Validation of CT Instrument

The second theme focuses on the theoretical frameworks guiding the analysis and validation of CT instruments, which are essential for assessing and measuring students' CT skills. This theory includes Multidimensional Item Response Theory (MIRT), CTT, IRT, Grounded Theory, and Confirmatory Bi-Factor IRT. The study revealed that CTT and IRT are the prevailing theories utilized for the analysis and validation of CT instruments. Table 4 provides the Theme 2 Theory for Analysis and Validation of CT Instrument.

Table 4: Theme 2 Theory for Analysis and Validation of CT Instrument

Authors and Source title	Title	Result and Findings	Theory	Participants
Kang C.; Liu N.; Zhu Y.; Li F.; Zeng P. (2023) Education and Information Technologies (2023)	Developing College students' computational thinking, multidimensional tests based on Life Story situations	The study's CT test, with its strong internal validity and ability to discriminate across various college disciplines, is deemed an effective assessment tool.	Multidimensional Item Response Theory (MIRT)	College students aged 18-22 (n = 433)
El-Hamamsy L.; Zapata-Cáceres M.; Marcelino P.; Bruno B.; Dehler Zufferey J.; Martín-Barroso E.; Román-González M. (2022) Frontiers in Psychology (2022)	Comparing the psychometric properties of two primary schools Computational Thinking (CT) assessments for grades 3 and 4: The Beginners' CT test (BCTt) and the competent CT test (CCTt)	The study reveals that the BCTt, while easier to use, is better suited for identifying low-ability students in grades 3-4, while the cCTt is preferred for grades 3-4 due to its ability to discriminate between low and medium-ability students.	Classical Test Theory (CTT) and Item Response Theory (IRT)	Primary school grades 1–6 (n = 575)

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Tucker-Raymond E.; Cassidy M.; Puttick G. (2021) Computers and Education (2021)	Science teachers can teach computational thinking through distributed expertise	The study identified five key themes: releasing student responsibility, co-learning, encouraging independent problem-solving, building interdependence, and providing multiple resources.	Grounded Theory	Grade 8 science teachers (n = 15)
Boulden D.C.; Rachmatullah A.; Oliver K.M.; Wiebe E. (2021) Education and Information Technologies (2021)	Measuring in-service teacher self-efficacy for teaching computational thinking: development and validation of the T-STEM CT	The study discovered a reliable tool measuring teaching efficacy beliefs for CT without bias with gender, race, or experience. However, no significant predictors were discovered using demographic characteristics, suggesting further research.	Classical Test Theory (CTT) and Item Response Theory (IRT)	In-service teachers (n = 330)
Lai R.P.Y.; Ellefson M.R. (2023) Journal of Educational Computing Research (2023)	How Multidimensional is Computational Thinking Competency? A Bi-Factor Model of the Computational Thinking Challenge	The study suggests a bi-factor IRT model for CT competency, recommending a general competency factor and two specific factors for programming and non-programming problem-solving with good psychometric properties.	Multidimensional Item Response Theory Analysis (MIRT) and Confirmatory Bi-Factor Item Response Theory	Secondary school students (n = 1,130)
Li Y.; Xu S.; Liu J. (2021) Journal of Pacific Rim Psychology (2021)	Development and Validation of Computational Thinking Assessment of Chinese Elementary School Students	The CTA-CES is a reliable and valid tool for measuring CT literacy in Chinese children, with Cronbach's alpha, IRT, construct validity, and fMRI confirming its validity.	Item Response Theory (IRT)	Elementary student grade 3-6 (n = 280)
Kong S.C.; Wang Y.Q. (2021)	Item response analysis of computational thinking practices: Test	The study outlined four-dimensional CT practices: reusing, remixing, abstracting, modularizing, testing,	Item Response Theory (IRT)	Primary school students grade 4–6 (n = 13,956)

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Computers in Human Behavior (2021)	characteristics and students' learning abilities in visual programming contexts	and algorithmic thinking, compatible with programming environments like Alice, Scratch, and App Inventor.		
de Ruiter L.E.; Bers M.U. (de Ruiter & Bers, 2022) Computer Science Education (2022)	The Coding Stages Assessment: development and validation of an instrument for assessing young children's proficiency in the ScratchJr programming language	The CSA is reliable, construct-valid, and correlates with CT ability, with good discrimination and difficulty levels, despite gender and age bias.	Classical Test Theory (CTT) and Item Response Theory (IRT)	Primary students aged 5-8 (n = 118)
Tsai M.-J.; Chien F.P.; Wen-Yu Lee S.; Hsu C.-Y.; Liang J.-C. (2022) Journal of Educational Computing Research (2022)	Development and Validation of the Computational Thinking Test for Elementary School Students (CTT-ES): Correlate CT Competency with CT Disposition	The CTT-ES, consisting of 16 items, effectively evaluates elementary students' CT competencies, with significant correlations with CTS scores and supporting the Developmental Model of CT.	Classical Test Theory (CTT) and Item Response Theory (IRT)	Elementary school students (n = 631)
Rachmatullah A.; Wiebe E.N. (2023b) Science Education (2023)	Exploring middle school students' interests in computationally intensive science careers: The CISCI instrument validation and intervention	The study discovered that CISCI is a reliable tool for measuring students' career interests, with science and CS attitudes, CT, and prior experience being significant predictors.	Classical Test Theory (CTT) and Item Response Theory (IRT)	Middle school students aged 11–14 (n = 934)

Discussion

This study conducted a systematic review of literature focusing on the theory of CT in education, utilizing Scopus and WoS databases. The review identified two primary themes: (1) Learning theory on CT and (2) Theory for Analysis and Validation of CT Instrument. The first theme encompasses the integration of various learning theories within the CT context, highlighting the complexity of developing CT skills in educational settings. The research revealed that constructivism and constructionism stand as the prevailing learning theories predominantly utilized for integrating CT within educational contexts. These theories include constructionism, which emphasizes active knowledge construction. Vygotsky's Social

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Constructivism focuses on collaborative learning. While Piaget's Cognitive Theory outlines cognitive development stages, Bandura's Social Cognitive Theory stresses observational learning. Furthermore, the study explores Action-Process-Object-Schema (APOS) theory in mathematical understanding, Artifact-Centric Activity Theory, Self-Determination Theory, theories of Planned Behavior, Algorithmic Graph Theory, Expectancy-Value Theory, the 5E Model of inquiry-based learning, Experiential Learning Theory, and technology-related theories like Technological Pedagogical Content Knowledge (TPACK) and TPACK-CT.

The integration of learning theories yields positive impacts on students whereby they attain higher scores in CT assessments and increased levels of classroom interaction (Zhan et al., 2022), improve academic achievements (Pürbudak & Usta, 2021; J. H. Zhang et al., 2021) and enhancing student engagement during class (Markandan et al., 2022). Other study demonstrates that constructionism activities and spreadsheets can effectively enhance student CT in accounting spreadsheet classrooms through critical, creative, systematic, and logical thinking (Muchsini et al., 2023). Furthermore, implementation of the 5E-based FCM significantly enhanced students' comprehension of CT concepts and computational problem-solving abilities (Gao & Hew, 2021).

The second theme addresses the development as well as validation of CT assessment tools, integrating theories like MIRT, CTT, IRT, and Confirmatory Bi-Factor IRT for precise validation. Moreover, Grounded Theory is also employed for empirically based instrument development. The research findings indicated that CTT and IRT emerge as the predominant theoretical frameworks employed for analyzing and validating instruments assessing CT. Various instruments have been developed for studies on CT, encompassing a variety of fields. The study includes measuring the career interests of middle school students (Rachmatullah & Wiebe, 2023b), measuring CT literacy in Chinese children (Y. Li et al., 2021), measuring in-service teacher self-efficacy for teaching CT (Boulden et al., 2021) and CT practices (Kong & Wang, 2021).

Conclusion

In conclusion, this research underscores the importance of a diverse theoretical framework in CT education, acknowledging the complexity of cultivating CT skills. This framework aids in formulating customized instructional strategies and enhances the ongoing development of CT educational practices in response to evolving educational and technological environments. Additionally, the synthesized theories provide essential tools for the rigorous analysis and validation of CT assessment instruments, ensuring their effectiveness and reliability. The study's extensive participant range, from kindergarten to higher education students, teachers, and parents, ensures a comprehensive understanding of CT theory's application across educational levels. The broad participant base significantly enriches the study's findings, offering valuable insights for adapting CT education to various learning contexts and informing educators, researchers, and policymakers. For future investigations, researchers may consider consulting additional research databases beyond those utilized in the present study to access a broader array of data.

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