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COMPUTATIONAL THINKING IN PHYSICS TEACHING AND LEARNING: A SYSTEMATIC LITERATURE MAPPING

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ABSTRACT

This systematic literature mapping (SLM) analyzes the integration of computational thinking (CT) into the teaching and learning of physics by reviewing 20 articles published between 2019 and 2025, resulting from debugging 10,196 initial documents retrieved from six international databases. Findings reveal a boom in publications (a maximum in 2025), geographical concentration in Indonesia, Colombia and the United States; thematic predominance in mechanics (60%) and electromagnetism (20%); and prevalent use of tools such as GeoGebra simulators (40%), Python (30%), and robotics (20%), with active methodologies such as STEM (45%). Five reciprocal mechanisms between physics and CT are identified—modelling, data practices, decomposition, abstraction and iteration—, together with challenges such as teacher education and digital gaps, thus projecting future scenarios with AI and communities of practice for transversal paradigms.

KEYWORDS: Computational Thinking, Teaching Physics, Systematic Literature Mapping, Computational Modelling, Educational Robotics, STEM Education.

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1. INTRODUCTION

In the educational context, marked by the fourth revolution and the digital world, integrating computational thinking (CT) into traditional disciplines such as physics is a pedagogical imperative to promote 21st century competencies, such as algorithmic modeling and the iterative resolution of complex problems. However, questions about the global trends in this intersection remain: dominant subjects, mutual contributions between CT and physics teaching, and infrastructural and training challenges that limit their scalability, particularly in regions such as Latin America where scientific production is still emerging. This gap is highlighted by previous reviews, such as that of Riwayani et al. (2025), which concentrates 91% of the evidence in the United States and Indonesia, leaving aside Ibero-American contributions and middle school contexts. Therefore, a more inclusive systematic literature mapping (SLM) is justified. Following the consolidated guidelines (Petersen et al., 2015; Arksey & O'Malley, 2005), this study performs an exploratory SLM in six databases (Springer, Scopus, Google Scholar, ScienceDirect, Redalyc, Dialnet). It began with 10,196 documents; these were filtered and 20 rigorous articles published between 2019-2025 were obtained. Search strings in English and Spanish were used to capture a broader picture. The main objective is to identify research trends of CT in the teaching-learning of physics (OB1), guided by three questions: (Q1) What topics or methodologies does the CT relate to?; (Q2) How does physics contribute to CT?; (Q3) What future opportunities, challenges, and scenarios are possible? Results outline a growing field, with an emphasis on mechanics and tools such as Python and robotics, thus laying the foundations for the use of validated teaching strategies.

2. METHODOLOGY

Systematic Literature Mapping (SLM) is a methodological approach that organizes and characterizes a research field in a structured way, providing an overview rather than an exhaustive synthesis of findings (Petersen et al., 2015). In contrast to traditional systematic reviews, which aim to integrate evidence to answer narrowly defined questions, SLMs map the existing literature by classifying studies according to predefined categories and making visible both areas of concentration and gaps that merit further investigation (Arksey & O′Malley, 2005).

According to Petersen et al. (2015), an SLM typically involves: formulating broad research questions, conducting searches with relatively inclusive terms, applying explicit inclusion and exclusion criteria, extracting data through classification schemes, and summarizing results with descriptive statistics and visual representations, without resorting to in-depth synthesis techniques such as meta-analysis. In parallel, Arksey and O′Malley (2005) conceptualized similar procedures as "scoping studies" in the health sciences, a framework later refined by Levac et al. (2010), who highlighted the value of multidisciplinary teams, iterative and transparent decision-making, and, where appropriate, consultation with key stakeholders to enhance knowledge translation.

Therefore, SLM allows researchers to examine, classify and analyze the existing knowledge on a specific research topic by evaluating and counting the contributions made by different authors (Pérez et al., 2023). It is carried out in four stages: (i) Defining the objectives and research questions, (ii) establishing the search and selection strategy, (iii) conducting the literature review, and (iv) presenting the analysis of results obtained in the SLM (Pérez et al., 2023).

2.1. *Search Objective and Research Questions*

The SLM requires defining at least one objective and some guiding questions (Pérez et al., 2023). Hence, a search objective (OB) and, in this case, three research questions (Q) that help to center the review process were defined. Tasks such as inclusion, exclusion, comparison and analysis of the articles were carried out to meet the objective. Research questions worked as a research framework. This SLM sought to support research that relates, among other aspects, the teaching of physics and the natural sciences with CT in the international arena.

The search objective (OB) proposed for systematic mapping is described in Table 1.

Table 1: Search Objective of the SLM.

ITEM	SEARCH OBJECTIVE (OB)
OB1	Identify the main research trends in works on CT in the context of physics teaching and learning

At this stage, the recommendations of the Goal-Question-Metric (GQM) used in other literature search works were followed (Pérez et al., 2023). Recommendations suggest three levels: (i) conceptual level (goal), speaks of the purpose of the search, there is a search objective; (ii) operational level (question), questions are described and give focus, characterize, and structure the evaluation of studies related to education in physics, natural sciences, and CT; (iii) quantitative level (metric), which asks to establish certain metrics to evaluate specific aspects of the project in question and needs of the research.

Therefore, considering the search objective, three (3) research questions (Q) were proposed. They enabled segmenting and categorizing the most relevant literature on CT and physics teaching. Table 2 presents the questions and motivation for each one.

Table 2: Research Questions in the SLM.

ITEM	RESEARCH QUESTION (Q)	MOTIVATION
Q1	What topics or methodologies are related to CT in the context of physics teaching and learning?	Identify the research topics or methodologies that address CT in the context of physics teaching and learning
Q2	What pedagogical contributions or processes are reported in literature on CT and physics teaching?	Determine the possible incidents, contributions and processes that relate CT with physics teaching
Q3	What are the current opportunities, problems or challenges, and future scenarios identified in the reviewed studies?	Identify the current problems and future scenarios that appear in the review

These questions, in addition to supporting the systematic search, also clarify that they are not exhaustive or exclusive and that they promote broader searches and panoramas than the one initially proposed.

2.2. Initial Search Procedure

First, the main search string was determined, using logical operators and quotation marks to guarantee most precise results in the search engines of each database consulted. To obtain the main search string in English and Spanish, and after a previous scientific literature review, the following steps were followed: i) the key search concepts "teaching physics", "learning physics", "practical laboratory work", "experimental work" and "computational thinking" were chosen, ii) with these concepts, search strings were built in Spanish and English using the "AND" and “OR” Boolean operators, in such a way that “computational thinking” had a higher hierarchy and was indispensable to obtain results in each search engine. The strings obtained are presented in Table 3.

Table 3: Search Strings Used in the SLM.

ITEM	SEARCH STRING (SS)
SS1	"Computational Thinking" AND ("practical laboratory work" OR "experimental work" OR "physics teaching" OR "experiential learning" OR "physics learning")
SS2	"Pensamiento Computacional" AND ("trabajo práctico de laboratorio" OR "trabajo experimental" OR "enseñanza de la física" OR "aprendizaje experiencial" OR "aprendizaje de la física")

Both search strings were applied in six (6) databases (DB). The purpose is to obtain a broad and international view of the concepts chosen within the framework of the SLM. Databases are listed in Table 4.

Table 4: Databases Used for the Search.

ITEM	**DATABASES CONSULTED (DB)**
DB1	Springer Nature Link
DB2	Scopus
DB3	Google Scholar
DB4	ScienceDirect
DB5	Redalyc
DB6	Dialnet

The initial search was carried out on January 5, 2026, between 08:00 am and 04:00 pm. The search in six databases yielded a total of 10,196 documents in English and Spanish according to the search strings.

The search string in English yielded 9749 documents; in Spanish, 447. They are distributed as shown in Table 5.

Table 5: General Initial Search Results in English and Spanish.

Databases	Name of the database	Search Strings		Total documents SS1 + SS2
		SS1 (English)	SS2 (Spanish)	

DB1	Springer Nature Link	464	0	464
DB2	Scopus	73	0	73
DB3	Google Scholar	9050	435	9485
DB4	ScienceDirect	148	0	148
DB5	Redalyc	10	10	20
DB6	Dialnet	4	2	6
Total (6 databases)		9749	447	10196

In total 10,196 documents, potentially eligible for the study in question, were retrieved from six indexed databases. The absence of relevant information in Spanish in databases such as Springer, Scopus and ScienceDirect stands out. In turn, there is a greater amount of material available in Google Scholar in English and Spanish.

2.3. Debugging Search Results

To facilitate and centralize the first analysis, it is necessary to refine the search. The intention is that results are relevant to the objective and framed within the three (3) research questions to guarantee the academic quality and the temporal validity of the articles to be reviewed. The corresponding inclusion criteria (IC) are listed in Table 6.

Table 6: Inclusion Criteria.

IC	INCLUSION CRITERIA (IC)
IC1	Full articles published in the last seven 7 (+2026) years
IC2	Articles in English or Spanish that refer to CT in the context of physics teaching and learning
IC3	Articles that have been published in prestigious peer-reviewed journals, congresses or conferences
IC4	Articles whose main theme is CT in physics teaching and learning

The task was completed by filtering documents that would be reviewed in depth according to the following exclusion criteria (EC), as described in Table 7.

Table 7: Exclusion Criteria.

EC	EXCLUSION CRITERIA (EC)
EC1	Books or book chapters, papers or reports
EC2	Publications made more than seven (7) years ago
EC3	Restricted access articles
EC4	Duplicate articles
EC5	Articles without evidence of complete investigation or that superficiality in the investigation is suspected
EC6	Articles that do not address problems related to physics teaching and learning in relation to CT or vice versa

Then, the filtering tools of the databases were used—with the support of other tools such as Microsoft Excel and Perplexity in strictly repetitive and classification tasks—to gradually apply inclusion and exclusion criteria. Results after applying such criteria are detailed in Figure 1.

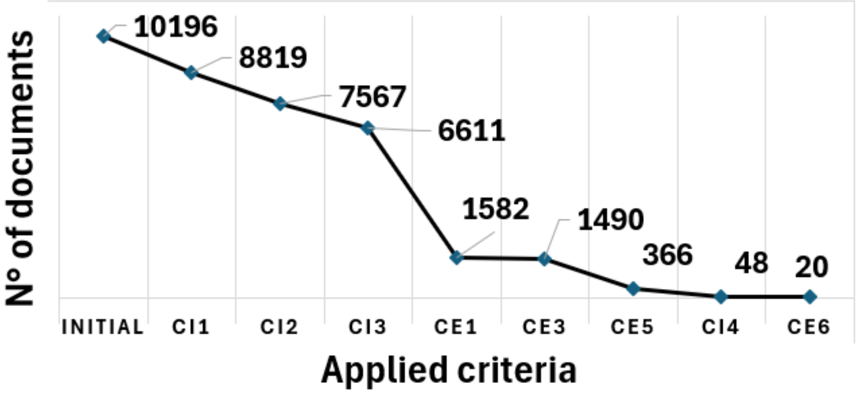

Figure 1: Inclusion And Exclusion of Documents by Criteria.

The initial review included 10,196 documents in English and Spanish. The publication age criterion (7 years) only allowed the inclusion of 8,819 documents. The sample was reduced to 7,567 (IC2). Taking only the documents published in peer-reviewed or prestigious journals, the number drops to 6,611 (IC3). A broad reduction occurs with exclusion criterion 1 (EC1) since a high percentage are book chapters, books or reports, these are mostly found in Google Scholar. The number is reduced to 1,582 findings. Due to exclusion criterion 3 (EC3), articles with restricted access, the sample drops to 1,490 documents. The articles that report work on teaching and learning physics and CT total 366 (EC5). After reviewing the titles, abstracts, keywords, and conclusions, there are 48 articles whose central or main theme is CT in the teaching and learning of physics (IC4). In the final stage, after a thorough review of the complete documents, 28 articles were removed from the sample: 2 for being duplicates (EC4), 9 for not presenting depth or consolidated research (EC5) and 16 for not focusing exclusively on CT and the teaching and learning of physics (EC6). At the end, there are 20 articles for reading and analysis in the detailed information search phase.

Table 8 shows the 20 articles with their identification code, year, authors and title (titles are presented in the original language).

Table 8: Selected Articles, Year of Publication, Authors, And Title.

CA	YEAR	AUTHORS	TITLE
A01	2025	Muhamad Yusup, Sardianto Markos Siahaan, M Rokhati Harianja	Integrating Energy Literacy and Computational Thinking in Secondary Education: A Rasch-Based Analysis to Support Game-Based Physics Learning
A02	2025	Fabián A. Jalk D., Sonia Valbuena D., Francisco J. Racedo N.	Pensamiento computacional a través de una simulación dinámica de la relación carga-masa del electrón
A03	2025	Uğur Sari, Alperen Ulusoy, Hüseyin Miraç Pektaş	Computational Thinking in Science Laboratories Based on the Flipped Classroom Model Computational Thinking, Laboratory Entrepreneurial and Attitude
A04	2025	Kartini Herlina, Abdurrahman Abdurrahman, Ahmad Naufal Umam, Ayu Nurjanah, Ghani Fadhil Rabbani, Ficha Aulia Indah Pratiwi	Expression-based e-worksheet EBEW an effort to enhance student computational thinking skills
A05	2025	Phongsak Phakamach, Pinya Sukwiphat, Songdet Sonjai, Natchaya Sommartdejsakul, Ritthidech Phomdee	Strategies for Utilizing AI Technology to Enhance Science Learning Management within the stem Education Approach
A06	2025	Duván Felipe Martínez Nava, Angie Alejandra Moreno Católico, Daniel Alejandro Valderrama, Santiago Vargas Domínguez	Pensamiento computacional en la enseñanza de la Astrofísica Estelar Análisis desde una intervención didáctica
A07	2025	Alberto Pacheco González	Aplicando Pensamiento Computacional y Programación en Vivo para crear Juegos Serios en Cursos de Física
A08	2025	Vladimir Carlos Martínez Nava, Kristo Fabián Salinas Palomo, Alan Steve Valencia Uriegas	Robótica Educativa y su impacto en el logro del perfil de egreso de formación inicial.Un caso con estudiantes de la Licenciatura en Enseñanza y Aprendizaje de la Físicaen Educación Secundaria
A09	2025	Riwayani, Edi Istiyono, Supahar, Riki Perdana, Jumadi, Soeharto	A Systematic Literature Review of Computational Thinking Study in Physics Learning
A10	2024	Walter Oswaldo Arias Villalba, Wilmer Enrique Quimbita Zapata, Wendy Joana Vélez Sarmiento, Carolina Jessica López González	Scratch para mejorar el aprendizaje de la física en estudiantes de primer año de bachillerato de la Unidad Educativa Hermano Miguel – Marianistas en el periodo 2023-2024
A11	2023	Rizki Zakwandi, Edi Istiyono	A framework for assessing computational thinking skills in the physics classroom: study on cognitive test development
A12	2023	Mario Bernal, Luz K. Peña	Competencias Investigativas Modelización con PYTHON para enseñanza de física mecánica
A13	2023	W. Brian Lane, Terrie M. Galanti, X. L. Rozas	Teacher Re-novicing on the Path to Integrating Computational Thinking in High School Physics Instruction
A14	2023	Johannes Addido, Andrea C. Borowczak, Godfrey B. Walwema	Teaching Newtonian physics with LEGO EV3 robots: An integrated stem approach
A15	2023	Ulfa Dwiyanti, Thufail Mujaddid Al-Qoyyim, Muhamad Hendri Diarta, Jaswadi	The Potential of Developing Computational Thinking Approach-Based Physics Learning Media as a Means of Increasing Students' Problem-Solving Ability
A16	2022	Omar Iván Trejos Buriticá, Luis Eduardo Muñoz Guerrero	Programación + Física: estrategia motivadora de aprendizaje en ingeniería de sistemas
A17	2022	Colby Tofel-Grehl, Kristin A. Searle, Douglas Ball	Thinking Thru Making: Computational Mapping Thinking Practices onto Scientific Reasoning
A18	2021	Consuelo Escudero, Daniela Zalazar García	Introducción al estudio de nociones básicas de física moderna mediante el uso de una propuesta integradora basada en software libre

A19	2021	Rebecca Vieyra, Joshua Himmelsbach	Teachers' Disciplinary Boundedness in the Implementation of Integrated Computational Modeling in Physics
A20	2019	Albiter Jaimes, J., Mendoza Méndez, R.V. and Dorantes Coronado	El pensamiento computacional en la electrónica la importancia del software de simulación en la comprensión del principio de funcionamiento de los componentes electrónicos

3. RESULTS

A total of 20 documents that address CT and physics teaching and learning between 2019 and 2025 were found. The set of documents shows various theoretical and methodological approaches aimed at incorporating CT into scientific education contexts, particularly in the field of physics. Texts examine pedagogical frameworks that incorporate digital tools, such as Python programming, Arduino microcontrollers, and robotics with LEGO EV3 to enhance skills such as abstraction, decomposition, and algorithm design. In addition, they evaluate the effect of innovative approaches, including gamification, playful learning, and virtual simulators on the understanding of complex topics such as Newtonian mechanics and energy literacy.

Results of this systematic literature mapping show a total of 64 authors involved in the 20 articles, with an average of 3.2 authors per article. The maximum was six (6) authors, and the minimum was one author. The mode and median are three authors per piece of writing. Only one author appears in two articles, (Riwayani et al., 2025) and (Zakwandi & Istiyono, 2023). Of the 64 authors, 21 are women and 43 are men. Moreover, the 20 articles total 327 pages (an average of 16.35 pages per article). The shortest document has 5 pages and the longest, 30 pages.

A first finding in search results highlight the systematic literature review (Riwayani et al., 2025) on CT and physics learning carried out in Indonesia (Vieyra & Himmelsbach, 2022). First because of the high level and quality of the research; second because it is very recent. Even though this is an exhaustive review, Latin America is absent from the results. This review delivers 68% of results in the United States and 23% in Indonesia, for a total of 91% (Riwayani et al., 2025) and generalizes education from early childhood to the last grades without detailing what happens in secondary education.

This SLM provides complementary information by using six (6) databases without limitation in the inclusion criteria, unlike (Riwayani et al., 2025), who only included two (2) databases. In addition, the inclusion of Spanish as one of the languages for search strings favored finding articles with a better global reach.

3.1. Geographical Scope

The 20 documents come from eight (8) countries. Five (5) of them focus on the American continent, two (2) on Asia, and one (1) on Europe. The distribution is mostly concentrated in three countries: Indonesia and Colombia, each with 25% of the research works; and the United States, with 20%. In total, 14 articles out of the 20. The rest of the findings are represented by Mexico, with 2 articles; Argentina, Ecuador, Turkey and Thailand, with 1 document each.

In Southeast Asia and Eurasia, studies show a high concentration of research on digital literacy and the use of accessible technologies to integrate CT into physics teaching. Indonesia occupies a central position, with work on energy literacy, design of e-worksheets based on problem learning models, development of psychometric frameworks to evaluate CT, and systematic reviews that confirm their leadership in this field. In the same region, Thailand develops proposals that incorporate artificial intelligence within the STEM approach to manage science learning, while Turkey explores the integration of CT in science laboratories through flipped classroom models.

In North America, scientific production is oriented both to the development of advanced theoretical frameworks and to teacher education for the integration of CT into physics. In the United States, studies on professional development of secondary school teachers to incorporate Python into the curriculum, use LEGO EV3 robotics to teach Newton's second law in extracurricular programs, and experiences with e-textiles that link CT practices with scientific reasoning stand out. Likewise, disciplinary restrictions that make it difficult for teachers to implement integrated computational models are analyzed. In Mexico, research focuses on live coding to create serious games in university physics courses, the impact of educational robotics on the achievement of the graduation profile in teacher training colleges, and the value of simulation software to understand the operation of electronic components, in addition to participating in international initiatives that use Scratch in high schools.

In Latin America, particularly in the Andean Region and South America, the work is aimed at achieving greater pedagogical autonomy and modelling complex physical phenomena through digital and free resources. In Colombia, a line of research that uses Python for modeling in mechanics, didactic interventions in stellar astrophysics and mainstreaming of programming as a motivating strategy in engineering programs, together with dynamic simulations of the charge-mass ratio of the electron are consolidated. In Argentina, case studies that use free software, such as GeoGebra, to address basic notions of modern physics and favor the self-regulation of learning in simulation environments are documented. In Ecuador, meanwhile, experiences where Scratch is used to improve the learning of physics in high school freshman year by increasing conceptual understanding and student participation are reported.

Hence, recent evidence confirms that the United States and Indonesia concentrate the largest volume of publications on CT and physics learning, which gives them a hegemonic position in terms of academic production. However, countries such as Colombia and Mexico are making progress in consolidating communities of practice that articulate CT with the resolution of contextualized problems and teachers' education, thus configuring emerging poles of didactic innovation in this field.

3.2. Scope By Year

Analyses made in this review focused on 20 articles with possible dates between 2019 and 2025, thus ensuring some perspective from before the global pandemic, after the pandemic, and the most recent possible studies. In fact, the review began in the last quarter of 2025 and was last updated on January 5, 2026. The average number of publications is 2.86 articles per year.

Between 2019 and 2022, 5 publications are reported; between 2023 and 2025, 15 in total. There are three times as many publications with a high peak in 2025 (9 articles), which allows us to conclude that: i) there is a strong marked upward trend; and ii) the sample also guarantees an adequate timeliness in the research reviewed.

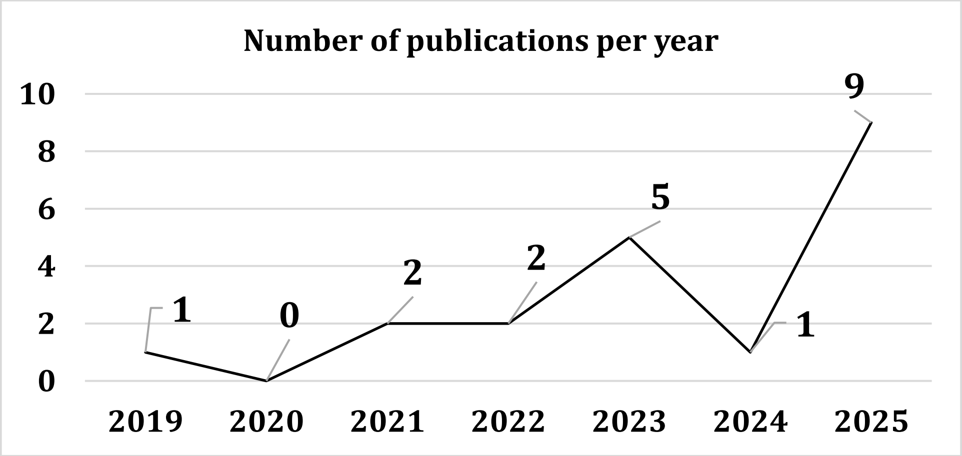

Figure 2: Number Of Publications Per Year.

3.3. Scope By Field

The 20 articles address diverse topics as part of research in the field of physics. The most prominent topic is mechanics, with 60% of the documents analyzed, this is equivalent to 12 out of the 20 articles reviewed. Electromagnetism with 20% of the articles; one article focused on STEM, specifically on atomic and molecular phenomena (Phakamach et al., 2025); another article focuses on astrophysics (Martínez Rava et al., 2025); another one on modern physics (Escudero & Zalazar García, 2021); and one more on wave phenomena (Zakwandi & Istiyono, 2023). It should be noted that 80% of the topics focus on mechanics and electromagnetism, only two (2) articles include work in modern physics and astrophysics.

In relation to the educational level at which the research was carried out, it is pertinent to show that 40% of the results correspond to higher or university education; that is, a total of eight (8) articles, of which four belong to engineering. Six (6) papers focused on secondary education; this is 30% of the findings. Two (2) focusing on a general context, usually called K-12 literature, are also referenced. Regarding professional teacher development, there are two (2) contributions. There is one single multi-stage research including both secondary and higher education (Riwayani et al., 2025) and non-formal education in STEM areas (Addido et al., 2023).

3.4. Approach, Sample, Research Population

Regarding the approach and design of the research, it should be noted that 50% of the 20 works have a qualitative approach. Within this category, research with conceptual framework analysis, documentary review, case studies, action research, and a comprehensive literature review stand out. Six (6) documents (30%) report a quantitative approach with predominance in quasi-experimental designs, interventions with pre- and post-test, and psychometric analysis. In addition, four (4) investigations report having worked with mixed approaches in their research, one of them predominantly quantitative (Trejos & Muñoz, 2022). Research in Turkey reports a concurrent nested design (Sari et al., 2025).

In relation to the accumulated population in the systematic literature mapping article (Riwayani et al., 2025), a total of 3269 participants is reported. In this mapping specifically, there are 1060 participants. In total there are 4356 people involved in studies that worked with people. More particularly, studies applied in secondary education represent six (6) articles out of the 20 available. With a total of 763 students, on average 127 students per study. The study with the largest number of participants has 354 and the smallest in the sample includes 31 students. For higher education, six (6) investigations were found with a total of 167 students, on average 55 students per research paper. For teacher education and teacher professional development, there are 4 articles with a cumulative total sample of 67 teachers. In broad contexts, with more general populations, for example, K-12 or ʻNon-Formalʻor ʼAfter-schoolʻeducation, there are 74 participants in total.

The educational contexts in which research was conducted are traditional or common spaces such as public and private schools and high schools, as well as public and private universities. A particularly divergent context is that found in research in the United States with a STEM approach; it was carried out outside regular classes (Addido et al., 2023) and reported a sample with adolescents of various ages using LEGO.

3.5. Technologies Used

The findings of the SLM highlight a wide range of technological tools used for research in CT related to teaching physics. Starting from the use of programs such as GeoGebra, simulators such as PhET, and virtual laboratories (Jalk et al., 2025), (Herlina et al., 2025), (Phakamach et al., 2025), up to high-level programming languages and professional environments such as Python, Pyret, Godot, among others (Pacheco et al., 2025), (Bernal & Peña, 2023), (Lane et al., 2023). Block-friendly programming platforms such as Scratch, LEGO, among others were also used (Sari et al., 2025), (Martínez Nava et al., 2025), (Addido et al., 2023). In addition, there are research based on emerging technologies such as physical computing, programmable hardware, sensors for real-time data collection such as Arduinos, accelerometers, among others (Yusup et al., 2025), (Martínez Rava et al., 2025), (Tofel et al., 2022).

A proposed taxonomic categorization and total contributions are presented in Table 9.

Table 9: Technologies Used in CT Research and Physics Teaching.

TAXONOMIC CATEGORY	DESCRIPTION OF TECHNOLOGICAL RESOURCES	INCLUDED ITEMS	FREQUENCY	PERCENTAGE
Interactive Simulators and Virtual Labs	Software that allows the manipulation of physical variables without code (GeoGebra, Virtual Labs, Multisim, PhET)	(Jalk et al., 2025), (Herlina et al., 2025), (Phakamach et al., 2025), (Riwayani et al., 2025), (Zakwandi & Istiyono, 2023), (Dwiyanti et al., 2023), (Escudero & Zalazar, 2021), (Albiter et al., 2019)	8	40.0%
Textual Programming Environments and Development Engines	High-level languages and professional environments that require structured syntax (Python, Pyret, Godot, Jupyter Notebooks)	(Pacheco et al., 2025), (Bernal & Peña, 2023), (Lane et al., 2023), (Trejos & Muñoz, 2022), (Vieyra & Himmelsbach, 2022)	6	30.0%
Visual Programming and Educational Robotics	Block-based platforms that reduce cognitive load in use (Scratch, LEGO Mindstorms, mBlock)	(Sari et al., 2025), (Martínez Nava et al., 2025), (Arias et al., 2024), (Addido et al., 2023)	4	20.0%
Physical Computing and Emerging Technologies	Programmable hardware and sensors for real-time data collection (Arduino, E-textiles, Accelerometers)	(Yusup et al., 2025), (Martínez Rava et al., 2025), (Tofel et al., 2022)	3	15.0%

The article published by (Zakwandi & Istiyono, 2023) presents a cognitive assessment instrument and the use of specialized software to perform psychometric validations. In this case, this study is atypical in relation to the rest of the SLM results.

3.6. Methodologies, Pedagogies, And Didactics

In relation to the pedagogical methodologies included in the 20 reported research works, there is a clear predominance of active learning methods and scientific inquiry such as the stem Approach, Action research, modeling, and guided inquiry (Herlina et al., 2025), (Martínez Rava et al., 2025), (Pacheco et al., 2025), (Martínez Nava et al., 2025), (Bernal & Peña, 2023), representing almost 50% of the works. With less participation (25% approx.), there are constructivist and meaningful learning models such as constructionism, critical meaningful learning, self-regulation, and Brain Based Learning (Jalk et al., 2025), (Arias et al., 2024), (Dwiyanti et al., 2023). Reports of working with flipped classrooms, game-based learning, among other ICT-mediated methodologies were also found (Yusup et al., 2025), (Sari et al., 2025), (Phakamach et al., 2025). In an atypical category, as in the report on technologies, there is research that works on the framework for evaluating and developing CT skills (Zakwandi & Istiyono, 2023).

A categorization and total contributions on these methodologies can be seen in Table 10.

Table 10: Methodologies Used in CT Research and Physics Teaching.

TAXONOMIC CATEGORY	METHODOLOGIES INCLUDED	INCLUDED ITEMS	FREQUENCY	PERCENTAGE
Active Learning and Scientific Inquiry	STEAM Approach, Action Research (AR), Modeling and Guided Inquiry	(Herlina et al., 2025), (Martínez Rava et al., 2025), (Pacheco et al., 2025), (Martínez Nava et al., 2025), (Bernal & Peña, 2023), (Lane et al., 2023), (Addido et al., 2023), (Tofel et al., 2022), (Vieyra & Himmelsbach, 2022)	9	45.0%
Constructivist and Meaningful Learning Models	Constructionism, Critical Significant Learning, Self-Regulation and Brain Based Learning	(Jalk et al., 2025), (Arias et al., 2024), (Dwiyanti et al., 2023), (Trejos & Muñoz, 2022), (Escudero & Zalazar, 2021), (Albiter et al., 2019)	6	30.0%
ICT-Mediated Instructional Architectures	Flipped Classroom, Connectivism, Game-Based Learning and Personalization	(Yusup et al., 2025), (Sari et al., 2025), (Phakamach et al., 2025)	3	15.0%
Psychometric Assessment and Development Frameworks	Item Response Theory (IRT), Rasch Model and validation of cognitive instruments	(Riwayani et al., 2025), (Zakwandi & Istiyono, 2023)	2	10.0%

As for the methodologies related to constructivist models and that point to significant learning, the research project that relates CT and Brain Based Learning (BBL) (Trejos Buriticá & Muñoz Guerrero, 2022) should be mentioned as a notorious finding. This work seeks to develop a model for science teaching and learning by taking advantage of computer programming.

3.7. CT Skills That Impact Learning Processes

Empirical research, represented in the 20 articles of this review, documents significant increases in specific competencies after CT-mediated didactic intervention in classrooms, both in school and university environments.

- Abstraction and generalization: an improvement in the ability to identify critical variables and filter irrelevant information in complex systems is reported. It allows students to model laws of nature in a simplified but functional way (Yusup et al., 2025), (Martínez Rava et al., 2025), (Zakwandi & Istiyono, 2023), (Escudero & Zalazar, 2021).
- Problem decomposition: students demonstrate a greater ability to fragment complex physical phenomena, direct current circuits or stellar nucleosynthesis into smaller and more manageable problems, thus facilitating the structuring of systematic solutions (Herlina et al., 2025), (Martínez Rava et al., 2025), (Zakwandi & Istiyono, 2023), (Dwiyanti et al., 2023).
- Algorithmic thinking: the development of a sequential logic to represent physical processes through flow diagrams and pseudocodes is evidenced. It strengthens "mathematization"

and the understanding of causality (Sari et al., 2025), (Pacheco et al., 2025), (Bernal & Peña, 2023).

- Debugging and metacognition: A central gain is frustration tolerance and self-regulation. Students learn to see the error in the code or in the simulation not as a failure, but as a datum for the critical review of their initial mental models (Sari et al., 2025), (Bernal & Peña, 2023), (Escudero & Zalazar, 2021), (Vieyra & Himmelsbach, 2022).

4. DISCUSSION

4.1. Q1. What Topics or Methodologies Are Related to CT In the Context of Physics Teaching and Learning?

Within the framework of educational research in recent years, the integration of CT into physics teaching has been consolidated as a cross-cutting axis that covers various domains of the discipline. Mainly, a strong incidence is observed in the study of classical mechanics, addressing topics such as linear kinematics, parabolic movement, and Newton's laws of dynamics (Pacheco et al., 2025), (Martínez Nava et al., 2025), (Arias et al., 2024), (Bernal & Peña, 2023), (Addido et al., 2023), (Trejos & Muñoz, 2022), (Vieyra & Himmelsbach, 2022). Likewise, literature found in the SLM documents significant applications in the field of electromagnetism and electronics, focusing on the charge-mass relationship of the electron, the analysis of direct current circuits, and the operation of complex electronic components (Jalk et al., 2025), (Herlina et al., 2025), (Riwayani et al., 2025), (Albiter et al., 2019). At greater abstraction levels, CT has been linked to the stellar astrophysics teaching; the study of wave phenomena, such as sound waves; and the introduction to modern physics through modeling of photoelectric effect (Martínez Rava et al., 2025), (Zakwandi & Istiyono, 2023), (Escudero & Zalazar, 2021). These studies find in CT a possibility and a formal language that facilitates the transition from abstract concepts to deterministic models through the mathematization and algorithmic representation of natural phenomena (Pacheco et al., 2025), (Bernal & Peña, 2023), (Tofel et al., 2022), (Escudero & Zalazar, 2021).

Methodologically, CT is implemented through active learning and research-action paradigms that prioritize scientific inquiry and "learning by doing" (Martínez Rava et al., 2025), (Pacheco et al., 2025), (Bernal & Peña, 2023), (Tofel et al., 2022). Predominant strategies are identified, e.g., the use of educational robotics to make physical forces and interactions more tangible or evident (Martínez Nava et al., 2025), (Addido et al., 2023), as well as computational modeling supported by high-level programming languages such as Python and Pyret, or visual environments such as Scratch (Riwayani et al., 2025), (Arias et al., 2024), (Bernal & Peña, 2023), (Lane et al., 2023), (Trejos & Muñoz, 2022), (Vieyra & Himmelsbach, 2022). Complementarily, methodologies based on the flipped classroom, digital game-based learning (DGBL), and the transversalization of knowledge between physics and engineering are reported (Yusup et al., 2025), (Sari et al., 2025), (Pacheco et al., 2025), (Trejos & Muñoz, 2022). These approaches constitute cognitive structures that strengthen not only technical competence, but also higher order processes such as metacognition, self-regulation, and the resolution of systemic problems within the STEM educational ecosystem (Sari et al., 2025), (Herlina et al., 2025), (Dwiyanti et al., 2023), (Escudero & Zalazar, 2021).

4.2. Q2. What Pedagogical Contributions or Processes Are Reported in Literature on CT And Physics Teaching?

According to the corpus of 20 articles analyzed, physics teaching and learning shows a close relationship with CT through some pedagogical mechanisms and processes.

The five (5) most relevant mechanisms and processes in these reports are detailed below:

- Modelling and mathematization of natural phenomena. Physics as a discipline provides the conceptual substrate for students to move from qualitative observation to formal representation through algorithms. In the study of kinematics and dynamics, designing mathematical models allows learners to structure computational solutions under a "mathematization" approach, where the laws of nature are expressed through code and simulations (Pacheco et al., 2025), (Bernal & Peña, 2023), (Vieyra & Himmelsbach, 2022). This process allows complex concepts such as non-linear movement to be simplified through algorithmic reasoning and at the same time enhance CT (Lane et al., 2023), (Escudero & Zalazar, 2021), (Vieyra & Himmelsbach, 2022). Likewise, modeling in high-level programming environments, such as Python, favors the understanding of physical causality through computational logic (Bernal & Peña, 2023), (Trejos & Muñoz, 2022).
- Data practices and symbolic representation. The environment of the physics laboratory,

whether virtual or physical, requires a systematic processing of information similar to CT processes. Students develop data representation skills by interpreting motion graphs, vectors, and electromagnetic signals by translating them into data structures understandable by processing agents (Herlina et al., 2025), (Martínez Rava et al., 2025), (Riwayani et al., 2025), (Zakwandi & Istiyono, 2023). The need to collect, organize, and analyze variables in real time—using microprocessors and sensors—trains the student in the identification of patterns, selecting only the relevant physical parameters to solve a specific problem (Sari et al., 2025), (Zakwandi & Istiyono, 2023), (Tofel et al., 2022).

- Complex Problem Decomposition. Physics learning and teaching addresses complex systems that need to be divided into smaller units, therefore, manageable for their study. This "decomposition of problems" is clearly manifested when students analyze the evolutionary cycle of the stars or the operation of direct current circuits by translating each phase of the phenomenon into logical blocks or subproblems (Herlina et al., 2025), (Martínez Rava et al., 2025), (Dwiyanti et al., 2023). In educational robotics applied to Newton's laws, task fragmentation (mechanical construction vs. logical programming) allows the student to identify the roots of errors in the behavior of the system, thus strengthening their capacity for mental structuring (Martínez Nava et al., 2025), (Addido et al., 2023).
- Abstraction and dynamic simulation. The abstract nature of modern physics and electromagnetism, insofar as many of its phenomena are impossible to observe or experience directly, demands tools that make tangible what is intangible. The use of simulations in GeoGebra or game engines allows the student to ignore technical details of the experimental assembly or avoid having to perform them to focus on the functional relationships of the variables (Jalk et al., 2025), (Escudero & Zalazar, 2021), (Albiter et al., 2019). This abstraction practice takes place when the student must predict the behavior of charged particles or the impact of gravitational forces, adjusting parameters in a virtual environment that functions as an "external memory", extending their cognitive capacity to reason about abstract models (Jalk et al., 2025), (Escudero & Zalazar, 2021).
- Iteration, debugging and metacognition. Computer-mediated physics learning as a tool introduces a recursive cycle of trial and error. The process of "debugging" is central when a code does not faithfully replicate the expected physical phenomenon, thus forcing the student to self-regulate their knowledge and logically review their conjectures (Sari et al., 2025), (Pacheco et al., 2025), (Bernal & Peña, 2023), (Tofel et al., 2022). Solving challenges and programming promote critical thinking where error is seen as data for the optimization of the model, thus promoting the autonomy that links scientific inquiry with computational efficiency (Pacheco et al., 2025), (Bernal & Peña, 2023), (Addido et al., 2023).

In short, physics not only benefits from technological tools, but acts as a discipline that confers meaning to algorithms as such. The transversalization of physical content in teaching provides context to computational logic and becomes an educational space that promotes CT, going from memorizing formulas to a process of creation and technological innovation (Trejos & Muñoz, 2022), (Albiter et al., 2019).

4.3. Q3. What Are the Current Opportunities, Problems or Challenges, And Future Scenarios Identified in the Reviewed Studies?

4.3.1. Opportunities

In the review and analysis of the documents, some important and noteworthy opportunities have been found:

- From CT towards teaching and learning physics. Studies agree that the main opportunity lies in the ability of CT to act as a “cognitive bridge” between abstract theory and experiential or phenomenological reality. The use of interactive simulations and virtual laboratories (e.g., GeoGebra, PhET, Multisim) enables visualizing unobservable entities, such as electromagnetic fields, subatomic trajectories or quantum energy states, thus facilitating processes of abstraction and abduction that chalk and the board limit (Jalk et al., 2025), (Escudero & Zalazar, 2021), (Albiter et al., 2019). The integration of high-level languages such as Python not only modernizes the curriculum but also fosters a culture of computational modeling that gives meaning to the laws of physics. This allows students to "do science" in an authentic and participatory way (Bernal & Peña, 2023), (Trejos & Muñoz, 2022), (Vieyra & Himmelsbach, 2022). Finally, CT and educational robotics are emerging as a boost for intrinsic motivation by increasing interest in STEM careers and reducing dropout rates in initial natural science courses (Addido et al., 2023), (Trejos & Muñoz, 2022).

- In developing countries, the integration of CT into physics education is conditioned by structural constraints such as limited digital infrastructure, uneven access to laboratory resources, and fragmented policy frameworks for STEM innovation. In these contexts, the predominance of tools like GeoGebra, Arduino, or low-cost robotics kits reported in the reviewed studies suggests that scalable interventions must rely on open-source software, affordable hardware, and hybrid modalities that combine unplugged and plugged activities to mitigate connectivity gaps. Rather than transferring high-cost solutions designed for well-resourced systems, context-sensitive designs offer a more viable route for aligning CT with local curricular demands and material conditions.
- At the same time, the reviewed evidence indicates that CT in physics may become a catalyst for broader educational transformation when it is connected to authentic problems and socio-scientific issues that are especially relevant in developing regions, such as energy transitions, environmental sustainability, or technological dependence. Integrating CT-rich physics activities into regional or national initiatives through school-university partnerships, teacher-student inquiry projects, or community-based laboratories may help reduce dependence on imported models while fostering locally meaningful innovation. However, these possibilities require that CT be recognized not as an optional technological complement, but as a strategic component of science education policy, particularly in under-resourced school systems.
- From the educational environment of physics towards CT. In relation to the benefits and opportunities for the development of CT in physics teaching-learning environments, the personalization of learning through the deployment of Intelligent Tutoring Systems (ITS) and learning analytics allow adjusting the scaffolds to the speed and style of learning and thinking of each student (Phakamach et al., 2025). The visualization of unobservable phenomena (Jalk et al., 2025), (Dwiyanti et al., 2023), (Escudero & Zalazar, 2021), (Albiter et al., 2019) facilitates the mental processes typical of CT in its various stages. It also highlights computational modeling (Lane et al., 2023), (Vieyra & Himmelsbach, 2022), which allows improving access to various advanced problems without the need for complex mathematics by focusing the process on improving CT skills and creativity. The use of programming languages to solve problems fosters an active and creative role in students, rather than simply being "consumers" of formulas (Bernal & Peña, 2023), (Trejos & Muñoz, 2022). Using the science environment, with scientific problems or everyday problems, encourages self-management to solve real problems beyond the board or chalk (Martínez Nava et al., 2025), (Tofel et al., 2022).

4.3.2. Problems And Challenges

In relation to current problems and challenges, some structural and cognitive barriers stand out. Along with the benefits described, studies also report critical challenges that condition the success of integrating CT and physics teaching-learning processes and applying it in current educational contexts.

At the teaching level, the phenomenon of "re-novicing" is central: even experienced teachers in physics lack pedagogical knowledge of the specific content for integration and even for working on CT, which generates tensions when trying to mediate programming processes with their students (Lane et al., 2023). This limitation is aggravated by the "disciplinary boundedness", where some teachers perceive computing as an additional burden outside of physics or as a mere supplementary resource, instead of integrating it as a central scientific practice (Vieyra & Himmelsbach, 2022).

Furthermore, regarding teachers and CT, the reviewed studies suggest that the integration of CT into physics cannot be sustained without stronger initial and continuing preparation capable of articulating disciplinary knowledge, pedagogical reasoning, and computational practices. Experiences involving robotics, programming, computational modeling, and flipped laboratory work show that many teachers must temporarily assume the position of learners again when approaching CT, which demands time, institutional support, and spaces for guided experimentation. This indicates that teacher education should move beyond isolated workshops or merely technical instruction and instead include longer formative processes in which teachers design, test, and refine CT-enriched physics activities in authentic educational settings.

Likewise, the literature points to the importance of collaborative professional cultures for consolidating CT in physics teaching. Communities of practice, shared repositories, peer mentoring, and links between schools and universities appear especially relevant for helping teachers progress from occasional users of digital tools to reflective designers of computationally enriched learning environments. In developing contexts, where workload, turnover, and limited resources often weaken innovation processes, these collective models may be more sustainable than fragmented training initiatives focused only on tools. Their consolidation, however, depends on institutional recognition, protected time for professional learning, and policy support that grants continuity to teacher development processes.

From the perspective of the student, the main challenge is that, in the academy, CT is constantly and strongly related only to programming, and this immediately raises the excessive cognitive load derived from syntax and programming logic. This could divert attention from the physical concept towards computer error (debugging) (Sari et al., 2025), (Pacheco et al., 2025), (Lane et al., 2023). Moreover, there are infrastructure barriers; for instance, the digital divide, unequal access to computing devices, and limitations in internet connectivity persist as obstacles to the democratization of these innovations (Phakamach et al., 2025), (Herlina et al., 2025). Finally, the lack of standardized evaluation frameworks to measure CT competences within science laboratories makes it difficult to monitor learning achievements at the macro level (Zakwandi & Istiyono, 2023), (Riwayani et al., 2025).

4.3.3. Future Scenarios

The literature reviewed in this SLM suggests that next steps in physics education do not go towards instrumental use of tools but the consolidation of an integrated computational modeling ecosystem, which serves as an environment for learning and solving scientific problems in line with the digital world. CT should facilitate these processes.

Thus, scenarios can be anticipated where: i) Artificial Intelligence (AI) is used as a constant collaborative assistant for the collection, analysis, and inference of data in real time, thus transforming the teaching role from transmitter to facilitator of complex inquiry (Phakamach et al., 2025), (Riwayani et al., 2025); ii) Teacher education evolves towards models of communities of practice that normalize ambiguity and continuous learning of the algorithm together with students (Lane et al., 2023), (Vieyra & Himmelsbach, 2022); iii) Curricular integration no longer takes an approach of "technological patches" but adopts transversal methodologies, where CT and programming are natural tools of expression and solution in physics, thus allowing students to address highly complex problems (e.g., non-linear mechanics, astrophysics) from early educational levels and up to university (K-12) (Bernal & Peña, 2023), (Dwiyanti et al., 2023), (Tofel et al., 2022).

Hence, the transition to these scenarios requires not only technological investment, but a paradigm change in the pedagogical mentality, where error is assumed as essential data in the iterative cycle of the construction of scientific knowledge mediated by the computer (Pacheco et al., 2025), (Bernal & Peña, 2023), (Escudero & Zalazar, 2021) and CT is constitutive of the processes, not only when teaching and learning, but, especially to solve problems of the context through science.

5. CONCLUSIONS

This SLM identifies a growing consolidation of CT in physics teaching through 20 studies published between 2019 and 2025 that reflect an exponential increase in publications, particularly in 2025 (9 articles), and a geographical distribution led by Indonesia (25%), Colombia (25%) and the United States (20%). Thematically, mechanics stands out with 60% of contributions, followed by electromagnetism (20%). Active pedagogical approaches such as STEM, modeling, and guided inquiry represent 45%, supported by various tools: simulators such as GeoGebra (40%), textual programming such as Python (30%), and visual robotics (20%). This panorama shows how CT is positioned as a formal tool to move from conceptual abstractions to algorithmic representations, thus strengthening metacognitive processes in diverse educational contexts, from secondary to higher education.

The reciprocity between physics and CT is evidenced in five key mechanisms derived from the analyzed corpus: modeling of natural phenomena via algorithms that mathematize complex causalities, data practices in laboratories that train patterns and symbolic representation, decomposition of systems into manageable subproblems, such as stellar cycles or circuits, abstraction through simulations that make tangible what is intangible, and iteration with purification that transforms errors into opportunities for self-regulation. Empirical studies report significant improvements in these skills, with accumulated samples of 4356 participants. Quasi-experimental interventions in secondary (763 students) and higher education (167) stand out, where physics provides the problematic substrate for CT to emerge as a rigorous tool for inquiry and solution of scientific problems.

However, challenges such as teacher disciplinary limitation, lack of training to face "re-novicing" and gaps in standardized psychometric evaluation—aggravated by inequalities in technological access, particularly in regions with greater economic difficulties—emerge. Future opportunities reside in transversal paradigms driven by AI and communities of practice, which could position CT as an integral curricular axis for learning contextualized physics, demanding professional development policies and validation of instruments to scale impacts in K-12 and beyond. This SLM not only supports the feasibility of hybrid teaching strategies but also invites local research that closes gaps in Latin America.

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