

Unplugged Computing for Computational Thinking Development: A Systematic Mapping Study on Educational Games and Learning Environments

Isabela de Souza¹, Jorge Lucas S. Luz²,
Gabriel P. Toledo², Lucas Caixeta³, Sandra S. Rodrigues¹, Samira S. Silva¹,
Racyus D. G. Pacífico³, Cristiane Ap. Lana¹

¹Federal University of Lavras - Paraíso Campus – São Sebastião do Paraíso, MG, Brazil

²Center of Exact Sciences - Univiçosa – Viçosa, MG – Brazil

³Federal University of Ouro Preto (UFOP) – João Monlevade - MG, Brazil.

{isabela.souza5@estudante.ufla.br
{sandra.rodrigues, samirasilva, cristiane.lana}@ufla.br
{jorge.lucasluz, gabrieltoledol11}@hotmail.com
{lucas.caixeta, racyus.pacifico}@ufop.edu.br

Abstract. *Teaching Computational Thinking (CT) through Unplugged Computing is widely adopted in contexts lacking technological resources, though gaps in evidence and inclusion remain. This systematic mapping of 66 studies investigates how unplugged activities contribute to CT development. Results highlight a predominance of physical games in primary and secondary education, frequently serving as introductory scaffolding for visual programming platforms like Scratch. While these tools enhance CT skills and collaboration, a "transfer gap" requires explicit teacher mediation to connect physical games with formal coding concepts. Finally, recurring limitations regarding accessibility for students with disabilities, standardized assessments, and longitudinal evaluations underscore the urgent need for more structured, accessible, and inclusive educational approaches.*

1. Introduction

Computational Thinking (CT) has become a central topic in Computing Education due to its potential to foster problem-solving, abstraction, decomposition, pattern recognition, and algorithmic reasoning skills [Wing 2006, Grover and Pea 2013]. Recognized as a fundamental competency for the twenty-first century, CT has been progressively incorporated into basic educational initiatives worldwide, motivating the development of pedagogical approaches that facilitate the learning of computational concepts among diverse student populations [Wing 2006, Brennan and Resnick 2012]. Among these approaches, Unplugged Computing has emerged as a promising alternative for teaching computing concepts through games, physical activities, and collaborative exercises without requiring computers or digital devices [Bell et al. 2009]. This characteristic makes unplugged activities particularly suitable for educational contexts with limited technological infrastructure while promoting active participation and engagement among learners [Chen et al. 2023]. Recent studies have shown that unplugged activities can effectively support the development of CT skills and improve students' motivation and interest in computing-related subjects [Brackmann et al. 2017, Battal et al. 2021].

The growing adoption of Unplugged Computing has resulted in a substantial increase in research investigating its application across different educational levels and learning environ-

ments. These studies explore a wide range of objectives, including the introduction of computational concepts, preparation for programming activities, and the promotion of inclusive and accessible computing education [Resnick et al. 2009, Grover and Pea 2013, Chen et al. 2023]. Despite these advances, the existing body of literature remains fragmented, with considerable variation in research designs, educational contexts, target audiences, and assessment methods. This heterogeneity creates challenges for consolidating knowledge in the field and identifying evidence-based practices. In particular, previous studies have reported difficulties in comparing outcomes due to the diversity of evaluation instruments and methodological approaches employed to assess CT development [Shute et al. 2017, Battal et al. 2021]. Furthermore, important topics such as accessibility, inclusion of students with disabilities, and longitudinal evaluations of learning outcomes remain underexplored in the literature [Battal et al. 2021, Chen et al. 2023].

Although previous reviews have provided insights into the benefits and challenges associated with unplugged approaches, the rapid growth of publications in recent years highlights the need for an updated and comprehensive synthesis of existing evidence [Battal et al. 2021]. Such a synthesis can support researchers and educators in understanding current research trends, identifying gaps, and guiding future investigations. Therefore, this study presents a Systematic Mapping Study (SMS) on the use of Unplugged Computing for the development of Computational Thinking. Following the guidelines proposed by [Kitchenham and Charters 2007a], studies were identified through searches in major scientific databases. After applying predefined inclusion and exclusion criteria, 66 primary studies were selected and analyzed. The mapping investigates publication trends, educational contexts, target audiences, teaching strategies, assessment methods, and reported outcomes.

The synthesis of the selected studies in this systematic mapping reveals that unplugged computing is predominantly supported by active learning, constructionism, and game-based learning. The results show an emphasis on collaborative problem-solving and kinesthetic activities, with board games and card games being the most frequently used resources. These activities are primarily applied in elementary and middle school settings to introduce foundational Computational Thinking concepts, such as sequencing, decomposition, and algorithmic thinking, often serving as a scaffolding step before introducing visual programming environments. Furthermore, while the literature highlights that unplugged approaches are highly effective in increasing student engagement and promoting equity, a transfer gap remains when students transition to formal programming logic. Finally, the findings indicate a significant lack of standardized assessment tools and inclusive designs tailored for students with disabilities, pointing to essential directions for future research in the field.

The remainder of this paper is organized as follows. Section 2 reviews the related work of Unplugged Computing and Computational Thinking. Section 3 describes the planning and conduction of the SMS, including the research protocol, search strategy, and selection criteria. Section 4 presents the results obtained from the analysis of the selected articles and discusses the implications of these findings. Section 5 proposes a future research agenda based on the identified gaps. Finally, Section 6 concludes the paper and outlines directions for future research.

2. Related Work

CT has become an important topic in Computing Education since the work of [Wing 2006]. To support the development of CT skills, different educational approaches have been proposed.

Among these approaches, Unplugged Computing has received strong attention. The Computer Science Unplugged initiative shows that computing concepts can be taught through games, puzzles, and physical activities without using computers [Bell et al. 2015]. This approach is especially useful in schools with limited technological resources and in early learning stages.

Several studies report positive results from unplugged activities. [Brackmann et al. 2017] found improvements in CT skills in elementary students. Other studies also report gains in learning, engagement, and motivation. More recent evidence includes experimental studies comparing different approaches. For example, [Zhang et al. 2025] compared unplugged activities, robotics, and traditional teaching in early childhood education and found positive effects for all approaches, with stronger gains for robotics in some outcomes.

Moreover, secondary studies have also analyzed this field. [Huang and Looi 2021] discussed unplugged pedagogies in basic education and highlighted issues related to inclusion and classroom practice. [Battal et al. 2021] reviewed 55 studies and identified different types of unplugged activities, such as games, paper-based tasks, and storytelling. Chen et al. [Chen et al. 2023] performed a systematic review and meta-analysis and confirmed positive effects of unplugged activities on Computational Thinking development.

However, critical gaps remain open in these previous reviews. First, from a temporal perspective, data indicates that more than half of the primary studies in this field were published between 2022 and 2025. Consequently, previous secondary studies missed the recent and most substantial wave of empirical evidence regarding unplugged computing. Second, from a thematic perspective, while existing reviews successfully established that unplugged activities improve immediate learning outcomes, they gave limited attention to the instructional design of these environments, the specific challenges of accessibility for students with disabilities, and the critical "transfer gap" between physical activities and formal programming.

To address these limitations and provide updated evidence, this Systematic Mapping Study offers a comprehensive synthesis of studies. By organizing this recently expanded and fragmented body of knowledge, this mapping extends previous reviews, providing a structured overview of pedagogical practices, assessment limitations, and persistent inclusion gaps, ultimately proposing a renewed agenda for future research.

3. Planning and Conduction

This SMS was conducted between January and May 2026 by researchers with experience in Software Engineering, Computer Engineering, and Human-Computer Interaction (HCI). The study followed the guidelines proposed by [Kitchenham and Charters 2007a], which define three main phases: planning, conducting, and reporting¹. The planning and conducting phases are described in this section, while the reporting phase is presented in Section 4.

3.1. Planning

The research questions (cf. Table 1) were defined using the PICOC approach (Population, Intervention, Comparison, Outcomes, and Context), a framework widely adopted for structuring research questions and search strategies in evidence-based software engineering studies [?]. The *Population* comprised students from basic and higher education, the *Intervention* focused on unplugged computing activities, games, and non-digital learning resources, the *Outcomes*

¹The protocol is available at <https://osf.io/mfn39/files/w8rbd>

addressed computational thinking, logical reasoning, engagement, and motivation, and the *Context* encompassed educational settings such as schools, workshops, outreach projects, and informal learning environments. The *Comparison* element was omitted because this study is a systematic mapping rather than a comparative evaluation.

Table 1. Research Questions and Rationale

RQ	Research Question	Rationale
RQ1	What types of games and unplugged environments have been proposed to support Computational Thinking and logical reasoning, and what are their educational goals, target audiences, and application contexts?	To identify and characterize unplugged resources, their educational goals, target audience, application context, and Computational Thinking concepts.
RQ2	What empirical evidence has been reported regarding the effects of games and unplugged environments on learning outcomes, Computational Thinking development, student engagement, and motivation?	To investigate empirical evidence regarding research methods, assessment approaches, outcomes, benefits, and limitations related to Computational Thinking, learning, engagement, and motivation.
RQ3	How have educational design, pedagogical usability, accessibility, and inclusion principles been incorporated into the design, implementation, and evaluation of games and unplugged environments?	To investigate educational design, usability, accessibility, inclusion, stakeholder involvement, and reported challenges and good practices.

To identify primary studies, a search string was developed based on the research objective and questions. First, the main concepts related to the topic were identified, including “Unplugged Computing”, “Computational Thinking”, and “educational games”. To avoid missing relevant studies, synonyms and similar terms were added to the search string. Additional terms were suggested by experts in the field, such as “*unplugged computing*”, “*computer science unplugged*”, and “*CS unplugged*”. A pilot study was conducted, and the search string was improved several times. The authors and experts discussed the results and suggested changes. The search string was tested and improved several times in the selected databases to retrieve relevant studies. The final string adopted in this SMS is presented below:

("unplugged computing" OR "computer science unplugged" OR "CS unplugged" OR "unplugged activities" OR "unplugged games" OR "non-digital computing activities" OR "offline computing activities" OR "screen-free computing" OR "unplugged learning activities") AND ("computational thinking" OR "algorithmic thinking" OR "logical reasoning" OR "problem solving" OR "computational skills" OR "algorithm design" OR "abstraction" OR "decomposition" OR "pattern recognition" OR "computational reasoning") AND ("educational games" OR "game-based learning" OR "board games" OR "non-digital games" OR "analog games" OR "tabletop games" OR "hands-on games" OR "learning through games" OR "teaching with games" OR "instructional games" OR "didactic games" OR "learning activities")

The publication databases were selected based on recommendations from the literature [Dieste et al. 2009, Kitchenham and Charters 2007b]. Scopus, ISI Web of Science, IEEE Xplore Digital Library, ACM Digital Library, and ScienceDirect were chosen because they are widely used in Computer Science and Software Engineering research [Petersen et al. 2015, Kitchenham and Charters 2007b, Munir et al. 2014].

3.1.1. Inclusion and Exclusion Criteria

The inclusion (IC) and exclusion criteria (EC) were defined based on the guidelines proposed by [Kitchenham and Charters 2007a]. Studies were included when they addressed Unplugged Computing or activities carried out without the direct use of computers (**IC1**), investigated Computational Thinking, logical reasoning, or algorithmic thinking (**IC2**), and used games, playful activities, or physical materials for teaching and learning purposes (**IC3**).

Studies were excluded when they were not related to Unplugged Computing (**EC1**), did not focus on Computational Thinking, logical reasoning, or algorithmic thinking (**EC2**),

or focused only on digital environments, software, or programming activities using computers (**EC3**). Studies conducted outside educational settings (**EC4**), duplicate papers (**EC5**), incomplete publications such as abstracts or posters (**EC6**), non-peer-reviewed documents (**EC7**), studies published in languages other than English or Portuguese (**EC8**), studies without full-text access (**EC9**), and secondary studies, such as systematic literature reviews, systematic mappings, and meta-analyses (**EC10**) were also excluded.

3.1.2. Data Extraction and Synthesis Method

Data extraction was conducted using *Parsifal*², Canva³, and Microsoft Excel, based on a form derived from the research questions. The form was piloted on a small set of studies and refined as needed. The first four researchers extracted the data, while the remaining authors reviewed it for completeness and consistency. Disagreements were resolved through discussion until consensus was reached. The extracted data were analyzed using qualitative and descriptive approaches. A thematic grouping process classified pedagogical methodologies (e.g., collaborative learning and embodied learning) and unplugged tools (e.g., board games, card games, and kinesthetic activities), while descriptive statistics were used to identify trends, common findings, and research gaps.

3.2. Conduction

The search strategy was adapted and applied to five digital libraries, resulting in 402 studies: ACM Digital Library (262), Web of Science (47), ScienceDirect (44), Scopus (41), and IEEE Xplore Digital Library (8). After removing 81 duplicate studies, 321 studies remained. The inclusion and exclusion criteria were then applied through the analysis of titles and abstracts, reducing the number of studies to 86. Next, a full-text review was conducted. At this stage, 20 studies were excluded, resulting in a final set of 66 primary studies, published between 2009 and 2026, for data extraction and analysis⁴⁵.

4. Results and Discussions

4.1. General Characterization of the Primary Studies

The temporal distribution of publications, shown in Figure 1, indicates an increase in research on Unplugged Computing over the last decade. From 2009 to 2016, the number of studies was low. Starting in 2017, and especially after 2019, the number of publications increased. This growth is more evident in recent years (2022-2025), which represent more than half of the selected studies. These results show that Unplugged Computing and its role in Computational Thinking education have gained more attention in recent years, especially due to efforts to include computing in basic education.

Regarding publication venues, most studies were published in conferences and journals in Computer Science Education. A large number of studies come from ACM events, such as the ACM Technical Symposium on Computer Science Education (SIGCSE) (S18, S26), the Conference on Innovation and Technology in Computer Science Education (ITiCSE) (S07,

²<https://parsif.al/>

³<https://www.canva.com/>

⁴The data extraction process is available in OSF Repository

⁵The complete list of selected primary studies is available in the external repository OSF Repository

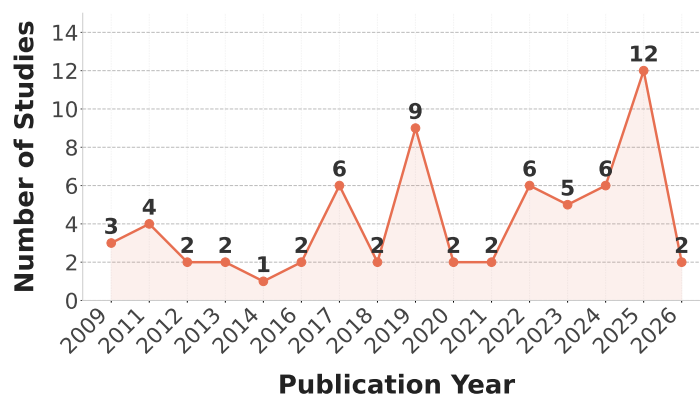


Figure 1. Temporal distribution of the included primary studies.

S29, S33), and the Workshop in Primary and Secondary Computing Education (WiPSCE) (S12, S17, S23).

This distribution shows that Unplugged Computing is mainly studied within the core Computing Education community. This concentration suggests that the field is still strongly connected to teaching and learning research in Computer Science, rather than being widely explored in interdisciplinary areas such as education or psychology. Consequently, while the literature excels at validating the immediate effectiveness of these tools in basic education, it often lacks deeper comparative analyses on the psychological and cognitive differences among diverse student profiles.

4.2. Research Questions Results

The following subsections present the results of the selected studies based on the research questions of this systematic mapping study. The findings summarize unplugged approaches for Computational Thinking, reported empirical evidence, and educational design aspects. They also highlight methodological trends, common practices, and research gaps in Unplugged Computing. Each research question is discussed separately to present the main results.

4.2.1. RQ1 - Types and Characteristics of Unplugged Games and Environments for Computational Thinking

The analyzed studies show that board games, collaborative activities, and paper-based tasks are the most common approaches used to teach introductory Computational Thinking (S11). The most frequent concepts are sequencing (S01, S13, S40, S41, S58, S60), decomposition (S01, S30, S40, S56, S58, S60), and algorithmic thinking (S01, S13, S30, S41, S56, S58), especially in elementary and middle school education. As shown in Figure 2, most studies use general approaches such as CS Unplugged and game-based learning. Some studies also use specific tools, such as board games, card games, and robotics, to support learning activities.

The scientific literature presents different physical and playful resources for teaching Unplugged Computing. These approaches move away from traditional teaching methods and use hands-on and interactive activities. Board games, like those presented in S21, S32, S34, and S58, and card games (S05, S22, S31, and S50) are common resources. They are used to represent logical rules and programming ideas. Examples include cards for teaching conditionals (S22), optimization games such as the Traveling Salesperson Problem (S34),

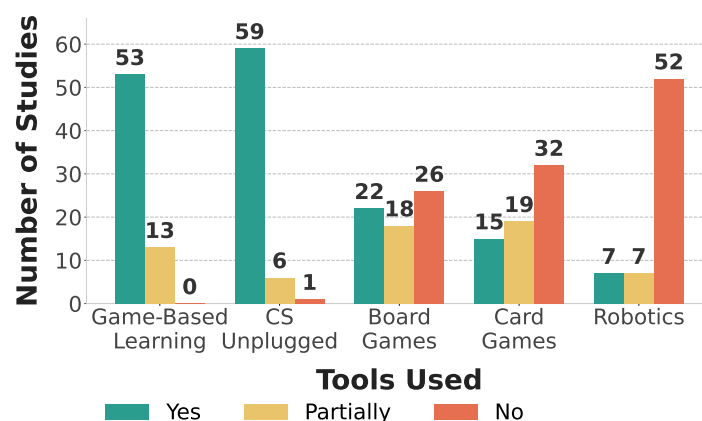


Figure 2. Distribution of the types of tools used across the reviewed studies.

and pattern recognition games like Ghost Blitz and Sushi Go! (S31). Other studies use kinesthetic and physical activities, where students take part in the computation using their bodies and space. Examples include giant sorting networks (S07, S18), physical simulations of concurrency and multicore processing (S29), and role-playing activities (S54).

Besides board games and physical activities, the literature also reports puzzles, magic tricks, tangible interfaces, smart toys, and unplugged robotics as learning resources. Magic tricks are used to explain concepts such as modular arithmetic, binary representation, and algorithms (S09, S15). Puzzles like the Towers of Hanoi are used to introduce recursion and divide-and-conquer strategies (S02, S04). In addition, tools such as KIBO, Cubetto, Bee-Bot, and Qobo allow students to program movements using physical pieces without screens (S41, S43, S55, S60). Some studies also include maker activities, such as weaving (S24) and cross-stitch (S57), to support abstraction, pattern recognition, and sequencing.

These results show that Unplugged Computing is not limited to basic concepts. Most studies focus on core Computational Thinking skills, such as abstraction, decomposition, pattern recognition, and algorithmic thinking. Many activities also introduce programming logic concepts, including sequencing, loops, conditionals, variables, and debugging (S17, S21, S22, S32, S41). An emerging group of studies extends unplugged approaches to more advanced topics, such as Artificial Intelligence and Machine Learning (e.g., KNN simulation S35, S42, S62), Cryptography and Cybersecurity (S16, S38), Concurrent and Parallel Programming (S17, S29), and Quantum Computing (S63).

Regarding educational goals, target audience, and context, most studies focus on primary and secondary education, especially elementary and middle school, as shown in Figure 3. However, unplugged activities are also used in other contexts, such as early childhood education (S43, S55, S60), introductory university courses (S29, S59, S66), and teacher training programs (S26, S33, S47, S64). Across these contexts, the main goal is to increase student engagement, motivation, and collaborative problem solving through active and game-based learning approaches (S05, S14, S34, S56).

Pedagogically, unplugged resources are often used as an introductory step to explain abstract computer science concepts. They help students build basic understanding before moving to visual and block-based programming environments, such as Scratch and Alice S17, S20, S24, S30. In terms of application context, most interventions take place in formal

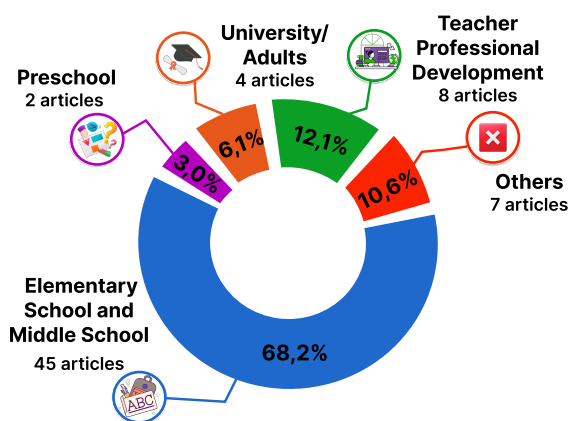


Figure 3. Distribution of target audiences across the reviewed studies

classroom settings. However, many studies also report the use of unplugged activities in extracurricular environments, such as summer camps, after-school coding clubs, and science museums (S16, S18, S30, S62). Some studies also focus on rural, low-resource, or vulnerable communities, showing that unplugged approaches can be used in contexts with limited technological infrastructure. These studies also mention goals related to equity, including gender inclusion and support for language learners (S18, S25, S26, S33, S51). Despite this variety of contexts, the literature still shows a gap in accessibility. Few studies explore in detail how unplugged activities can be adapted for students with disabilities or how inclusive design strategies can be systematically applied in these educational interventions.

Furthermore, a cross-analysis between the pedagogical approaches and the target educational levels reveals a clear methodological progression. In early childhood and elementary education, there is a strong correlation with the use of embodied learning and kinesthetic activities. In these settings, physical space and board games (e.g., S40, S45, S60) are predominantly used to concretize foundational concepts like sequencing and decomposition through gross motor skills. Conversely, studies targeting middle and high school students (e.g., S02, S29, S62) exhibit a shift away from physical movement, favoring instead abstract problem-solving through card games or role-playing to represent complex logic, such as conditionals, optimization, and parallel computing. This indicates that unplugged instructional design is highly age-dependent, evolving from physical simulation in the early years to abstract cognitive modeling in later educational stages.

4.2.2. RQ2 - Empirical Evidence on Unplugged Games for Computational Thinking, Engagement, and Motivation

The reviewed studies use three main research approaches: quantitative, qualitative, and mixed methods. Quantitative studies focus on measuring learning outcomes using statistical analysis. Qualitative studies focus on understanding student behavior and experiences in context. Mixed methods combine both approaches to provide a more complete view of the results [Creswell 2009, Fraenkel et al. 2012]. As shown in Figure 4, the studies present a diverse methodological distribution.

In unplugged computing research, different evaluation tools are used depending on the study design. Quantitative studies often use pre and post-tests and quasi-experimental

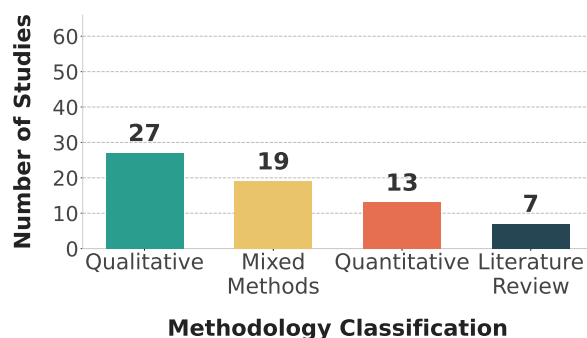


Figure 4. Distribution of research designs across the reviewed studies

designs. Common instruments include the Computational Thinking Test (CTt), Bebras tasks, and early childhood tools such as TechCheck-K and OSCTU (S45, S47, S48, S49, S55). While these instruments provide quantitative data, they differ significantly in their scope and target audiences. For instance, the CTt and Bebras tasks are typically employed for primary and middle school students to assess algorithmic logic, abstractions, and problem-solving skills. In contrast, tools like TechCheck-K and OSCTU are tailored for early childhood education, often utilizing age appropriate, screen free formats to evaluate foundational concepts. However, a major limitation identified across the studies is the lack of consensus on how these instruments are applied and compared. Because they measure different cognitive constructs of Computational Thinking, cross-study comparability is severely restricted. This fragmented evaluation landscape makes it difficult to conduct comprehensive meta-analyses and highlights the urgent need for standardized, multi-dimensional assessment frameworks that can be consistently adapted across different educational levels. Beyond quantitative assessments, qualitative studies use observations, interviews, focus groups, think-aloud protocols, and game analysis to understand student behavior (S13, S43, S49, S58). Furthermore, mixed-method studies combine both types of data to comprehensively measure learning outcomes while simultaneously explaining engagement and collaboration processes.

Regarding learning outcomes, while most studies report positive baseline effects of unplugged activities on Computational Thinking (S01, S27, S31, S48, S55), a deeper comparative analysis reveals important differences depending on the instructional design and target audience. For instance, while purely physical and kinesthetic approaches are highly effective for engaging early childhood and elementary students in basic CT concepts (S45, S60), studies targeting middle and high school students (e.g., S02, S29, S62) suggest that older learners require a more explicit and faster transition to digital tools to sustain cognitive gains and apply complex concepts like parallel computing or Artificial Intelligence.

Furthermore, comparative studies present divergent results when evaluating unplugged versus plugged methods. While some authors argue that unplugged approaches can be as effective as traditional methods for introductory learning (S11) and may promote better long-term retention of abstract concepts such as sorting algorithms (S50), other studies highlight distinct limitations. For example, S17 observed that students who started with unplugged activities struggled more with programming syntax when transitioning to visual environments (like Scratch) compared to those who learned directly on computers. These differences indicate that unplugged computing is not a universal replacement for digital interaction, but rather a context-dependent scaffolding strategy whose effectiveness relies heavily on how the teacher bridges the physical-digital gap.

In addition to cognitive results, the studies report positive effects on engagement and motivation. Students show higher participation, curiosity, and classroom interaction during unplugged activities (S09, S15, S29, S59). These activities also support collaboration, as students often work in groups to solve problems, share strategies, and discuss solutions (S02, S22, S34, S42). However, some limitations are also reported. Many studies use small sample sizes or do not include control groups, which limits the strength of the evidence (S02, S06, S14, S31, S34; S01, S22, S27, S33). Most interventions are short-term, and there are few long-term studies that evaluate lasting learning effects (S16, S18, S32, S40, S50).

4.2.3. RQ3 - Educational Design Principles, Usability, and Inclusion in Unplugged Games and Environments

This research question analyzes how educational design principles, usability aspects, and inclusion strategies are used in unplugged computing activities. Figure 5 shows that most studies are based on active learning, game-based learning, and constructionist approaches (S01, S13, S21, S41). These approaches indicate a clear focus on learning by doing, where students build knowledge through interaction and problem solving. Across the studies, problem-solving and collaboration appear as central design elements (S05, S22, S48, S54). Students are often required to work in groups, discuss strategies, and jointly solve tasks. This supports engagement and shared reasoning. In addition, many activities use embodied and kinesthetic learning, where students simulate computational processes using their bodies and physical space (S06, S27, S43, S62). These strategies help make abstract concepts more concrete and easier to understand. Gamification elements are also frequently used to maintain motivation and improve usability during activities (S12, S34, S55, S59). Some studies also highlight participatory design, involving teachers in the creation of the activities to better align them with classroom needs (S36, S37).

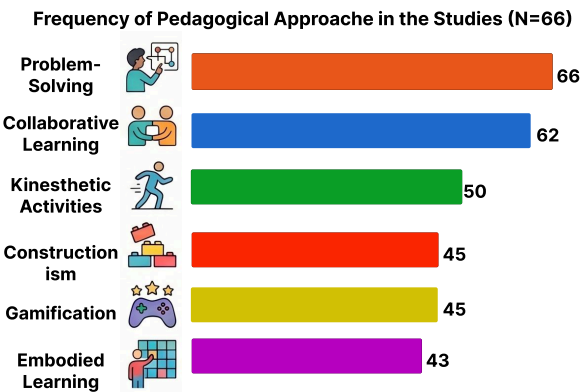


Figure 5. Frequency of pedagogical methodologies across the reviewed studies

Concerning inclusion and equity, the studies show that unplugged activities can support different educational contexts and student profiles. Some works use culturally relevant activities, such as cross-stitch and crafting tasks (S57) or cooking-based activities (S51), to connect computing concepts with students’ daily experiences. These approaches also help increase participation of girls in computing education (S25). Other studies adapt activities for English Language Learners by using visual support and collaborative interaction instead of technical vocabulary (S33). However, despite these advances, there is still limited work on

accessibility. Few studies propose unplugged activities specifically designed for students with physical or cognitive disabilities.

The analysis also reveals important challenges and best practices. A common challenge is the difficulty students have in connecting unplugged activities with formal computing concepts, known as the “transfer gap” (S03, S10). In some cases, students enjoy the activities but do not fully understand their relation to programming or Computational Thinking. To address this issue, studies highlight the importance of teacher mediation and structured reflection. Effective approaches include guided discussions after activities and clear connections between unplugged tasks and programming concepts, often described as an “unplugged-to-plugged” transition (S17, S32). These practices help students link physical experiences to formal computational thinking concepts.

4.3. Threats to Validity

The execution of this systematic mapping study is subject to some threats to validity. These threats were reduced through a planning process based on Kitchenham’s guidelines [Kitchenham and Charters 2007a].

Construct Validity. To mitigate the risk of omitting relevant primary studies, the search string was iteratively refined using synonyms and alternative terms for Unplugged Computing, Computational Thinking, and educational games. After validation through pilot searches, the final search was conducted across five major digital libraries (ACM Digital Library, IEEE Xplore, Scopus, Web of Science, and ScienceDirect), maximizing the coverage of the relevant literature.

Internal Validity. To reduce selection bias, inclusion and exclusion criteria were established *a priori*. Studies were selected through a structured process involving title, abstract, and full-text screening, with all decisions documented. Disagreements were resolved by consensus, with an external expert consulted when necessary to support the final decision.

External Validity. The generalizability of the findings is constrained by publication bias and the heterogeneity of the included studies. Despite searching five major digital libraries, studies reporting positive or statistically significant outcomes are more likely to be published, potentially influencing the synthesized evidence. Moreover, differences in educational level, cultural context, intervention design, and duration limit the applicability of the findings beyond the investigated settings.

Conclusion Validity. To ensure consistency, a predefined standardized extraction form was applied to all included studies. It systematically captured data on pedagogical approaches, assessment methods, target groups, and intervention outcomes, reducing subjective interpretation while improving the traceability and reproducibility of the synthesis.

5. Future Research Agenda

Although the results of this SMS demonstrate the relevance and growing maturity of Unplugged Computing for Computational Thinking development, the analysis also reveals structural limitations in the current body of knowledge. In particular, the literature is still characterized by fragmentation, methodological fragility, and limited theoretical consolidation, which restricts its evolution from exploratory interventions to a more robust and evidence-driven research field.

To address these limitations, this section proposes a structured Future Research Agenda, as outlined in Table 2. The agenda is organized into three complementary dimensions: Research Direction, Problem Statement, and Expected Contribution. Each direction is grounded in gaps identified across the 66 primary studies and reflects recurring issues observed in RQ1-RQ3, especially regarding evaluation rigor, accessibility, scalability, and theoretical grounding of unplugged interventions.

Table 2. Future Research Agenda for Unplugged Computing and Computational Thinking

Problem Statement	Evidence from Literature	Expected Contribution
Current studies rely heavily on short-term interventions and small samples, limiting causal inference and generalization of CT gains over time.	(S02, S06, S16, S18, S31, S50) report short interventions and lack of longitudinal follow-up.	Development of longitudinal experimental designs and validated assessment frameworks for sustained CT measurement.
There is no consensus on how CT should be measured, resulting in fragmented and non-comparable evaluation practices.	Multiple instruments (CTt, Bebras, TechCheck-K, OSCTU) are used inconsistently across studies (S45, S47, S48, S55).	Establishment of standardized, multi-dimensional CT assessment frameworks adaptable across educational levels.
Accessibility remains largely underexplored, with limited adaptation for learners with disabilities.	Few studies address accessibility beyond gender or language inclusion (S25, S33, S51).	Design of Universal Design for Learning (UDL)-based unplugged frameworks for inclusive CT education.
The field lacks a unified theoretical framework connecting pedagogical strategies, cognitive processes, and CT development mechanisms.	Studies are often empirical and isolated, without explicit theoretical grounding (S01, S13, S41).	Development of a conceptual model linking unplugged activities to CT cognitive constructs.
Students often fail to connect unplugged activities to formal programming concepts (transfer gap).	Reported in multiple studies highlighting the need for explicit scaffolding (S03, S10, S17, S32).	Design of structured transition models between unplugged activities and programming environments.
Many interventions are designed as isolated experiments rather than scalable classroom solutions.	Limited evidence of long-term integration in school curricula and teacher adoption (S16, S30, S62).	Development of scalable instructional models and teacher-ready unplugged curricula.

6. Conclusions and Directions for Future Research

This SMS presents an overview of the scientific literature on Unplugged Computing for Computational Thinking development. It summarizes the main approaches, educational contexts, empirical results, and pedagogical characteristics reported in the field. The results show a clear increase in publications in recent years, especially between 2022 and 2025. This growth indicates that Unplugged Computing is becoming an important topic in Computing Education research. It also shows that unplugged activities are increasingly recognized as useful approaches to support Computational Thinking in different educational settings.

The findings show that unplugged activities are applied across diverse educational levels and learning environments, using games, collaborative tasks, and physical learning resources. Overall, the studies indicate that these approaches support the introduction of computational concepts, enhance student engagement, and promote active learning, particularly in technology-constrained contexts. This mapping consolidates previously fragmented evidence, highlighting research trends, methodological approaches, key challenges, and opportunities for future research.

Despite recent advances, important gaps remain. Future research should adopt more standardized evaluation methods, conduct longitudinal studies to assess long-term learning effects, and prioritize accessibility and inclusion. In particular, more studies are needed to design and evaluate unplugged learning environments grounded in Universal Design for Learning principles, ensuring Computational Thinking education is accessible to diverse learners.

Using of AI tools

During the preparation of this manuscript, generative AI tools were used to assist with text structuring and grammatical revision. The SMS was planned and conducted entirely by the authors without AI support. Moreover, authorship and full responsibility for the final content, including plagiarism checking and corrections, are attributed to The first author.

Acknowledgments

The authors would like to thank the Research Support Foundation of the State of Minas Gerais (FAPEMIG) for their financial support and the Federal University of Lavras (UFLA) for the infrastructure provided during the execution of this research, which made its presentation possible.

References

- Battal, A., Afacan Adanır, G., and Gülbahar, Y. (2021). Computer science unplugged: A systematic literature review. *Journal of Educational Technology Systems*, 50(1):24–47.
- Bell, T., Witten, I. H., and Fellows, M. (2009). *Computer Science Unplugged*. CS Unplugged, 2 edition.
- Bell, T., Witten, I. H., and Fellows, M. (2015). Computer science unplugged: An enrichment and extension programme for primary-aged children. Available at <https://csunplugged.org>.
- Brackmann, C. P., Román-González, M., Robles, G., Moreno-León, J., Casali, A., and Barone, D. (2017). Development of computational thinking skills through unplugged activities in primary school. In *Proceedings of the 12th Workshop on Primary and Secondary Computing Education*, pages 65–72.
- Brennan, K. and Resnick, M. (2012). New frameworks for studying and assessing the development of computational thinking. In *Proceedings of the 2012 annual meeting of the American educational research association, Vancouver, Canada*, volume 1, page 25.
- Chen, P., Yang, D., Metwally, A. H. S., Lavonen, J., and Wang, X. (2023). Fostering computational thinking through unplugged activities: A systematic literature review and meta-analysis. *International Journal of STEM Education*, 10(1):47.
- Creswell, J. W. (2009). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE Publications, Thousand Oaks, CA, 3rd edition.
- Dieste, O., Grimán, A., and Juristo, N. (2009). Developing search strategies for detecting relevant experiments. *Empirical Software Engineering*, 14(5):513–539.
- Fraenkel, J. R., Wallen, N. E., and Hyun, H. H. (2012). *How to Design and Evaluate Research in Education*. McGraw-Hill, New York, NY, 8th edition.
- Grover, S. and Pea, R. (2013). Computational thinking in k–12: A review of the state of the field. *Educational Researcher*, 42(1):38–43.
- Huang, W. and Looi, C.-K. (2021). A critical review of literature on “unplugged” pedagogies in k–12 computer science and computational thinking education. *Computer Science Education*, 31(1):83–111.

- Kitchenham, B. and Charters, S. (2007a). Guidelines for performing systematic literature reviews in software engineering. Joint report, Keele University and Durham University.
- Kitchenham, B. and Charters, S. (2007b). Guidelines for performing systematic literature reviews in software engineering. Technical report, Keele University and Durham University Joint Report.
- Munir, H., Moayyed, M., and Petersen, K. (2014). Considering rigor and relevance when evaluating test driven development: a systematic review. *Information and Software Technology*, 56(4):375–394.
- Petersen, K., Vakkalanka, S., and Kuzniarz, L. (2015). Guidelines for conducting systematic mapping studies in software engineering. *Information and Software Technology*, 64:1–18.
- Resnick, M., Maloney, J., Monroy-Hernández, A., Rusk, N., Eastmond, E., Brennan, K., Millner, A., Rosenbaum, E., Silver, J., Silverman, B., and Kafai, Y. (2009). Scratch: Programming for all. *Communications of the ACM*, 52(11):60–67.
- Shute, V. J., Sun, C., and Asbell-Clarke, J. (2017). Demystifying computational thinking. *Educational Research Review*, 22:142–158.
- Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, 49(3):33–35.
- Zhang, X., Chen, Y., Hu, L., Hwang, G.-J., and Tu, Y.-F. (2025). Developing preschool children’s computational thinking and executive functions: Unplugged vs. robot programming activities. *International Journal of STEM Education*, 12(10):1–18.