Unplugged Activities for Developing Computational Thinking: A Bibliometric Analysis

Edna K. Conde V.[1,*,†], Hamirson Z. Barrera R.[1,†]

[1]Adventist University Corporation, Medellin, Colombia

Abstract

This paper presents a structured bibliometric analysis pipeline designed to evaluate the impact and implementation dynamics of "unplugged" activities for developing computational thinking. Given the importance of fostering digital literacy in contexts with limited technological resources, mapping the existing educational literature requires a systematic approach. The proposed system processes a corpus of 78 scientific articles through a three-phase workflow: data retrieval, bibliometric processing, and visual clustering using VOSviewer. The execution of this pipeline successfully identified five predominant thematic clusters, revealing that unplugged activities are highly effective at early educational stages, act as an equitable bridge for learning, and achieve optimal results when integrated into hybrid approaches. Ultimately, this system description demonstrates how automated bibliometric frameworks can effectively identify research trends, validating unplugged strategies as foundational components for inclusive computing education.

Keywords

Computational thinking, Unplugged activities, Bibliometric analysis system, Digital gap, Visual clustering

1. Introduction

Computational thinking has established itself as a critical skill in contemporary education by promoting the development of higher-order cognitive processes, such as abstraction, the decomposition of complex problems, pattern recognition, and the design of algorithmic solutions. Introducing it at an early age has proven most effective through the use of "unplugged" activities, which foster the construction of solid knowledge structures without relying on digital tools [1]. However, integrating these approaches into educational environments continues to face challenges related to teaching methodologies and available resources.

In this context, unplugged strategies emerge as an accessible alternative for fostering the development of computational thinking. Various studies have demonstrated their positive impact on strengthening logical reasoning, problem-solving, and other computational thinking skills among elementary and secondary school students [2].

In Latin America, these proposals take on particular significance due to persistent digital divides and limited access to technological resources. In this context, unplugged activities offer an alternative for promoting more equitable education, provided that their design and implementation are appropriate to the social, cultural, and educational characteristics of the contexts in which they take place [3].

Consequently, this study aims to analyze the impact and implementation dynamics of offline activities on the development of computational thinking through a process of bibliometric analysis. Based on an examination of the scientific literature, the study seeks to identify the main research trends, predominant themes, and emerging lines of work that can help guide future research and strengthen the design of evidence-based educational practices.

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*Corresponding author.

†These authors contributed equally.

docente.econdev@unac.edu.co (E. K. C. V.); hzbarrerar@unac.edu.co (H. Z. B. R.)

https://www.linkedin.com/in/katheecv (E. K. C. V.); https://www.linkedin.com/in/zamirtbarrera/ (H. Z. B. R.)

0009-0009-1105-2651 (E. K. C. V.); 0000-0002-8427-1654 (H. Z. B. R.)

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2. Proposed Approach

To address the objectives of this study, we propose a structured bibliometric analysis pipeline. This system is designed to process and evaluate scientific output from a quantitative perspective, assessing the impact of publications and the scientific productivity of authors, institutions, journals, and countries [4]. The proposed pipeline operationalizes indicators and metrics of publication impact, such as citation counts [5] and the h-index [6]. Beyond simple metric extraction, this analytical framework provides a broad view of the dynamics of knowledge. It functions as a system for identifying the most reliable and influential sources of scientific publication and leading scientific actors, thereby laying the foundations for guiding new developments in the field [7]. To execute this approach, our system is divided into three sequential processing phases: (1) Data retrieval and filtering, (2) Bibliometric processing, and (3) Visual mapping and clustering.

3. Resources Used

To conduct the bibliometric analysis, a structured process was carried out that initially consisted of a literature review following methodological criteria that ensure the transparency and reproducibility of the process. Based on this review, the articles that made up the set of documents used for the bibliometric analysis were identified and selected.

In this regard, inclusion and exclusion criteria were established to guide the selection of documents. Scientific articles published between 2013 and 2025 that focused on the use of playful tools to strengthen computational thinking were considered. Additionally, open-access documents (all open access) were prioritized to ensure the availability and verifiability of the information. Regarding document types, only research articles, conference papers, and review articles were selected.

The search phase was conducted in the Scopus database in August 2025, using a search equation designed to retrieve relevant literature aligned with the study's objectives:

$$\begin{gathered}\text{TITLE-ABS-KEY (”computational thinking” AND unplugged AND activit*)}\\ \text{AND PUBYEAR} > 2012 \text{ AND PUBYEAR} < 2026 \text{ AND (LIMIT-TO (OA, ”all”))}\end{gathered} \tag{1}$$

Finally, the data was processed and analyzed using VOSviewer software, a tool specialized in the construction and visualization of bibliometric maps [8]. This tool allows for the identification and grouping of related terms through a network of keyword co-occurrences, which facilitates the construction of thematic clusters that reflect the main lines of research in the analyzed field [8].

4. Results

A total of 78 studies were identified, which constituted the document corpus used for the bibliometric analysis process. Based on this set of publications, the main trends in scientific output, the documents with the greatest impact, and the conceptual structure of the field of study were analyzed. To this end, the temporal evolution of the publications was examined, and a co-occurrence analysis of keywords was conducted, which allowed for the identification of thematic clusters represented by different colors in the network. The grouping of terms within each cluster facilitated the identification of the main lines of research and the conceptual relationships between them. The complete list of the analyzed articles is available at the following link:

https://ingenieria.unac.edu.co/~edna.conde/pensamiento_computacional/LISTADO%20ARTICULOS.pdf

4.1. Featured Research Topics

A keyword co-occurrence analysis was conducted by constructing a network using the VOSviewer application to identify the main thematic clusters. Based on this network, groups of highly related

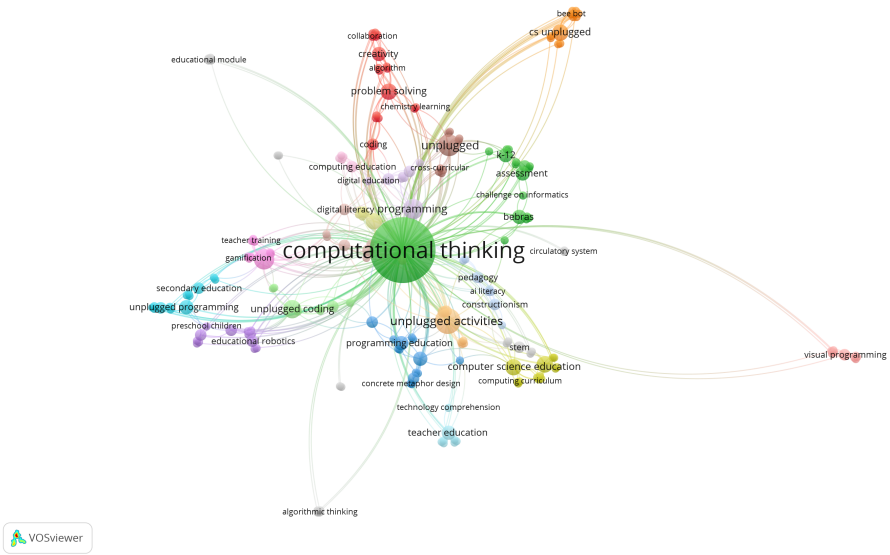

Figure 1: Co-ocurrence network generated using VOSviewer

terms were identified, which made it possible to analyze the conceptual structure of the field and understand the relationships between different lines of research. In addition, a detailed review of the selected documents was conducted, which allowed us to cross-check the information obtained from the co-occurrence network and validate the identification of the clusters. This process also facilitated the identification of relevant aspects such as the target audience of the studies and the strategies or tools implemented to develop computational thinking.

Figure 1 presents the keyword co-occurrence network generated with VOSviewer, which visualizes the thematic clusters identified in the field of study. Each color represents a group of terms, highlighting the main lines of research and the conceptual structure of the field.

Based on a review of the documents, common patterns were identified in terms of the target audience and the strategies used to develop computational thinking. This analysis made it possible to supplement the co-occurrence network and consolidate the definition of the thematic clusters, grouping the studies according to their pedagogical and contextual characteristics.

In this regard, five clearly differentiated clusters are proposed.

4.1.1. Cluster 1: Early Childhood, Elementary, and Secondary Education

First, a cluster focused on early childhood, elementary, and secondary education, located primarily on the left side of the network, in which studies targeting children and youth engaged in unplugged activities predominate [9, 10, 11, 12, 13, 14, 15, 16, 3, 17, 18]; physical, board, and card games [19, 2, 20, 21, 22]; kinesthetic activities and exercises, where information is best processed through movement, touch, and physical experience [23, 24**?** , 25, 26]; graphs and maps [27]; art workshop [1]; algorithms using kitchen utensils and real food [28]; algorithmic explanations on paper [29, 30]; and programming on paper [31, 32].

Studies agree that unplugged activities are an effective strategy for developing computational thinking in early childhood, elementary, and secondary education, demonstrating significant effects on skills such as logic, pattern recognition, and algorithmic reasoning. These methodologies are viable from an early age and promote conceptual understanding, learning, participation, collaborative work, and motivation, although their impact depends on factors such as the teacher, the activity design, and the educational context.

Furthermore, it has been observed that the development of computational thinking is influenced by variables such as age, educational level, and sociocultural background; therefore, teaching and

strengthening these skills is most effective when adapted to these characteristics and supported by appropriate pedagogical approaches.

4.1.2. Cluster 2: Teacher Training and Higher Education

A second cluster corresponds to teacher training and higher education, including college students and teachers in training or currently in the field. This cluster is located at the bottom of the network and is dominated by studies involving practicing teachers, as well as future teachers and college students from various majors.

Studies show that offline activities have great potential to facilitate the understanding of complex concepts by providing concrete, accessible, and meaningful experiences [33, 34, 35]. In this regard, teacher and university education benefits significantly from practical, progressive, and hybrid approaches—that is, those that combine these activities with digital tools [36, 37, 38, 39].

4.1.3. Cluster 3: Programming and Educational Robotics

A third cluster is visible in the lower left part of the network and focuses on visual, block-based, and paper-based programming [40, 41, 42, 43], educational robotics [44], and a hybrid approach involving programming or robotics and offline activities [45, 46, 47, 48, 49, 50, 51, 52]. Studies show that both robotics and visual programming have a positive impact on computational thinking. Educational robotics is most effective at an early age [47, 48, 51, 52], while visual programming is more suitable at higher levels [45, 48].

4.1.4. Cluster 4: Assessment

Likewise, a cluster focused on the assessment of computational thinking is identified on the right side of the network. In this cluster, Bebras emerges as a key international reference for providing tasks that assess computational skills without the need for programming [53, 54, 55, 56, 57].

Studies show that these types of instruments are not only valid for measuring computational thinking but can also be used as teaching tools, leading to significant improvements in skills such as abstraction, decomposition, and algorithmic thinking [53, 54, 56].

Furthermore, there have been notable advances in the development of assessment frameworks and tools, such as assessment matrices [58], hands-on challenges [59], constructivist projects [60], and specific tests [61, 62, 57], which seek to measure not only performance but also aspects such as student autonomy, skill progression, and the learning context.

4.1.5. Cluster 5: Soft Skills

Finally, a cluster associated with soft skills is identified, located at the top of the network, grouping terms such as creativity, collaboration, and problem solving. This cluster represents the connection between computational thinking and 21st-century skills. It links pedagogical approaches or active methodologies such as collaborative learning [63, 64] and gamification [63].

It is evident that computational thinking is closely linked to emotional and motivational factors [65, 66], positioning it not only as a technical skill but also as a vehicle for students' holistic development, in which active methodologies and the socio-emotional component play a key role.

4.2. Future Research Areas

Table 1 presents the proposed research topics for future studies and the references supporting each of these contributions.

This organization allows us not only to visualize current trends in research on computational thinking and its reinforcement through unrelated activities, but also to identify gaps and opportunities for study, facilitating a structured understanding of the field and guiding the development of future research.

Table 1
Summary of future research topics identified in each cluster.

Cluster	Topics for Future Research
1. Early Childhood, Elementary, and Secondary Education	• Explore the cognitive and affective factors of learning [18, 26, 67]. • Assessing the impact and expanding the empirical evidence by conducting studies with larger samples, in different contexts and areas of the curriculum, and using more robust methodologies [2, 68, 31, 15, 17, 67]. • Creation of progressive programs integrated into the curriculum [19, 29, 25]. • Design of educational resources and teaching materials accessible to students and the general public [9, 27, 22].
2. Teacher Training and Higher Education	• Strengthening teacher training in computational thinking [36, 39]. • Validating theoretical models in different educational contexts [34, 37, 38]. • Investigating the influence of the educational context and institutional resources [36, 38]. • Implementing new teaching strategies [33, 35].
3. Programming and Educational Robotics	• Expansion of robotics and programming to more grade levels [41, 42, 51]. • Integration of robotics and programming into the curriculum [44, 47, 50, 51]. • Combination of quantitative and qualitative data [50, 43, 52]. • Longitudinal studies to analyze whether improvements are sustained over time [45, 48].
4. Assessment	• Assess the long-term retention of skills and the cumulative impact of extended interventions [61, 60, 53, 54, 57]. • Confirm findings across diverse populations [58, 61, 53, 56, 57]. • Develop digital tools for assessment and use more advanced predictive models [62, 69, 57]. • Optimizing the pedagogical quality of tasks [58, 70, 59]. • Comparison of pedagogical approaches [61, 60, 53, 54].
5. Soft Skills	• Analyze long-term effects on motivation, performance, and learning [23, 71, 64]. • Identify the optimal time to transition from unplugged activities to digital tools [63, 64, 72]. • Design personalized strategies based on age, gender, and grade level [65, 73, 63, 74]. • Identify barriers to implementation [66, 28, 75]. • Diversify technology and educational tools [76, 63, 75].

5. Conclusions

After completing the analysis of the collected scientific literature, it can be concluded that computational thinking is undergoing a process of maturation in which its dependence on hardware is being successfully challenged. The trend of sustained growth identified in the bibliometric analysis is not merely an academic fad, but a response to the need for digital literacy in a complex world. It has been demonstrated that unplugged activities are not a secondary resource compared to computers; on the opposite, they constitute the ideal pedagogical foundation for abstraction and logic to develop in a natural and tangible way, especially in the early stages of education.

One of the most significant findings of this research is the ability of these strategies to serve as bridges to equity. In contexts where technological resources are limited, the "unplugged" approach removes the technical barrier and allows students to focus on the thought process rather than the tool. This approach transforms computer science education into an inclusive experience, where play and physical movement become vehicles for understanding concepts that were traditionally considered difficult. However, it is vital to emphasize that the success of these interventions does not depend on chance, but rather on strong teacher guidance and the ability to progressively integrate these dynamics into hybrid models.

Regarding the implications for future publications and educational practices, this study highlights the importance of moving away from viewing computational thinking as a subject isolated from technology. Future lines of research should focus on how these skills, once cultivated through analog methods, transfer and enhance performance when students eventually access digital programming environments. Finally, this review reaffirms that teaching students to think does not require a computer screen, but

rather a well-designed pedagogy that values creativity and problem-solving as the primary drivers of 21st-century education.

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Declaration on Generative AI

During the preparation of this work, the authors used ChatGPT (OpenAI, GPT-5.5) to assist with grammar and spelling correction and improve the clarity and readability of the manuscript. After using this tool, the authors carefully reviewed and edited all the content and take full responsibility for the accuracy, originality, and integrity of the publication.

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