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GLOBAL ACADEMIC EXCELLENCE

A BIBLIOMETRIC ANALYSIS OF COMPUTATIONAL THINKING IN SCIENCE LITERACY FOR EARLY CHILDHOOD EDUCATION

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Abstract:

This study explores the burgeoning field of Computational Thinking (CT) within Science Literacy for Early Childhood Education, highlighting its increasing significance in developing essential skills for the digital age. Despite the recognized importance of integrating CT in early educational curricula, there remains a substantial gap in comprehensive, empirical studies that map the evolution and impact of this integration. Employing a bibliometric analysis, this research utilized Scopus Analyzer and VOSviewer software to examine scholarly publications and delineate trends and patterns in the literature. A total of 1,027 documents were analyzed to extract data on publication trends, keyword occurrences, and international co-authorship dynamics. The analysis reveals a significant increase in research output over recent years, emphasizing the growing academic and educational interest in CT. The most frequent keywords associated include "computational thinking," "programming," and "educational technology," which are often linked with interactive and interdisciplinary teaching methods enhancing problem-solving and critical thinking skills among early learners. Additionally, the study identifies robust collaborative networks across highly contributing countries like the United States, the United Kingdom, and Taiwan, which are pivotal in advancing the research and application of CT in science literacy. The findings underscore the critical role of CT in early childhood education as a catalyst for developing future-ready skills, suggesting an ongoing need for strategic educational reforms and enhanced teacher training programs to integrate CT effectively into early childhood curricula. The study concludes that while the interest and research in CT are growing, concerted efforts are necessary to optimize its educational implementation and impact.

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Keywords:

Computational Thinking, Science Literacy, Learning, Education, Early Childhood.

Introduction

Computational thinking (CT) has emerged as a critical skill in the digital age, essential for problem-solving and understanding complex systems. Integrating CT into early childhood education is increasingly recognized as a foundational step in fostering these skills from a young age. Research indicates that early exposure to CT can significantly enhance children's abilities in pattern recognition, sequencing, and algorithm design, which are fundamental components of CT (Saxena et al., 2020; Bati, 2021). By embedding CT within the context of physical and natural science courses, educators can create engaging and developmentally appropriate learning experiences that promote these skills (Kalogiannakis & Kanaki, 2020). Implementing CT in early childhood education often involves a combination of unplugged and plugged activities. Unplugged activities, which do not require digital devices, provide young learners with concrete experiences that are crucial for their cognitive development (Saxena et al., 2020; Bati, 2021).

These activities can be designed to be playful and interactive, leveraging game-based and project-based learning principles to maintain children's interest and motivation (Kalogiannakis & Kanaki, 2020; González-González et al., 2021). For instance, educational robotics and interactive programmable toys have been shown to effectively support the development of CT skills in preschoolers by fostering creativity, collaboration, and problem-solving (González-González et al., 2021; Wang et al., 2021). Teachers play a pivotal role in facilitating CT learning in early childhood classrooms. Effective CT instruction requires educators to employ a range of scaffolding strategies, such as questioning, modeling, and providing motivation and encouragement (Wang et al., 2021; Rehmat et al., 2020). Professional development and support for teachers are essential to equip them with the necessary skills and knowledge to integrate CT into their teaching practices effectively. Additionally, inclusive approaches that address diversity and eliminate gender stereotypes are crucial to ensure that all children, regardless of background, have the opportunity to develop CT skills (González-González et al., 2021).

Literature Review

Computational thinking (CT) has increasingly been recognized as an essential skill for early childhood education, offering foundational support for science literacy and STEM fields. Studies emphasize the developmental appropriateness of CT activities, asserting that young children can meaningfully engage with computational principles through age-suitable tools and activities that strengthen literacy and logical reasoning (Bers, 2018; Miguel, 2023; Gao *et al.*, 2023). Moreover, research such as that by Quinn *et al.* (2023) underscores the importance of cultural relevance, showing that embedding CT within familiar cultural contexts can enhance engagement and foster a sense of belonging in STEM fields among young learners. The culturally inclusive robotics program discussed in their study reflects an innovative approach to making computational skills accessible and meaningful for diverse preschool classrooms.
The integration of CT with traditional literacy frameworks has been explored through both screen-based and unplugged programming tools. For example, Umaschi Bers (2019) advocates for "Coding as Another Language," a pedagogical approach designed to merge CT and literacy learning in a developmentally appropriate manner. This framework is echoed by Campollo-

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Urkiza (2023), who introduces music as a medium for unplugged CT activities, thereby broadening CT learning opportunities beyond digital screens. Using tangible tools like KIBO and ScratchJr supports this integration, providing young children with interactive, non-screen methods to develop a computational understanding (Campollo-Urkiza, 2023; Bers, 2018). Studies by Metin *et al.* (2024) also emphasize the need for valid assessment tools for CT in early childhood, with the Turkish adaptation of TechCheck-K offering insights into effective evaluation methods. Collectively, these studies illustrate the potential of diverse pedagogical approaches, highlighting both the strengths of combining CT with various subjects and the limitations of relying on digital-only methods.

Despite these advances, notable gaps in current CT research for early childhood remain, particularly regarding the cultural adaptation of CT frameworks and the scarcity of empirical data validating such adaptations. For instance, Levinson & Bers (2024) illustrate successfully adapting the "Coding as Another Language" framework for prekindergarten classrooms, suggesting that CT curricula can be adapted across various educational settings. However, the research also highlights challenges faced by teachers in integrating these curricula, especially in bilingual or multicultural settings. This points to a broader need for research on culturally adaptive CT models that address diverse linguistic and socioeconomic backgrounds (Quinn et al., 2023; Otterborn et al., 2020). As CT continues to be integrated into early education, more research is needed to empirically assess these cultural adaptations and their long-term effects on science literacy and computational skills development.

Future research is also necessary to investigate the socio-emotional dimensions of CT in early childhood education. According to Bers (2021), the "Coding as Another Language" approach, which incorporates socio-emotional learning, allows children to develop positive behaviors and moral values alongside computational skills. Similar findings by Castellanos et al. (2023) indicate that engaging with CT concepts can enhance students' collaborative and reflective abilities, suggesting that CT learning may foster socio-emotional growth. However, research exploring these intersections is limited, and additional empirical studies are required to confirm the socio-emotional benefits of CT, particularly in diverse and inclusive classroom environments.

In conclusion, current research demonstrates promising advancements in integrating computational thinking into early childhood science literacy through culturally relevant, inclusive, and developmentally appropriate methods. Meanwhile, tools like TechCheck-K and programs such as "Coding as Another Language" provide solid foundations. Further research is needed to address cultural inclusivity, valid assessment methods, and the socio-emotional dimensions of CT learning. Future studies could greatly benefit by focusing on the longitudinal outcomes of these approaches, potentially uncovering how early exposure to CT influences children's STEM engagement and proficiency in the years to come.

Research Question

What are the research trends in online learning studies according to the year of publication?

a. Who and how much has been published in the area with regard to the authors?
b. Who are the top 10 authors based on citation by research?
c. What are the popular keywords related to the study?
d. What are co-authorship countries' collaboration?

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Methodology

Bibliometrics involves collecting, managing, and analyzing bibliographic information from scientific publications (Alves *et al.*, 2021; Assyakur & Rosa, 2022; Verbeek *et al.*, 2002). This field covers basic descriptive statistics like publishing journals, publication years, and main author classifications (Wu & Wu, 2017), as well as more complex techniques such as document co-citation analysis. Conducting a successful literature review requires an iterative process: identifying appropriate keywords, searching the literature, and thoroughly analyzing the findings to build a comprehensive bibliography and achieve reliable results (Fahimnia *et al.*, 2015).

With this in mind, our study focused on top-tier publications because they provide valuable insights into the theoretical perspectives shaping the evolution of the research domain. To ensure the reliability of our data, we relied on the SCOPUS database for data collection (Al-Khoury *et al.*, 2022; di Stefano *et al.*, 2010; Khiste & Paithankar, 2017). Additionally, we included only articles published in rigorously peer-reviewed academic journals, deliberately excluding books and lecture notes to maintain high quality (Gu *et al.*, 2019). Notably, Elsevier's Scopus, known for its extensive coverage, enabled us to collect publications from 2018 to 2024 for our analysis.

Data Search Strategy

Advanced searching is a method used in databases and search engines to refine and narrow down search results by applying specific criteria or filters. Unlike a simple keyword search, which often yields a broad set of results, advanced searching allows users to include multiple parameters and conditions to locate the most relevant information efficiently. This technique is especially valuable in academic and research databases, where precision and relevance are crucial.

In advanced searching, users can combine keywords with Boolean operators (like AND, OR, and NOT) to connect terms in a way that defines their relationship. For instance, using "AND" between keywords requires both terms to appear in the results, while "OR" expands the search by including results with either term. Additionally, advanced searches often include filters for criteria such as publication year, language, document type, subject area, and author names. This targeted approach enables users to focus on recent publications, specific languages, or certain types of documents (e.g., peer-reviewed articles only).

Table 1

The search string.

Scopus	**TITLE-ABS-KEY ((computational AND thinking) AND (skills OR learning) AND (science) AND (children OR preschool OR learning OR kindergarten) AND (education)) AND PUBYEAR > 2017 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE, "English")).**

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Table 2
The Selection Criterion Is Searching.

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2018–2024	< 2018

Data Analysis

VOSviewer is a widely used bibliometric software developed by Nees Jan van Eck and Ludo Waltman at Leiden University in the Netherlands (van Eck & Waltman, 2010, 2017). Known for its ease of use, VOSviewer allows researchers to visualize and analyze scientific literature, create network visualizations, cluster related items, and produce density maps. It offers tools to explore co-authorship, co-citation, and keyword co-occurrence networks, making it easier for researchers to understand complex research landscapes. The software's interactive interface and regular updates enhance its ability to handle large datasets dynamically. With features for metric calculations, customizable visualizations, and compatibility with various bibliometric data sources, VOSviewer is an essential tool for scholars looking to gain insights into complex research domains.

One of VOSviewer's standout features is its ability to turn complex bibliometric data into visually accessible maps and charts. The software focuses on network visualization, excelling at clustering related items, analyzing keyword patterns, and generating density maps. Both new and experienced researchers find its interface easy to navigate, making the exploration of research trends and relationships efficient. Thanks to continuous development, VOSviewer remains a leading tool in bibliometric analysis, providing customizable visualizations and metrics. Its flexibility with different types of bibliometric data, such as co-authorship and citation networks, makes VOSviewer a versatile and valuable resource for gaining a deeper understanding of various research domains. In this study, datasets were collected from the Scopus database in PlainText format, covering information like publication year, title, author, journal, citation count, and keywords from 2020 to December 2023. These datasets were analyzed using VOSviewer software version 1.6.19, applying VOS clustering and mapping techniques to generate visual maps. Unlike the Multidimensional Scaling (MDS) method, which calculates similarity measures like cosine and Jaccard indices, VOSviewer places items in low-dimensional spaces, where the distance between items reflects their relatedness and similarity (van Eck & Waltman, 2010). This technique uses association strength (ASij) to normalize co-occurrence frequencies, making the VOSviewer's approach better suited to bibliometric analysis (van Eck & Waltman, 2007):

ASij ¼ Cij,

Wiwj,

which is "proportional to the ratio between on the one hand the observed number of cooccurrences of i and j and on the other hand the expected number of co-occurrences of i and

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j under the assumption that co-occurrences of i and j are statistically independent" (Van Eck and Waltman, 2010, p. 531).

Result And Discussion

What Are The Research Trends In Online Learning Studies According To The Year Of Publication?

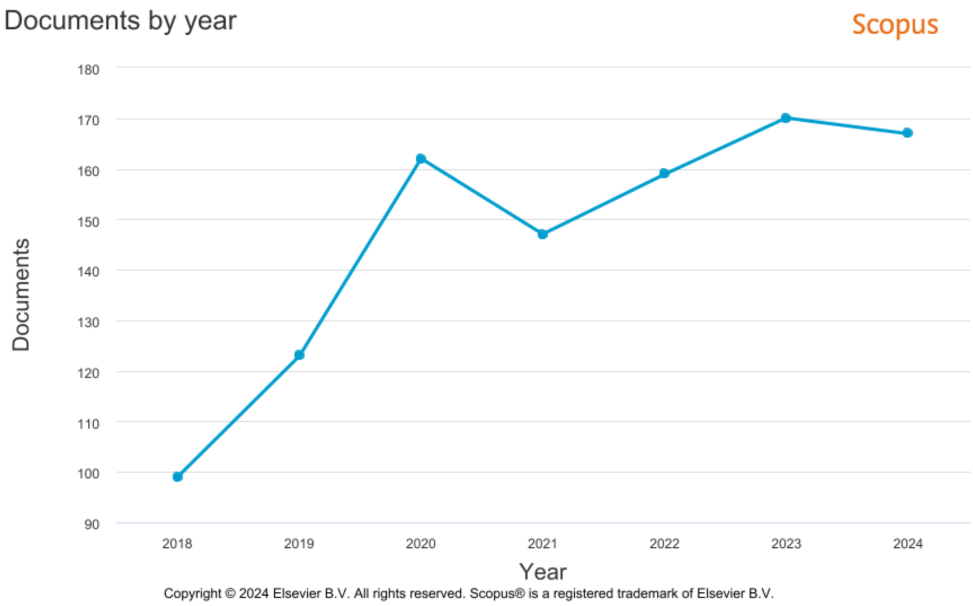

Figure 1: Plotting Document Publication For "Computational Thinking In Science Literacy For Early Childhood Education" By years.

The publication trend for "Computational Thinking in Science Literacy for Early Childhood Education" from 2018 to 2024 shows an overall upward trajectory with notable fluctuations. Starting in 2018 with just under 100 publications, the trend increased significantly over the next two years, peaking in 2020 at approximately 160 publications. This rapid growth suggests a growing research interest in computational thinking and science literacy within early childhood education during this period, likely due to increased recognition of the importance of these skills in early childhood development.

Following the peak in 2020, there was a slight decline in 2021, with the number of publications dropping to around 150. However, the trend rebounded and rose steadily in 2022, reaching close to the 2020 peak again by 2023. A slight dip is observed in 2024, but the number remains high, indicating sustained interest. This pattern suggests that while research in this field remains active, it might face challenges such as funding, shifting educational priorities, or publication delays. Overall, the trend reflects a strong and consistent interest in integrating computational thinking into early science literacy, reinforcing its value in early childhood education research.

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Who Writes The Most Cited Articles?

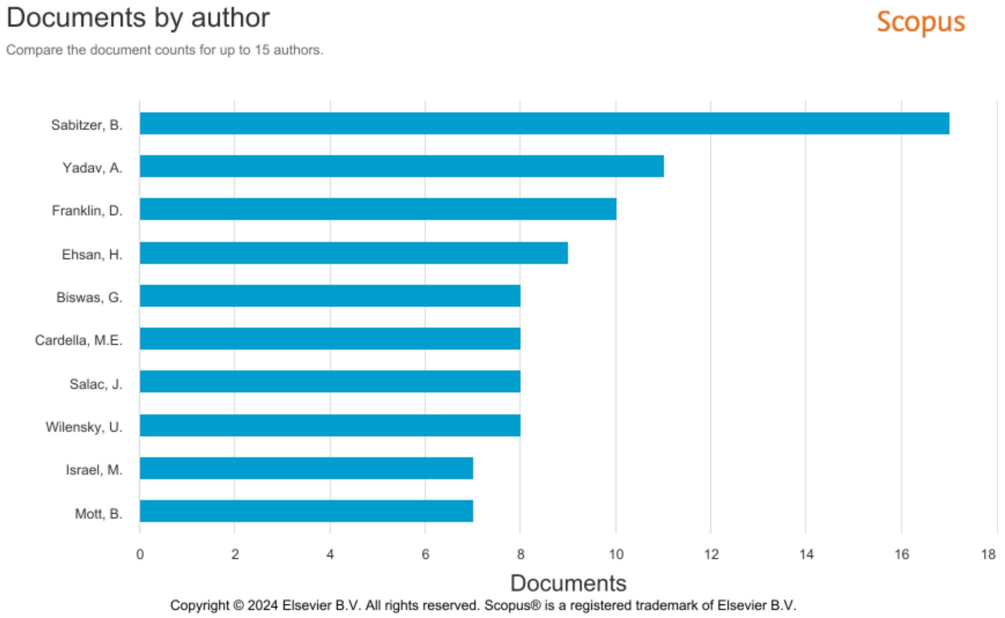

Figure 2: A Bibliometric Analysis Of Author Contributions To The Field Of Computational Thinking In Science Literacy.

The figure displays a bibliometric analysis of the author's contributions to the field of computational thinking in science literacy, specifically in early childhood education, as gathered from Scopus. Sabitzer, B. leads with the highest number of documents, suggesting significant contributions and possibly pioneering work in this niche area. This high document count could indicate that Sabitzer's research has had a strong impact on shaping current understanding and methodologies in computational thinking for young learners. Following Sabitzer, authors like Yadav, A. and Franklin, D. also show substantial contributions, though with fewer publications, pointing to them as influential figures who have provided noteworthy insights or frameworks. The frequency of publications by these authors highlights their commitment to advancing computational thinking as an educational focus in early childhood science literacy.

The variety of authors represented in the chart underscores the growing interest and collaborative efforts in this field, with authors such as Ehsan, H. and Biswas, G. contributing a notable body of work. This collective effort by various researchers likely contributes to a broad and multi-faceted understanding of computational thinking in early childhood, covering various perspectives, methodologies, and educational strategies. These authors' work not only adds empirical evidence but may also support theoretical and practical advancements in integrating computational thinking into science literacy curricula. Their research contributions lay the groundwork for further studies, which can expand on these foundations to improve early childhood education practices globally.

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Table 1: The Contributions Of The Top Authors In The Area Of "Computational Thinking In Science Literacy For Early Childhood Education."

AUTHOR NAME	Number of Document	Percentages
Sabitzer, B.	17	1.655
Yadav, A.	11	1.071
Franklin, D.	10	0.974
Ehsan, H.	9	0.876
Biswas, G.	8	0.779
Cardella, M.E.	8	0.779
Salac, J.	8	0.779
Wilensky, U.	8	0.779
Israel, M.	7	0.682
Mott, B.	7	0.682

Table 3 summarizes the contributions of the top authors in the area of "Computational Thinking in Science Literacy for Early Childhood Education" based on the results from an advanced search in the Scopus database. This table ranks authors by the number of documents they have published on the topic, along with their percentage share of the total dataset. The top author, Sabitzer, B., has 17 documents, representing 1.655% of the total publications. This suggests that Sabitzer is a leading contributor in this research domain, likely making substantial advancements or establishing foundational theories and practices in computational thinking for early education. Yadav, A. follows with 11 publications (1.071%), and Franklin, D. has 10 publications (0.974%), both contributing a significant body of work.

These authors appear to be key influencers within the field, as their research outputs form a notable portion of the literature. The presence of these authors with relatively high publication counts highlights their likely involvement in developing or implementing computational thinking frameworks or conducting studies that support science literacy in early childhood education. Other authors, such as Ehsan, H. with 9 documents (0.876%) and Biswas, G., Cardella, M.E., Salac, J., and Wilensky, U., each with 8 documents (0.779%), also contribute prominently. This clustering of authors with similar publication counts points to a collaborative and dynamic research environment where multiple experts contribute to expanding knowledge in this field. Israel, M., and Mott, B., with 7 documents each (0.682%), complete the list of top authors, indicating their active engagement and influence in this area. Overall, this diverse authorship reflects a growing interest and a well-supported knowledge base in computational thinking and science literacy for early childhood education, laying a strong foundation for future research and educational application.

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Table 2: Top Ten Authors Based On Citation On Computational Thinking In Science Literacy For Early Childhood.

Authors	Title	Year	Source Title	Cited by
Hsu T.-C.; Chang S.-C.; Hung Y.-T.	How to learn and how to teach computational thinking: Suggestions based on a review of the literature	2018	Computers and Education	474
Angeli C.; Giannakos M.	Computational thinking education: Issues and challenges	2020	Computers in Human Behavior	171
Lee I.; Ali S.; Zhang H.; Dipaola D.; Breazeal C.	Developing Middle School Students' AI Literacy	2021	SIGCSE 2021 - Proceedings of the 52nd ACM Technical Symposium on Computer Science Education	133
Ioannou A.; Makridou E.	Exploring the potentials of educational robotics in the development of computational thinking: A summary of current research and practical proposal for future work	2018	Education and Information Technologies	125
Noh J.; Lee J.	Effects of robotics programming on the computational thinking and creativity of elementary school students	2020	Educational Technology Research and Development	117
Su J.; Yang W.	Artificial intelligence in early childhood education: A scoping review	2022	Computers and Education: Artificial Intelligence	112
Ketelhut D.J.; Mills K.; Hestness E.; Cabrera L.; Plane J.; McGinnis J.R.	Teacher Change Following a Professional Development Experience in Integrating Computational Thinking into Elementary Science	2020	Journal of Science Education and Technology	100
Román-González M.; Pérez-González J.-C.; Moreno-León J.; Robles G.	Can computational talent be detected? Predictive validity of the Computational Thinking Test	2018	International Journal of Child-Computer Interaction	99
Fagerlund J.; Häkkinen P.; Vesisenaho M.; Viiri J.	Computational thinking in programming with Scratch in primary schools: A systematic review	2021	Computer Applications in Engineering Education	99
Tissenbaum M.; Sheldon J.; Abelson H.	Viewpoint from computational thinking to computational action	2019	Communications of the ACM	97

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The VOSviewer data provided highlights the central role of computational thinking in the domain of "Computational Thinking in Science Literacy for Early Childhood Education." The keyword "computational thinking" stands out significantly, with 541 occurrences and a link strength of 911, indicating its pivotal role and frequent association with other educational concepts and technologies. This prominence suggests that computational thinking is a core focus in early childhood education, particularly in enhancing science literacy. Moreover, the data reveals a strong trend towards integrating technology into early childhood education, as seen in keywords such as "robotics" (29 occurrences, 80 link strength), "programming" (54 occurrences, 141 link strength), and "educational technology" (8 occurrences, 29 link strength). This trend supports the development of foundational computational skills through interactive and technology-enriched learning environments, demonstrating a shift towards more engaging educational practices.

What Are The Popular Keywords Related To The Study?

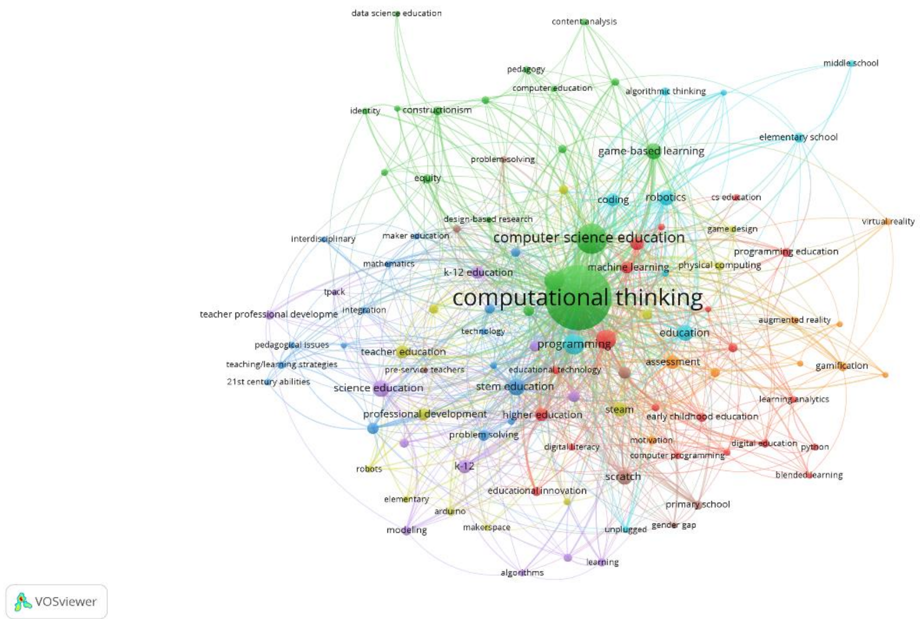

Figure 3: Network Visualization Map Of Keywords' Co-Occurrence.

Additionally, emerging educational paradigms like "game-based learning" (33 occurrences, 74 link strength) and "STEM education" (51 occurrences, 138 link strength) are also highlighted, indicating a growing focus on interdisciplinary approaches that enhance critical thinking and problem-solving skills from an early age. Integrating these paradigms with computational thinking points to a transformative phase in early childhood education emphasizing digital fluency and technological integration.

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What Are Co-Authorship Countries' Collaboration?

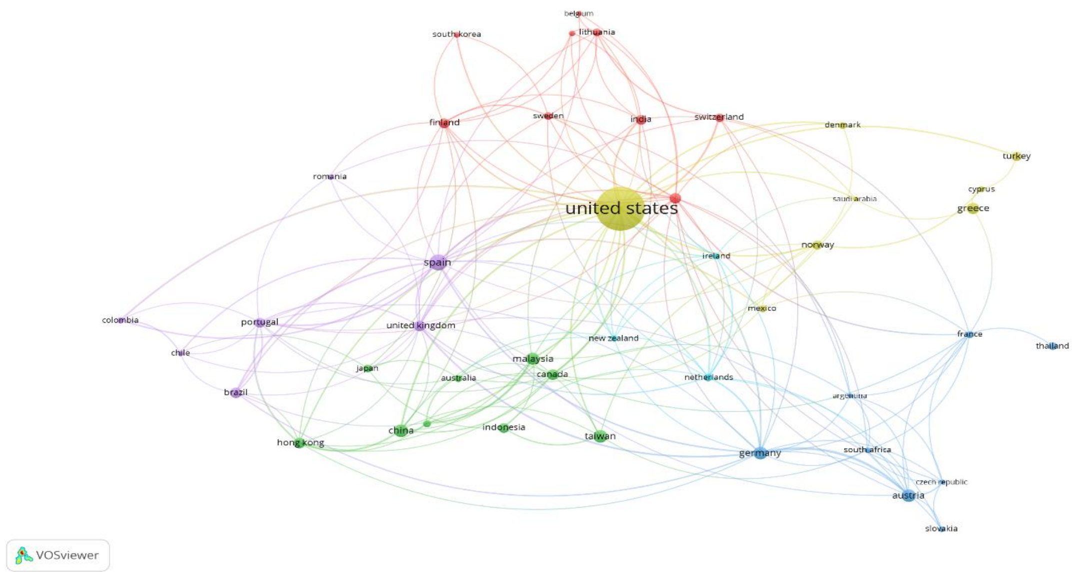

Figure 4: Countries whose authors collaborate on Computational Thinking in Science Literacy for Early Childhood Education.

The VOSviewer data provided on co-authorship countries' collaboration in "Computational Thinking in Science Literacy for Early Childhood Education" reveals a diverse global engagement in this academic field. The United States stands out prominently with the highest number of documents (391), citations (3482), and total link strength (71), indicating a leading role in research and development of computational thinking in early childhood science literacy. Other notable contributors include the United Kingdom and Taiwan, suggesting robust research outputs and significant contributions to the field. High citation counts in these regions imply influential research that potentially sets benchmarks or introduces innovative practices in educational technology and computational thinking. European countries like Germany, Spain, and France also show considerable involvement with high document counts and link strengths, suggesting active collaboration and research dissemination within the region. Spain, in particular, has 56 documents and the highest citation count among European countries at 750, alongside a link strength of 38, which highlights its significant impact and leadership in European research on this topic.

This trend suggests a strong network of collaboration and knowledge exchange across Europe that enriches the research landscape. Emerging contributors such as China and India, with substantial document counts of 32 and 21, respectively, and moderate citation rates, indicate growing interest and development in computational thinking in early childhood education within these countries. This reflects broader educational trends in Asia, where there is increasing emphasis on integrating computational thinking into early educational curricula to enhance science literacy and prepare younger generations for a technologically advanced future. The data underscores a global acknowledgment of the importance of foundational skills in computational thinking as crucial components of early childhood education.

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Conclusion

The publication trends from 2018 to 2024 in the field of "Computational Thinking in Science Literacy for Early Childhood Education" illustrate an overall positive growth, with significant fluctuations across the years. Starting modestly in 2018 with just under 100 publications, the number escalated sharply by 2020, peaking at around 160. This spike reflects an escalating interest in embedding computational thinking within early childhood education, possibly driven by a broader recognition of these skills' importance in foundational development. Post-2020, there was a noticeable dip in publications, which briefly declined to around 150 in 2021, but the subsequent years saw a rebound close to the 2020 levels. This oscillation may highlight external factors such as funding shifts or educational priorities influencing research output. However, the consistently high figures toward the latter part of the period indicate a continued strong interest in integrating computational thinking into early educational curricula. Regarding citations, a few researchers have notably influenced the domain, led by individuals like Sabitzer, B., Yadav, A., and Franklin, D., who have been pivotal in shaping the methodologies and understanding of computational thinking for young learners. Their frequent publications underscore a deep commitment to enhancing educational practices around computational thinking in science literacy. Moreover, the collaborative nature of this research field is evident as numerous authors, including Ehsan, H., and Biswas, G., contribute extensively, enriching the discourse with diverse methodologies and educational strategies. These contributions not only bolster empirical evidence but also foster theoretical and practical enhancements in how computational thinking is integrated into science literacy curricula, setting a robust foundation for future explorations aimed at augmenting educational practices globally.

The analysis of keyword occurrences from VOSviewer underscores computational thinking as a pivotal theme in "Computational Thinking in Science Literacy for Early Childhood Education," evidenced by its high occurrence and link strength, highlighting its frequent interconnection with other educational technologies and concepts. The emphasis on computational thinking aligns with its critical role in enhancing science literacy from the early stages of education. Further examination reveals a strong inclination towards incorporating technological elements in early childhood education settings, illustrated by the presence of keywords such as "robotics," "programming," and "educational technology." Such trends advocate cultivating fundamental computational skills through dynamic and technology-rich learning environments. Moreover, the emergence of "game-based learning" and "STEM education" as significant themes point towards an interdisciplinary approach that fosters critical thinking and problem-solving abilities early in child development, marking a phase of transformative integration of digital fluency into educational foundations. Regarding international collaborations, VOSviewer data illuminates extensive global participation in this research area, with the United States, the United Kingdom, and Taiwan leading in document production, citation impacts, and collaborative strength. This global network indicates a dominant influence of these regions in shaping research and practices in computational thinking within early childhood education. The data also highlights active research contributions from European nations such as Germany, Spain, and France, which are pivotal in fostering collaborative networks and disseminating research across Europe. The noteworthy involvement of emerging research centers in China and India, with considerable document outputs and citation impacts, reflects a growing commitment to embedding computational thinking in early educational systems, aiming to equip future generations with essential skills for a technologically advanced landscape. This broad international engagement underscores a

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collective recognition of computational thinking as a fundamental aspect of early childhood educational curricula worldwide.

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