MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2025, 21(3), em2602
ISSN:1305-8223 (online)
OPEN ACCESS Review Article https://doi.org/10.29333/ejmste/16050

Educational robotics for primary education: An analysis of research trends

Ezequiel Martínez Rojas [1], Alejandro Valencia-Arias [2*], Manuel Humberto Vásquez Coronado [3], José Manuel Barandiarán Gamarra [4], Erica Agudelo-Ceballos [5], Martha Luz Benjumea-Arias [6], Luis Vega Mori [7]

[1] Vicerrectoría de Investigación e Innovación, Universidad Arturo Prat, Iquique, CHILE
[2] Escuela de Ingeniería, Universidad Señor de Sipán, Chiclayo, PERU
[3] Facultad de Ingeniería, Arquitectura y Urbanismo, Universidad Señor de Sipán, Chiclayo, PERU
[4] Facultad de Ingeniería y Arquitectura, Universidad Señor de Sipán, Chiclayo, PERU
[5] Departamento de Ciencias Administrativas, Instituto Tecnológico Metropolitano, Medellín, COLOMBIA
[6] Facultad de Ciencias Económicas y Administrativas, Instituto Tecnológico Metropolitano, Medellín, COLOMBIA
[7] Instituto de Investigaciones y Estudios de la Mujer, Universidad Ricardo Palma, Santiago de Surco, PERU

Received 13 November 2024 ▪ Accepted 01 February 2025

Abstract
The present study explores the benefits and challenges of integrating technology into the early stages of education, including the use of robotics in primary education. While social and emotional learning has been widely studied in the Ibero-American context, there is a paucity of comprehensive studies examining the integration of robotics at this educational level. The present study aims to identify research trends through a bibliometric analysis conducted in accordance with the PRISMA statement, utilizing the Scopus and Web of Science databases. The results of this study highlight key developmental periods and reveal a significant increase in the volume of literature on the topic. The thematic evolution, from compilers to educational technology and teaching programming, reflects adaptation to educational and technological demands, identifying thematic clusters and potential areas of interconnection. Emerging keywords suggest a balance between continuity and innovative exploration. This analytical framework provides strategic guidance for academics, educators, and policymakers, facilitating the planning of initiatives to advance the integration of robotics in primary education.

Keywords: active learning, innovative teaching, cognitive development, technology in education, curricular integration

INTRODUCTION

The integration of robotics in primary education has emerged as a significant area of research, aiming to examine the potential benefits and challenges associated with the introduction of technology in the initial stages of the educational process (Pérez-Marín et al., 2020). The nexus between primary education and robotics presents a promising avenue for investigating how technological instruments, particularly those pertaining to programming and robotics, can facilitate learning during the crucial formative years. This approach not only addresses the acquisition of technical skills but also drives the development of cognitive and social-emotional skills.

Researchers have investigated the enhancement of computational thinking through a methodology based on metaphors and Scratch to educate children in programming (Pérez-Marín et al., 2020). The study underscores the significance of innovative pedagogical strategies to facilitate the comprehension of computational concepts in primary education. Other research involved a systematic literature review to examine the characteristics of educational robotics and STEM research in primary education (Tselegkaridis & Sapounidis, 2022). The work offers an overview of the

✉ emartinezr@unap.cl ✉ valenciajho@uss.edu.pe **(*Correspondence)** ✉ mhumbertovc@uss.edu.pe ✉ barandiara@uss.edu.pe ✉ ericaagudelo@itm.edu.co ✉ marthabenjumea@itm.edu.co ✉ iepvlvega@gmail.com

Contribution to the literature

- This study conducts a bibliometric analysis to identify research trends in educational robotics for primary education, addressing a gap in systematic reviews of this field.
- By mapping thematic evolution and emerging keywords, it highlights shifts in research priorities and areas of potential interconnection.
- The findings provide valuable insights for academics, educators, and policymakers, guiding future research and implementation strategies.

trends and approaches that are currently emerging in this evolving field.

Furthermore, some studies concentrate on the examination, conceptualization, implementation, and verification of a STEAM undertaking through educational robotics in primary education (Vicente et al., 2021). The research addresses the incorporation of robotics into the educational curriculum, emphasizing the significance of a comprehensive approach to enhancing learning. Other studies have examined international trends in the teaching of computer science in primary education, emphasizing the increasing significance of coding in the K-8 curriculum (Rich et al., 2019). These studies contribute to the existing body of knowledge regarding the critical role of robotics in primary education and its impact on students' academic and cognitive development.

The incorporation of robotics into primary education has been a pivotal aspect of the contemporary educational landscape. A substantial body of research has underscored the significance of this convergence, demonstrating how the integration of robotics in primary education classrooms can facilitate the comprehensive growth and development of students. Studies have demonstrated the efficacy of STEAM initiatives, such as the "sustainable city" project, which employs robotics to engage primary education students in envisioning and understanding the city of the future. This approach not only cultivates technological expertise but also fosters environmental awareness and sustainability from an early age (Ruiz Vicente et al., 2020).

The utilization of technological devices, such as tablets and applications, has been identified as a valuable resource for the promotion of robotics, mathematics, STEM education and literacy instruction in early childhood education (Dorouka et al., 2020). This interdisciplinary approach not only broadens the understanding of technological concepts but also reinforces the cognitive and creative skills essential for learning in primary education.

The use of gamification as a pedagogical strategy for teaching programming to primary education students has been the subject of recent research (Ocaña et al., 2023). The findings of this research highlight the importance of incorporating elements of play and emotion into the learning process. This emphasizes that robotics is not solely about developing technical skills; it is also about fostering emotional and motivational aspects that influence students' development.

Moreover, some reviews and meta-analyses offer a comprehensive overview of robotics and STEM education in primary education (Sapounidis et al., 2022). This comprehensive analysis facilitates comprehension of the scope and trends in contemporary research, emphasizing the significance of a comprehensive approach to the integration of robotics at this educational level. Other studies underscore the value of a STEAM approach in primary education through the examination, design, implementation, and assessment of projects that integrate educational robotics (Sapounidis et al., 2022; Vicente et al., 2021). Collectively, these studies reinforce the significance of incorporating robotics in primary education, delineating a promising landscape for the academic and personal growth of students.

The intersection of primary education and robotics has recently garnered significant attention in scientific literature. Nevertheless, significant deficiencies have been identified that necessitate a comprehensive and systematic investigation to address these knowledge gaps. While social and emotional learning has been explored in the Ibero-American context, there is a paucity of research that provides a comprehensive examination of the integration of robotics in the field of primary education (Fernández-Martín et al., 2021). Moreover, although reviews and meta-analyses exist that focus on educational robotics and STEM in primary education, a more detailed evaluation of bibliometric trends in this specific field is still required (Sapounidis et al., 2022).

A systematic review of healthy nutrition intervention programs in primary education, for example, underscores the necessity for analogous studies that are specifically focused on the integration of robotics in the educational field (Collado-Soler et al., 2023). The aforementioned research gaps illustrate the necessity for bibliometric analysis in the field of primary education and robotics. Accordingly, the objective of this bibliometric analysis is to examine research trends in the field. To this end, the following questions have been formulated:

1. What are the years where there has been the most interest in primary education and robotics?

2. What type of growth is there in the number of scientific articles on primary education and robotics?
3. What are the main research references on primary education and robotics?
4. What is the thematic evolution derived from scientific production on primary education and robotics?
5. What are the main thematic clusters on primary education and robotics?
6. What are the growing and emerging keywords in the research field of primary education and robotics?
7. What themes are positioned as protagonists for the design of a research agenda on primary education and robotics?

This study is comprised of six sections. The initial section provides a comprehensive overview of the research, while the subsequent section presents an introduction to the study. The third section delineates the methodology employed, and the fourth section elucidates the principal findings. The fifth section elucidates the discussions based on the findings, and the final section presents the conclusions derived from the research.

METHODOLOGY

This research employs an exploratory approach based on secondary research sources with the objective of conducting a bibliometric analysis in the domain of primary education and robotics. This study adheres to the structure prescribed by the PRISMA-2020 statement (Page et al., 2021), an updated guide for the submission of systematic reviews. The methodology adopted herein is in accordance with the PRISMA-2020 principles, which encompass the identification, selection, data extraction, and synthesis of pertinent literature. The bibliometric analysis, based on this methodological structure, aims to provide a comprehensive and rigorous overview of the current research landscape at the intersection of primary education and robotics, identifying trends, gaps, and opportunities for future research in this area.

Eligibility Criteria

In this bibliometric study on primary education and robotics, particular inclusion criteria are employed in order to identify pertinent records. Firstly, the terms present in the titles and keywords are considered fundamental metadata, ensuring the accurate capture of literature related to the topic. Moreover, a combination of the terms "primary education" and "robotics" is employed in various forms of citation, including synonyms and lexical variations, with the objective of ensuring comprehensive retrieval of pertinent information. This refined methodological approach is designed to optimize the selection of records that align with the specific objectives of the research project, thereby providing a comprehensive view of the current state of knowledge at the intersection between primary education and robotics.

In the exclusion phase, three criteria are applied to guarantee the quality and relevance of the records analyzed. Firstly, documents with erroneous indexing are excluded, with the objective of maintaining the integrity and precision of the analyzed data. In the second phase of exclusion, documents for which access to the full text is not available are eliminated. This criterion is exclusively applicable to systematic literature reviews, given that bibliometrics is based solely on the analysis of metadata. The third phase of exclusion is intended to refine the sample by removing conference proceedings and documents with incomplete indexing, thereby ensuring the coherence and reliability of the data employed in this bibliometric study.

Source of Information

In the present bibliometric research on primary education and robotics, the Scopus and Web of Science databases were selected as the primary sources of scientific and academic information due to their prominence and recognition as the leading platforms for scholarly communication in the present era. Both databases are widely recognized in bibliometric studies for their comprehensiveness, multidisciplinary coverage, and rigorous peer review processes, which guarantee the quality of the data collected (Caputo & Kargina, 2022; Rodgers & Zhang, 2022). The selection of these platforms is based on the necessity to obtain a comprehensive overview of scientific output in the field of primary education and robotics, utilizing the diversity of sources and disciplines encompassed by these databases. The robustness and reliability of Scopus and Web of Science make them ideal tools for bibliometric research, allowing for a detailed and representative analysis of existing literature in this field.

Search Strategy

In order to conduct comprehensive and accurate search in the selected bibliometric databases on primary education and robotics, a methodological approach has been developed that includes the formulation of two specialized search equations. These equations have been meticulously designed to align with the pre-established inclusion criteria, considering the distinctive attributes of the field of study and the specific attributes of each database, namely Scopus and Web of Science. The formulation of search equations tailored to the distinctive characteristics of each platform guarantees the precise identification of pertinent literature, thereby facilitating the comprehensive retrieval of records aligned with the specific objectives of bibliometric research.

For the Scopus database: ((TITLE (“basic education” OR “primary education”) AND TITLE (“artificial intelligence” OR robotic* OR programming)) OR (AUTHKEY (“basic education” OR “primary education”) AND AUTHKEY (“artificial intelligence” OR robotic* OR programming)))

For the Web of Science database: ((TI = (“basic education” OR “primary education”) AND TI = (“artificial intelligence” OR robotic* OR programming)) OR (AK = (“basic education” OR “ primary education”) AND AK = (“artificial intelligence” OR robotic* OR programming)))

Data Management

In the context of this bibliometric study on primary education and robotics, the Microsoft Excel® software was employed to extract, store, and process the data obtained from the selected databases. The Microsoft Excel® software provided a versatile platform that allowed for the effective organization and structure of bibliographic data, thus facilitating subsequent analysis. Furthermore, the VOSviewer® software (van Eck & Waltman, 2010), an open-source tool designed for the visualization and analysis of bibliometric maps, was employed. This application was integrated into research to facilitate the visual mapping of relationships and collaborations between authors, institutions, and key terms identified in the reviewed literature. Likewise, Microsoft Excel was employed to generate illustrative graphs of the various bibliometric indicators subjected to analysis in the study. The combination of these tools facilitated the efficient management of bibliographic information and the visual representation of emerging patterns and trends in the field of primary education and robotics.

Selection Process

In accordance with the guidelines established in the PRISMA 2020 statement, it is of paramount importance to underscore the utilization of automatic classifiers and validation procedures throughout the process of study selection in a bibliometric review (Page et al., 2021). The implementation of an internal automatic classifier can be crucial to optimizing efficiency and accuracy in the identification of relevant records. Internal and external validation are also of great importance in the assessment of the risk of missing studies or incorrect classifications, thus allowing for a more robust understanding of the validity of the results obtained.

In this bibliometric study on primary education and robotics, internal automation tools based on Microsoft Excel® were utilized. These tools were developed collectively by all study researchers, who utilized them independently in the application of the inclusion and exclusion criteria. This strategy was implemented with the objective of mitigating the risk of lost studies or erroneous classifications by facilitating the convergence of results obtained independently by different researchers. This approach, supported by automated tools and internal validation, enhances the reliability and integrity of the bibliometric selection process conducted in this study. **Figure 1** shows the PRISMA flowchart.

Data Collection Process

As recommended in the literature, the necessity of clearly delineating the methodology employed to gather data in the context of a bibliometric study is underscored (Page et al., 2021). In this study on primary education and robotics, Microsoft Excel® was utilized as an automated tool for the data collection process from the two selected databases, thereby ensuring an efficient and structured organization of bibliographic information. Each of the study authors assumed the role of reviewer, carrying out the validation independently. Subsequently, the data confirmation process was conducted collectively, with the aim of unifying the criteria and discussing any discrepancies that had arisen during the individual review. This collaborative approach, supported by an automated tool and independent validation, ensured the rigor and reliability of the data collection process, resulting in absolute convergence of the obtained results.

Data Elements

In the context of the present bibliometric research on primary education and robotics, a systematic search for data was conducted for all articles that aligned with the predefined research objectives. This entailed the implementation of bespoke search equations tailored to each database, with the objective of comprehensively identifying all pertinent articles that addressed the nexus between primary education and robotics. With regard to other variables, comprehensive data were sought on the characteristics of the participants, the interventions, the funding sources, and other factors pertinent to the subject matter. However, the exclusion of non-relevant texts was established in the event of missing or unclear information, as this could impede the comprehension of the knowledge base on the topic. This exclusion strategy was implemented consistently to ensure coherence with the objectives and scope of the research, thus ensuring the reliability and validity of the results obtained.

Assessment of the Risk of Bias of the Study

A comprehensive approach was employed in the risk of bias assessment of the included studies. As both data collection and risk of bias assessment were conducted by all study authors, the resulting consistency and quality of both processes were assured. The automated Microsoft Excel® tool was employed in a consistent

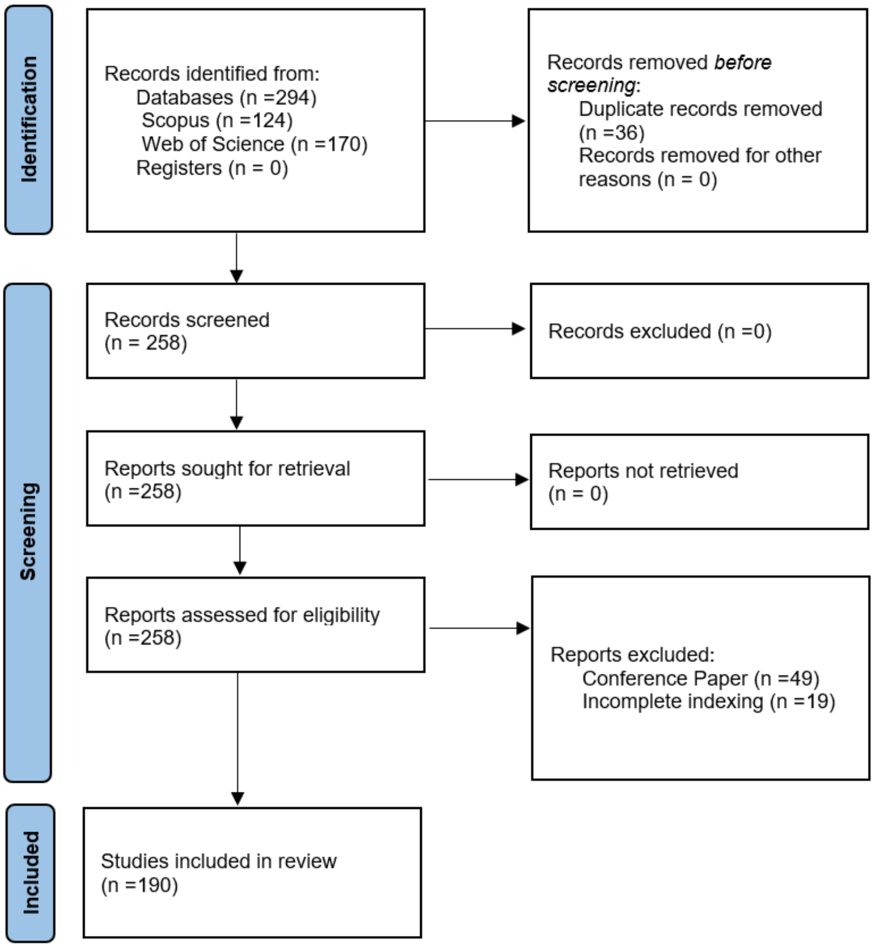

Figure 1. PRISMA flowchart (Source: Authors' own elaboration)

manner to assess the risk of bias in each study, thereby ensuring uniformity in the application of the evaluation criteria. This method permitted a comprehensive and standardized evaluation while reducing the likelihood of bias resulting from subjective interpretation. The utilization of this automated tool reinforced the rigor of the risk of bias assessment process, thereby enhancing the reliability and integrity of the findings derived from this bibliometric research.

Measures of Effect

The definition of effect measures is adapted to the specific characteristics of research based on secondary sources. In contrast with the techniques typically employed in primary research studies, such as the risk ratio or the difference in means, this research analyses bibliometric indicators. In lieu of effect measures, the number of publications and citations were evaluated as pivotal quantitative indicators, offering insight into the productivity and impact of the reviewed literature. Furthermore, the temporality of the use of each keyword was investigated, thereby providing insights into trends over time. These measures were obtained and analyzed using Microsoft Excel®, which facilitated the effective management and manipulation of bibliographic data. Similarly, VOSviewer® was employed for the graphical representation of thematic nodes, thereby facilitating the identification of associations and patterns in the reviewed literature. This methodological approach, adapted to bibliometric research, contributes to a comprehensive understanding of scientific production in the field of primary education and robotics.

Synthesis Methods

The process of selecting and preparing data for synthesis is described in detail. The eligibility of studies for inclusion in the synthesis was determined by comparing the characteristics of the interventions under investigation with the groups planned for each synthesis, with the objective of ensuring alignment with the research objectives. The preparation of the data entailed the handling of missing summary statistics and the requisite conversions to ensure the consistency of the results' presentation. To organize and present the data in a meaningful way, bibliometric indicators of quantity, quality, and structure were employed, following the methodology proposed by Durieux and Gevenois (2010). The aforementioned indicators were automatically applied to all documents that successfully completed the three exclusion phases through the use of Microsoft Excel®, thereby facilitating the standardization and objectivity of the presentation and synthesis of bibliometric results.

Assessment of Reporting Bias

It is acknowledged that the absence of results may be attributable to reporting bias. It is acknowledged that there may be a tendency towards the inclusion of specific synonyms present in thesauri, such as the IEEE, which is reflected in the inclusion criteria, search strategy, and data collection. This potential bias may impact on the identification and selection of documents, thereby limiting the representativeness of the reviewed literature. Moreover, the exclusion of conference proceedings and documents with incomplete indexing as exclusion criteria may result in the omission of valuable information that could contribute to the construction of knowledge on the subject. It is crucial to consider these limitations and potential biases when interpreting the results, as they may influence the conclusions drawn. Transparently addressing these issues in bibliometric analysis is essential.

Certainty Evaluation

In the context of the current bibliometric investigation into the nexus between primary education and robotics, the assessment of confidence in the body of evidence is addressed in a comprehensive manner. In contrast to the evaluation of certainty in primary studies, which is conducted on an individual basis, this research employs a more comprehensive approach. This entails the independent application of inclusion and exclusion criteria, as well as the definition of bibliometric indicators, to facilitate a general evaluation of certainty. Certainty is evaluated based on the reporting of potential biases, as outlined in the methodological design, and the inherent limitations of the study are addressed in the discussion. This comprehensive evaluation contributes to a global understanding of the robustness and reliability of the results obtained in bibliometrics, allowing a more informed interpretation of the body of evidence and its implications in the field of primary education and robotics.

Finally, the initial phase of the present bibliometric study on primary education and robotics concentrated on the identification of pertinent documents through the search strategy devised for the selected information sources. This was followed by the elimination of duplicate records to ensure the integrity of the database. Subsequently, the sample was refined through three exclusion phases. The first phase excluded records with erroneous indexing, the second phase eliminated documents without access to the full text, limiting this restriction to systematic literature reviews, and the third phase was responsible for excluding conference proceedings and documents with incomplete indexing. Upon completion of these stages, a final selection of 190 articles that met the inclusion criteria was achieved, thus consolidating the analytical basis for the bibliometrics in question. In conclusion, this meticulous selection process ensures the quality and relevance of the reviewed literature in the field of primary education and robotics, thereby establishing a robust foundation for the subsequent bibliometric analysis.

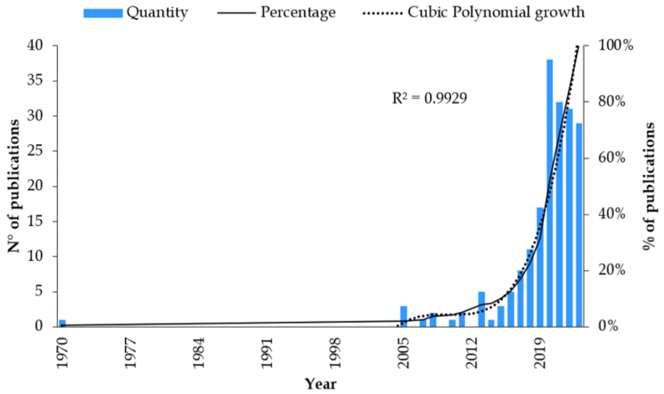

Figure 2. Publications by year (Source: Authors' own elaboration, based on Scopus and Web of Science)

RESULTS

The bibliometrics on primary education and robotics has enabled the identification of growth patterns, as illustrated in **Figure 2**, which depicts a notable increase represented by a cubic polynomial growth of 99.29%. This analysis illustrates the temporal evolution of scientific production at the intersection of primary education and robotics. The most notable years in terms of publications were 2020, 2021, 2022, and 2023, which demonstrate a growing interest and research activity in this specific area over the past decade. This quantitative approach provides a comprehensive overview of the current state of bibliographic research, emphasizing the significance and relevance of the topic within the academic and scientific community.

In the context of the most prominent authors in the field of bibliometrics on primary education and robotics, **Figure 3** illustrates the existence of three distinct groups. The first group comprises authors such as Zhong, B. C., Pizarro, C., and Pérez-Marín, D., who have distinguished themselves in terms of both productivity and impact, thereby establishing themselves as leading figures in the scientific production of this topic. In contrast, a second group comprises authors such as Chen, J., Wang, Q. Y., Li, Y., and Sáez-López, J.-M. Notwithstanding their relatively lower productivity index, these authors have made a notable impact through a considerable number of citations. Finally, the third group, represented by Martínez, M. J. B., Mellado, M. L., and Currás, M. P., is distinguished primarily for its high scientific productivity, despite the absence of a considerable number of citations. This analysis offers a comprehensive overview of the diverse profiles of authors who have contributed to the body of knowledge in the field of primary education and robotics.

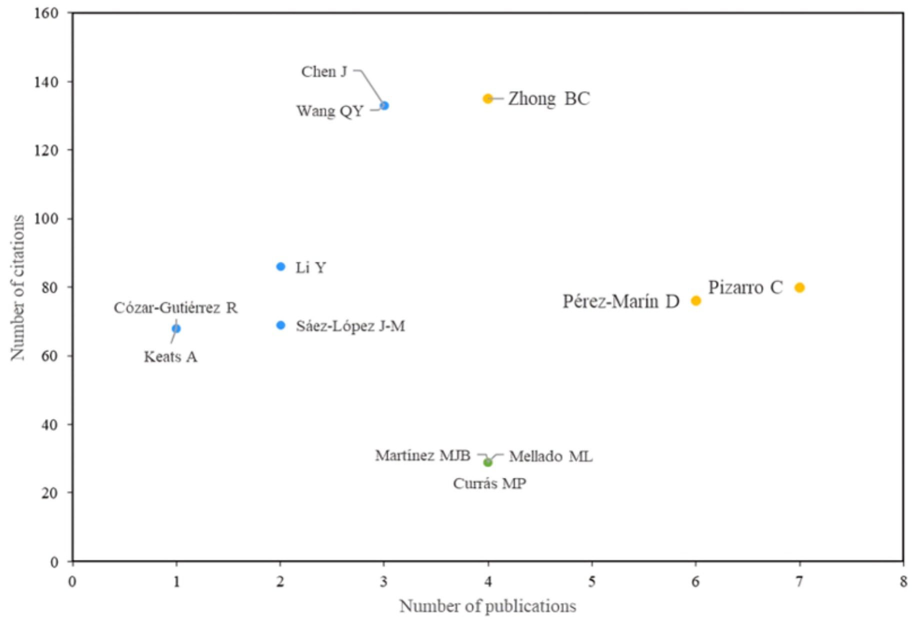

Figure 3. Main authors ((Source: Authors' own elaboration, based on Scopus and Web of Science)

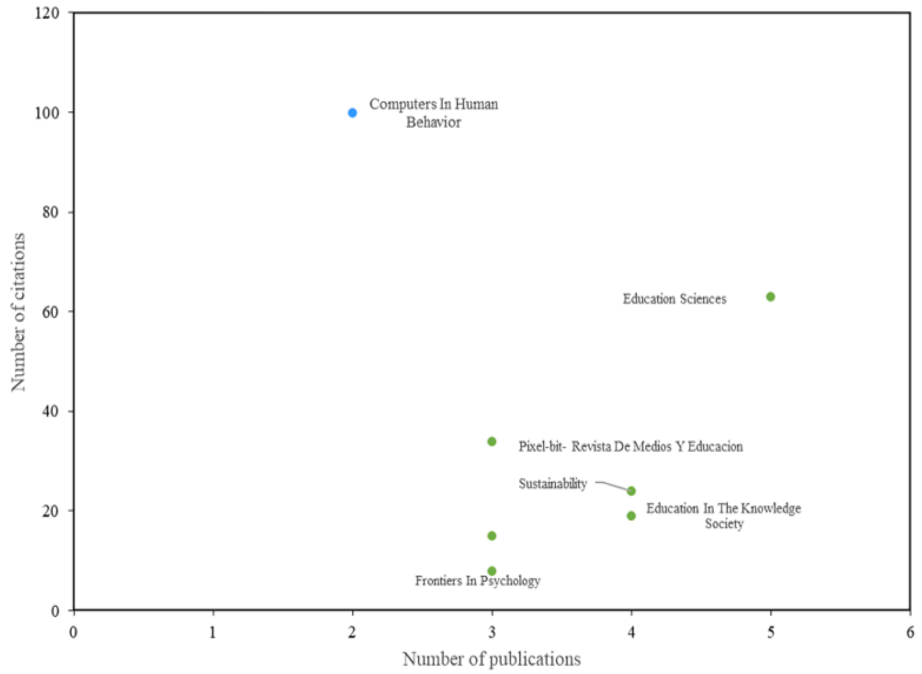

Figure 4. Main journals (Source: Authors' own elaboration, based on Scopus and Web of Science)

Subsequently, an analysis of the most prominent journals in the field of bibliometrics on primary education and robotics reveals the presence of two distinct groups (**Figure 4**).

The first group is distinguished by the journal Computers in Human Behavior, which is regarded as a leading source of information in its field despite exhibiting a relatively low level of scientific productivity. In contrast, the second group of journals, led by Education Science and Sustainability, is distinguished by its high scientific productivity, though it does not necessarily exhibit a high number of citations. This evaluation highlights the diversity in the particularities of the journals that have contributed to the body of knowledge in the field of primary education and robotics, demonstrating the various impact and dissemination strategies employed by the scientific community.

As illustrated in **Figure 5**, bibliometrics on primary education and robotics is dominated by two distinct groups of countries. The first group comprises countries such as Spain, the United States, and Greece, which demonstrate high levels of productivity and impact, positioning themselves as leading actors in scientific research on the subject. The second group, led by China and Turkey, is distinguished by its high scientific productivity, despite a relatively low number of citations.

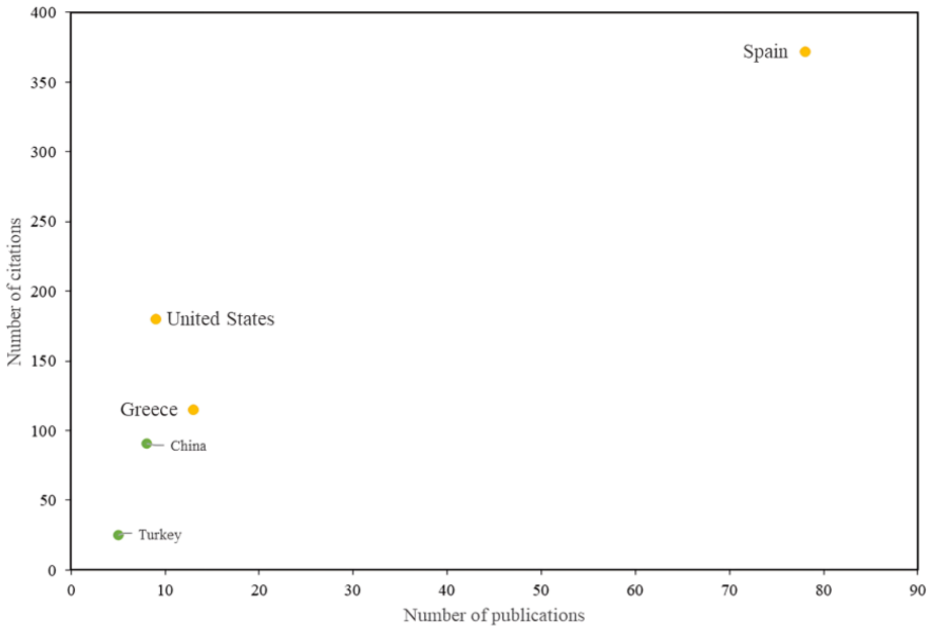

Figure 5. Main countries (Source: Authors' own elaboration, based on Scopus and Web of Science)

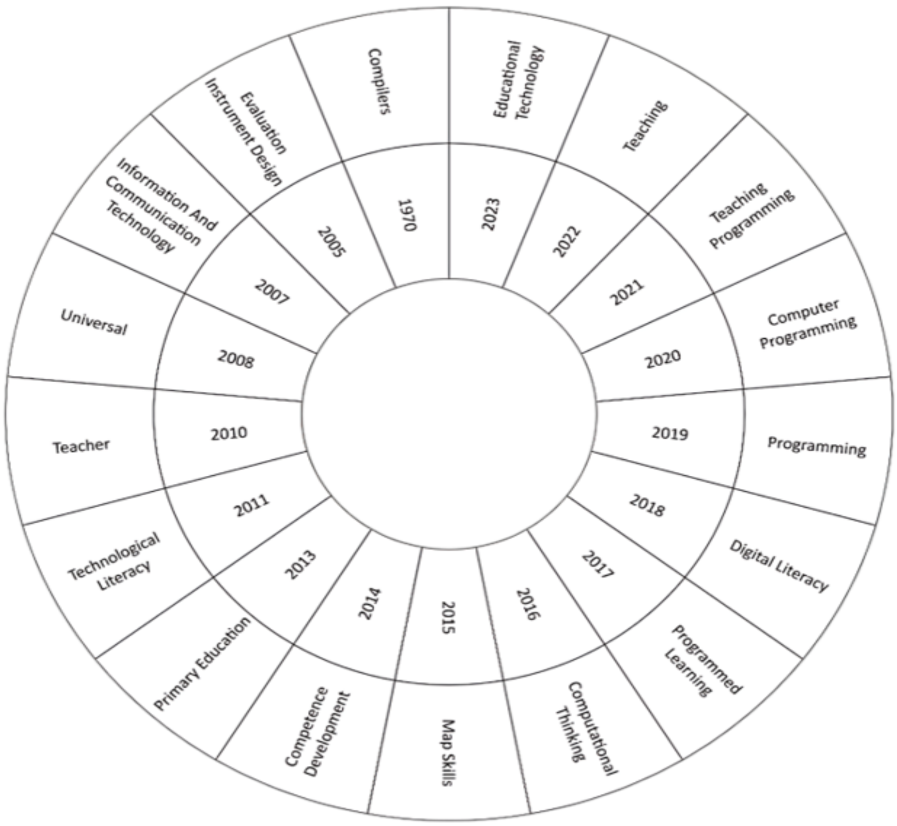

Figure 6. Thematic evolution (Source: Authors' own elaboration, based on Scopus and Web of Science)

This review underscores the diversity of contributions from around the globe, showcasing a range of strategies and perspectives in scientific production at nexus of primary education and robotics.

The study, as illustrated in **Figure 6**, addresses the analysis of the thematic evolution in the literature on primary education and robotics. The exploration was conducted by identifying the most frequently occurring keywords in each year of research, spanning from 1970 to 2023. In the initial year, 1970, the appearance of concepts such as "compilers" is noteworthy. In contrast, in more recent years, a prevalence of topics such as educational technology, teaching, teaching programming, and computer programming has been observed, reflecting current research trends in the field. This temporal analysis offers a comprehensive understanding of evolution and thematic dynamics at the intersection of primary education and robotics.

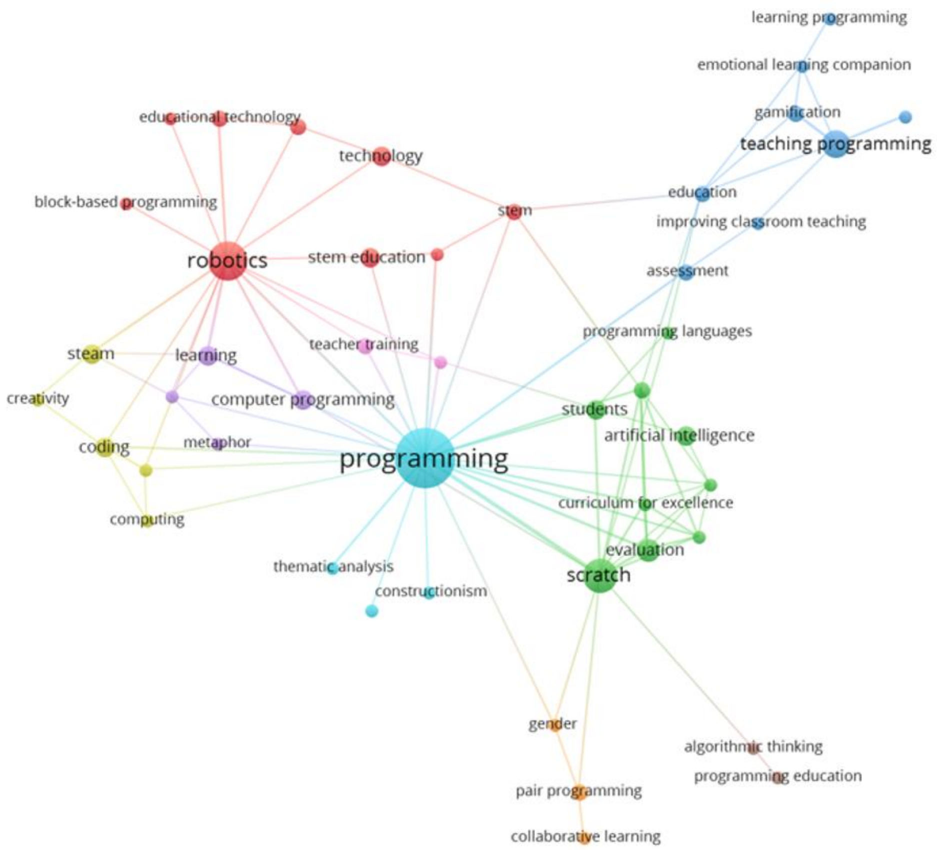

Figure 7. Keyword co-occurrence network (Source: Authors' own elaboration, based on Scopus and Web of Science)

The bibliometric research demonstrates the primary network of keyword co-occurrence through nine thematic clusters, as illustrated in **Figure 7**. The light blue cluster, comprising terms such as "programming," "thematic analysis," and "constructionism," is identified as the most prominent. Subsequently, the red cluster is evident, comprising terms such as "robotics," "STEM education," "STEM," "technology," "educational technology," and "block-based programming." Furthermore, additional clusters are identified with green, blue, purple, yellow, and orange colors, each reflecting specific elements of conceptual affinity. This keyword co-occurrence analysis offers a comprehensive overview of the central themes and their interconnections in primary education and robotics research.

The research proposes an innovative approach, namely the presentation of a Cartesian plane that measures both the frequency of use and the validity of keywords in the field of primary education and robotics. The visual methodology is illustrated in **Figure 8**, where the x-axis represents the frequency of use and y-axis represents the validity of use. The arrangement of the keywords in four distinct quadrants offers a distinctive vantage point from which to examine the evolving dynamics of research in this field. Of particular note are the keywords situated in quadrant 2, which represent rare yet highly current concepts, often considered to be emerging. These include emotional learning companion, constructionism, steam, reading, and educational technology. In contrast, established and growing concepts, such as secondary education, teacher training, teaching programming and Scratch, are situated in quadrant 1, thereby affording a comprehensive overview of the evolution of topics within the field.

In conclusion, this approach permits a more profound comprehension of the evolution of keywords over time, enabling the identification of both nascent and established domains within the scientific literature on primary education and robotics.

DISCUSSION

The discussion section of this research is of great importance, as it provides a comprehensive analysis of the results obtained in bibliometrics on primary education and robotics. Firstly, the identified trends, the principal authors, journals and countries, as well as thematic evolution over time, are subjected to meticulous examination. Furthermore, the practical implications of these findings for the academic community and education professionals are addressed. Furthermore, the study's inherent limitations are presented, a classification of keywords is carried out according to their function in the literature, and the main research gaps are identified. This critical analysis culminates in the formulation of a research agenda that identifies pivotal areas necessitating further investigation and advancement at the nexus of primary education and robotics.

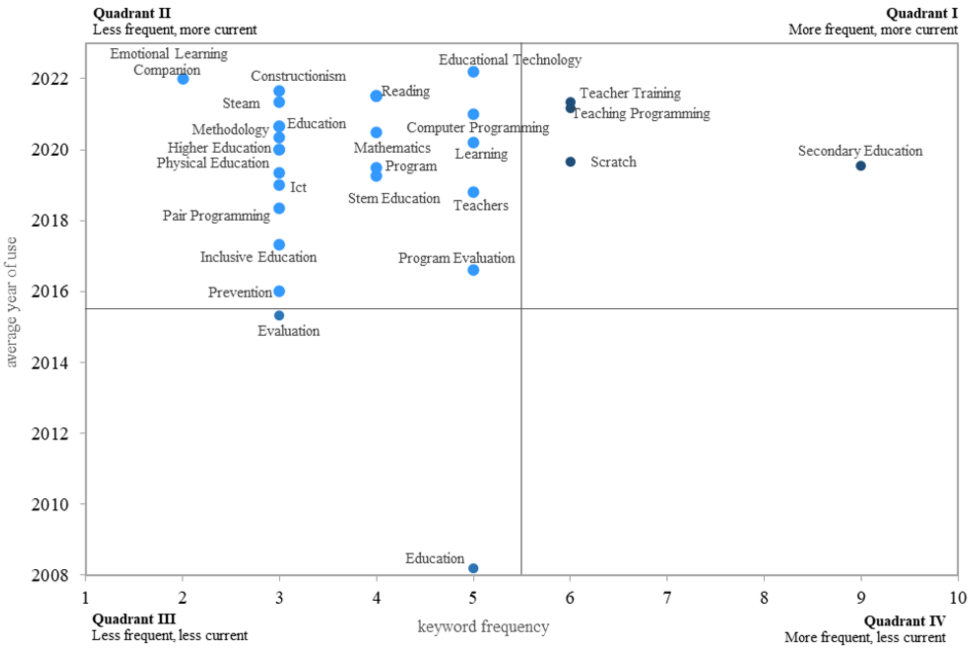

Figure 8. Validity and frequency of keywords (Source: Authors' own elaboration, based on Scopus and Web of Science)

Analysis of the Growth of Scientific Literature on Primary Education and Robotics

The analysis of the results revealed that, during the year 2020, a noteworthy contribution was made to the literature on primary education and robotics. One study developed an interactive environment through the use of small robots to teach mathematics, offering a novel perspective on the integration of robotics in education (Muñoz et al., 2020). Similarly, another research project investigated the use of tablets and applications to promote robotics, mathematics, STEM education, and literacy in early childhood education, emphasizing the diversity of technological approaches in the classroom (Dorouka et al., 2020).

In 2021, a topic was addressed that provided valuable insights by analyzing teachers' opinions on teaching the STEM approach in educational programming and robotics in primary education. The work offers a more nuanced understanding of the practical implementation of these approaches in the school environment (García-Carrillo et al., 2021).

In the year 2022, a study was conducted that undertook a systematic review of the literature on the key characteristics of research in educational robotics and STEM in primary education (Tselegkaridis & Sapounidis, 2022). The exhaustive analysis permitted the authors to present a panoramic view of the fundamental aspects that have been the object of study in this field.

In 2023, a significant contribution to the field was made by Topali and Mikropoulos (2023), who conducted a study exploring the quality and perceptions of Scratch-based learning objects for novice programmers in primary education. Their findings highlight the importance of visual programming tools in fostering early childhood computer skills development.

In conclusion, these studies illustrate the ongoing evolution and diversity of approaches to integrating robotics into primary education, offering valuable insights into the understanding and practical application of this topic in the field of education.

Analysis of Research References on Primary Education and Robotics

In the results section, it was determined that the primary authors in terms of productivity and impact were Zhong, B. C., Pizarro, C., and Pérez-Marín, D. Additionally, Chen J, in collaboration with Wang, Q. Y., Li, Y., and Sáez-López, J.-M., demonstrated notable impact, while Martínez, M. J. B., Mellado, M. L., and Currás, M. P. exhibited high productivity. A comprehensive three-dimensional exploration was conducted to evaluate computational thinking (Zhong et al., 2016). The study addressed key aspects in this field, significantly contributing to the understanding and evaluation of computational thinking in educational contexts (Zhong et al., 2016).

In Computers in Human Behavior, a group of authors conducted research to ascertain whether computational thinking could be enhanced through a methodology based on metaphors and Scratch. The objective was to facilitate the teaching of programming to children. The findings yielded valuable insights for the enhancement of computational thinking in educational settings (Pérez-Marín et al., 2020).

The study addressed the continuity of teaching programming to children during the pandemic, focusing on the use of a learning partner. This work made a valuable contribution to the field of education during exceptional situations (Ocaña et al., 2020).

A study examined the impact of social factors on pair programming in an elementary school and provided insights into the social dynamics inherent to this pedagogical approach (Zhong et al., 2016).

Conversely, other authors investigated the transition period in pair programming in an elementary school. This study enhanced comprehension of collaboration in programming (Zhong et al., 2017). Additionally, another study addressed visual programming by blocks in primary education. In particular, the field of social sciences has seen a number of studies on this topic (Sáez López et al., 2017). Another area of research has focused on the implementation of bilingual programs in primary education, providing insights into effective teaching strategies and assessment approaches (Bolarín Martínez et al., 2019).

In terms of the most prominent journals, it was determined that the journal Computers in Human Behavior has been instrumental in propelling the field of knowledge concerning primary education and robotics forward. A study was conducted to ascertain whether computational thinking could be enhanced through the utilization of a methodology based on metaphors and Scratch for the instruction of programming to children. This work provided invaluable insight into the manner in which innovative pedagogical strategies can have a beneficial impact on computational thinking in educational contexts (Pérez-Marín et al., 2020).

The journal Education Sciences presented a systematic review of the literature on educational robotics and STEM research in primary education. This review has significantly contributed to the understanding of the characteristics and approaches of educational robotics and STEM research, emphasizing the importance of these fields in the context of primary education (Tselegkaridis et al., 2022).

Sustainability magazine has served as a principal conduit for the dissemination of knowledge regarding the implementation of robotics in STEAM initiatives. A study examining the "sustainable city" project utilized robotics to facilitate a closer connection between primary education students and an envisioned future urban environment. This contribution has underscored the significance of sustainability and the integration of robotics in pioneering educational endeavors (Ruiz Vicente et al., 2020).

In the field of scientific production related to primary education and robotics, Spain has distinguished itself as a notable contributor, with studies such as visual block programming in primary education offering a valuable perspective on the implementation of innovative methods in teaching. These studies focus on the integration of programming in the educational context (Sáez López & Cózar Gutiérrez, 2017).

The United States has made a substantial contribution to the field of educational research. For instance, studies have examined the relationship between women's educational attainment and child health outcomes under the free primary education program in Uganda. These studies have provided critical insights into the connection between women's education and child health outcomes (Keats, 2018).

Greece has also made notable contributions to the field of educational robotics and STEM in primary education. Their systematic review of the literature in these areas offers a comprehensive perspective on the characteristics and approaches of research in educational robotics and STEM in the context of primary education (Tselegkaridis & Sapounidis, 2022).

With regard to productivity, China has constituted a notable point of reference. Some authors have conducted an analysis of the impact of social factors on pair programming in primary school, thereby contributing to an enhanced understanding of social dynamics in the teaching of programming in primary education. (Zhong et al., 2016). Additionally, Turkey has distinguished itself in the field of scientific production on primary education and robotics. Some studies have evaluated the efficacy of the educational process when programming with Scratch in primary school, offering valuable insights into the effectiveness of teaching programming in this educational context (Durak & Guyer, 2019).

Analysis of Thematic Evolution on Primary Education and Robotics

In the initial stages of research on primary education and robotics, the concept of "compilers" played a pivotal role in the development of knowledge on this nascent topic. The foundational work (Minsky, 1970) presented a foundational perspective on compilers and their relevance in computing. This initial approach provided the foundation for understanding the relationship between programming and primary education, establishing a conceptual framework that guided research in the early years. However, as the field has evolved, attention has shifted towards broader topics such as educational technology, teaching, teaching programming, and computer programming. Nevertheless, the conceptual legacy of compilers has remained a fundamental aspect of the initial understanding of the intersection between primary education and robotics.

At the present time, the subject of primary education and robotics has undergone a notable shift in its conceptual approach, as evidenced by the proliferation of research centered on pivotal concepts such as educational technology, teaching, teaching programming, and computer programming. In 2023, the assessment of the instruction of mathematical programming in fifth-year students in Spanish educational institutions was investigated, emphasizing the significance of educational technology in this context

(Perales et al., 2023). In 2022, research was conducted examining mathematics teaching with the support of robotics, providing valuable insights from future primary education teachers (Amador-Terrón et al., 2022). In 2021, they put forth the proposition of implementing a gamified approach to programming instruction in primary education, underscoring the significance of programmatic teaching within this particular educational context (Cruz García et al., 2021).

Finally, in 2020, the potential of robotics in primary education as a tool for fostering computational thinking was explored, reinforcing the value of computer programming in early education (Caballero-González & García-Valcárcel, 2020). These studies illustrate the advancement of the field towards the effective integration of educational technology and teaching. The integration of programming and robotics in primary education has significantly contributed to the current understanding of the relationship between primary education and robotics. These studies address pedagogical and technological aspects to improve teaching and learning in this specific context. The diversity of approaches and methodologies used in these investigations highlights the complexity and multidimensionality of the intersection between primary education and robotics today.

Analysis of the Thematic Clusters on Primary Education and Robotics

This study enables the identification of the principal network of keyword co-occurrence, represented by different thematic clusters. The most prominent cluster, identified by its light blue color, is composed of terms such as "programming," "thematic analysis," and "constructionism." This cluster reflects a thematic affinity with the objective of improving computational thinking and programming ability in the context of primary education. Key research contributing to this cluster includes the work of Pérez-Marín et al. (2020). This study examines how computational thinking can be enhanced through the utilization of metaphors and Scratch to educate children in the field of programming. Additionally, the narratives of teachers engaged in the process of learning to program are explored in Monjelat and Lantz-Andersson (2020). Furthermore, Bottino et al. (2023) address the development of computational fluency through multimedia storytelling in an educational context.

Secondly, the red cluster, which encompasses terms such as "robotics," "STEM education," "STEM," "technology," "educational technology," and "block-based programming," highlights the intersection between educational robotics and STEM teaching in primary education. This cluster includes the study by Dorouka et al. (2020), which explores the use of tablets and applications to promote robotics, mathematics, and STEM education in early childhood. In Vivas and Sáez (2019), the integration of educational robotics in primary education is investigated. In Socratous and Ioannou (2021), the structuring of the educational robotics curriculum and its impact on block-based programming are examined. These studies contribute significantly to the understanding of the relationship between robotics, educational technology, and STEM teaching in the field of primary education.

Analysis of the Frequency and Conceptual Validity Around Primary Education and Robotics

The bibliometric results section reveals the significant presence of emerging concepts in quadrant 2 of the Cartesian plane, with terms such as "emotional learning companion," "constructionism," and "steam" being particularly noteworthy. These concepts reflect both the future direction and the current nature of research at the intersection of education, primary, and robotics. The concept of an "emotional learning companion" is explored in (Ocaña et al., 2023) in the context of gamification as a means of teaching programming to primary education students. This approach suggests that there is growing attention being paid to the emotional component in learning programming. The concept of constructionism, evidenced in quadrant 2, connects with research (Silva & Barbosa, 2022), which explores the applications of robotics in mathematical and physical experiments. This approach highlights the importance of the active construction of knowledge through practical experiences with robotics in the educational field.

Similarly, the term "STEAM" (science, technology, engineering, arts, and mathematics) reflects the growing importance of interdisciplinary approaches. Manera (2020) contributes to this field of study by addressing the integration of educational robotics in early childhood and primary education from a STEAM perspective. This work underscores the significance of integrating disciplines to advance holistic and creative learning in the educational domain. The concepts that emerge in quadrant 2 indicate the evolution and diversification of research in primary education and robotics, with a shift towards more emotional, constructive, and multidisciplinary areas. Quadrant 1 of the Cartesian plane, which is characterized by the growth, advancement, and consolidation of concepts in the field of research, underscores the significance of keywords such as "secondary education," "teacher training," "teaching programming," and "scratch" in the context of primary education and robotics. Abeles (2016) underscores the significance of secondary education, emphasizing its pivotal position in the contemporary educational landscape. This well-established concept underscores the necessity for sustained attention towards the enhancement of secondary education and its ramifications for research in primary education and robotics.

Table 1. Classification of keywords according to their function

Keyword	Associated tools	Applications	Characteristics
Emotional learning companion	Virtual emotional learning environments & emotional feedback systems	Development of emotional intelligence & evaluation of emotional state	Improves student well-being & facilitates emotional self-awareness
Constructionism	Project construction platforms & educational robotics kits	Project-based learning & prototyping	Encourage creativity & develop problem-solving skills
Steam	Integration of science, technology, engineering, & art and mathematics	Interdisciplinary projects & holistic approach in education	Promote innovation & develop critical thinking
Reading	Interactive reading applications & reading comprehension platforms	Improving reading skills & promoting reading comprehension	Stimulates the love of reading & personalization of the learning process
Educational technology	Online learning platforms & interactive tools	Integration of technology in the classroom & personalization of learning	Improve accessibility & facilitate online collaboration
Secondary education	Secondary teaching strategies & advanced teaching materials	Development of specific skills & preparation for higher educational levels	Prepares for advanced education & subject-specific focus
Teacher training	Professional development programs & educational workshops	Improvement of pedagogical strategies & integration of technologies in teaching	Development of teaching competencies & continuous updating of educational personnel
Teaching programming	Programming teaching platforms & code development tools	Promotion of programming & development of computational thinking	Improve logic and problem-solving & prepare for the digital future
Scratch	Visual programming environments & game creation platforms	Creative programming development & teaching basic coding concepts	Facilitates introduction to programming & promotes digital creativity

In the field of teacher training, the demands of teachers are explored in (Manso & Garrido-Martos, 2021). The focus on teacher training highlights the importance of preparing educators to effectively integrate robotics into primary education, which plays a leading role in the successful implementation of innovative educational programs. Furthermore, the concept of teaching programming, as evidenced in quadrant 1, is addressed in Hijón-Neira et al. (2020). This highlights how the teaching of programming is a growing and consolidated area that influences the training of students from an early age.

Finally, Scratch, a visual programming language, has been demonstrated to be an effective tool for teaching programming. Iskrenovic-Momcilovic (2019) examines the practice of pair programming with Scratch, emphasizing its significance in programming education and training for primary school students. The concepts in quadrant 1 underscore the sustained relevance and prominence of secondary education, teacher training, teaching programming, and the use of tools such as Scratch in research on primary education and robotics.

Classification of Keywords on Primary Education and Robotics According to Their Function

Table 1 presents a comprehensive classification of the primary emerging and growing keywords related to the intersection of primary education and robotics, organized according to their specific function.

This classification allows for the identification and comprehension of the fundamental characteristics and the various applications of each of the categorized functions. It does so by organizing the keywords according to their role and contribution in the educational and robotic context. **Table 1** provides a comprehensive view of the topics emerging and growing research in this interdisciplinary field.

Theoretical Implications

This work has provided a comprehensive view of evolution and key trends in research on this topic. The analysis of the frequency of publications per year enabled the identification of periods of greatest research activity, with a notable surge in recent years, particularly in 2020, 2021, 2022, and 2023. This increase suggests a growing interest in the intersection between primary education and robotics, potentially influenced by technological advancements and shifts in educational practices.

The identification of the main theoretical references in literature provides a solid conceptual framework for understanding the diversity of approaches in research. It is evident that various authors adopt different strategies and approaches, which highlights the theoretical richness of the discipline and suggests the existence of multiple perspectives for addressing the integration of robotics in primary education.

The analysis of thematic evolution, based on the most used keyword each year, revealed significant changes in the conceptual approach over time. The appearance of concepts such as "compilers" in 1970 gave way to the prevalence of contemporary themes such as "educational technology," "teaching," and "computer programming" in recent years. These findings demonstrate the transformations in academic discourse and the adaptation of research to current educational demands.

The identification of the main keyword co-occurrence network across thematic clusters revealed significant groupings, which highlighted the importance of concepts such as "programming," "thematic analysis," and "constructionism" in one cluster and "robotics," "STEM education," and "block-based programming" in another. These findings suggest specific topic areas that have received greater attention and exploration in literature.

The classification of emerging and growing keywords, as well as their representation in a Cartesian plane that measures frequency and validity of use, provides a more detailed understanding of the research dynamics. The identification of emerging keywords such as "emotional learning companion" and "steam" in quadrant 2 highlights emerging but highly current thematic areas. In contrast, consolidated and growing concepts, such as "secondary education" and "teaching programming," are located in quadrant 1, indicating their continued relevance and consolidation in research.

In conclusion, the identification of research gaps provides valuable direction for future research. The identification of underexplored concepts or areas where research is limited suggests opportunities to fill gaps in literature and advance the understanding of the integration of robotics in education. In the context of primary education, these gaps may include specific topics, underutilized methodological approaches, or understudied student populations. This is a potential avenues for future research and theoretical development in this interdisciplinary area.

Practical Implications

This bibliometric analysis offers valuable practical implications that guide decision-making in the educational field. Thematic evolution is evidenced by the change from the initial study of "compilers" towards broader aspects such as "educational technology," "teaching," and "computer programming." This transition suggests the need to integrate technological tools and novel pedagogical approaches in primary education, aligning with contemporary trends.

The identification of the primary thematic cluster, composed of terms such as "programming," "thematic analysis," and "constructionism," highlights related conceptual areas that have received further attention and exploration. These findings indicate the presence of distinctive pedagogical and methodological approaches at the nexus of primary education and robotics. The practical implications are twofold: firstly, there is a need to advance research and the implementation of educational strategies based on these concepts, and secondly, to recognize them as fundamental in the interaction between students and technology.

The analysis of the frequency and validity of keywords provides a dynamic vision of research in the discipline. The identification of emerging concepts, such as "emotional learning companion," "constructionism," and "steam," along with growing ones, such as "secondary education," "teacher training," and "teaching programming," offers guidance for the formulation of educational policy and the development of pedagogical practices. It also implies a need to integrate emotional approaches and emerging technologies in primary education, while recognizing the continued relevance of more traditional themes.

The classification of keywords according to their function, as illustrated in **Table 1**, offers a practical tool for identifying the characteristics and applications of each term. This classification facilitates comprehension of the tools associated with the keywords and their potential applications in the context of primary education and robotics. The practical implications derive from the ability to customize educational strategies based on the distinctive characteristics of each tool, thus maximizing its effectiveness in the school environment.

In addition to the practical implications previously discussed, bibliometrics on primary education and robotics offers valuable insights in other dimensions and contexts. Primarily, the analysis of scientific production by year provides relevant information for strategic planning and resource allocation in the field of education. The identification of years of greatest scientific activity, such as 2020, 2021, 2022, and 2023, enables education policymakers to anticipate trends and direct efforts towards areas that have recently gained prominence.

From a broader perspective, the identification of leading countries in scientific production, such as the United States, Spain, and Greece, provides insight into the dominant geographies at the nexus of primary education and robotics. This information can inform international collaborations, exchanges of best practices, and joint efforts to address common challenges in the implementation of robotics in primary education.

In terms of impact, the recognition of prominent journals such as Computers in Human Behavior, Education Sciences, and Sustainability serves to reinforce the importance of these publications in the dissemination of knowledge. Researchers and educators may direct their efforts toward publication in these journals, thereby contributing to the consolidation and dissemination of significant advances in discipline.

In the pedagogical context, the classification of keywords according to their function in **Table 1** provides a tool directly applicable in the design of educational programs. By identifying the specific characteristics and applications of each keyword, educators can personalize their approaches to maximize the impact of robotics in primary education, adapting it to the specific needs and contexts of their students.

Limitations

The present bibliometric analysis, conducted with the PRISMA-2020 methodology and utilizing databases such as Scopus and Web of Science, is subject to certain limitations that must be considered when interpreting its findings. Primarily, reliance on a specific set of data sources could potentially introduce bias. Furthermore, the inclusion of relevant publications in these databases may be incomplete, and the accessibility of online information may fluctuate, potentially impacting the comprehensiveness of the bibliographic search.

Another limitation pertains to the selection of bibliometric analysis tools, including Microsoft Excel® and VOSviewer®. While these tools are widely utilized, each possesses distinct advantages and limitations, and the choice of these tools can influence the final results. Moreover, the capacity of these instruments to fully encompass the intricacies of bibliometric interconnections may be constrained, potentially affecting the comprehensive portrayal of the keyword co-occurrence network and the identification of nascent and expanding terminology.

The dynamic nature of the field of study also introduces inherent temporal limitations to bibliometrics. It is important to note that the trends and relationships identified may change over time, and that bibliometrics provides only a snapshot of the data over a specific period. It should be noted that the thematic evolution reflected may not capture more recent and emerging developments, necessitating regular updates to ensure the continued relevance of the findings.

It is essential to acknowledge that while bibliometrics offers valuable insights into quantitative and structural aspects of publications, it has inherent limitations in assessing the intrinsic quality of these works. The quality and relevance of publications may not be fully reflected in bibliometric indicators, and the use of alternative evaluation methods, such as qualitative systematic reviews, could enhance our understanding of the literature in primary education and robotics.

Investigative Gaps

Table 2 provides a comprehensive overview of the research gaps identified in the bibliometrics on primary education and robotics. These gaps underscore the necessity for further investigation into pivotal areas, including the comprehensive integration of robotics in the curriculum, the assessment of its pedagogical impact, ethical and social considerations, the efficacy of specific platforms, teacher training, and the inclusion of diverse student populations. **Table 2** provides a framework for future research in the field of primary education and robotics, highlighting specific areas where academic institutions can conduct further investigation to enhance the theoretical and practical comprehension of this phenomenon. Future research in these areas will contribute to the advancement of knowledge and the successful application of robotics in primary education.

Research Agenda

The topic of "secondary education" in the context of primary education and robotics is of great importance, as it concerns the ways in which the skills acquired in the early years are translated and developed in later educational stages. Currently, it has been recognized that secondary education represents a crucial period for consolidating and applying prior knowledge related to robotics and programming acquired in primary school. Consequently, future research could focus on evaluating the effectiveness of robotics programs implemented in primary education in terms of their long-term impact on secondary education. Additionally, it could explore how experiences in robotics during primary education influence students' academic and career choices during secondary education.

Scratch is a visual programming tool that is widely utilized in primary education with the objective of introducing coding concepts in a manner that is both engaging and accessible. Its significance lies in its capacity to foster logical and computational thinking from an early age. In the future, research may be conducted to analyze the evolution of students' programming skills who have used Scratch in primary school. This analysis could explore how this foundation impacts their learning in more advanced areas of programming in secondary education. Additionally, comparative studies could be developed to evaluate the effectiveness of Scratch compared to other programming platforms in the specific context of primary education.

The term "education" encompasses a multitude of facets and pedagogical approaches pertaining to the integration of robotics in the classroom. Future research could investigate the identification of innovative pedagogical practices that effectively integrate robotics into the primary education curriculum. Additionally, it could examine the influence of national and international educational policies on the adoption and approach to robotics in primary schools. Comprehensive evaluations of specific programs, teaching methods, and pedagogical strategies related to primary education and robotics would be valuable avenues for research.

Table 2. Research gaps

Category	Investigative gaps	Justification	Questions for future research
Thematic gaps	(a) Comprehensive pedagogical impact of robotics in the curriculum.	Despite the growth in research, a deeper understanding of the full impact of robotics in primary education is required, beyond specific approaches.	How does the full integration of robotics in multiple subjects influence primary education? What are teachers' perceptions of this comprehensive impact?
	(b) Ethical and social considerations of robotics teaching.	As robotics has become a common pedagogical tool, it is crucial to address the ethical and social issues that arise, ensuring responsible implementation.	What are the emerging ethical dilemmas related to teaching robotics in primary education? How can these dilemmas be addressed effectively in the educational environment?
	(c) Effectiveness of specific platforms in teaching.	More comparative research is needed on the effectiveness of specific robotics platforms to better understand which ones are most suitable and beneficial for primary teaching.	How do specific robotics platforms compare in terms of pedagogical impact and ease of use in primary education?
Geographic gaps	(a) Exploration of implementation in global contexts.	Most research focuses on specific countries, making it necessary to expand the exploration of the integration of robotics in diverse geographical contexts.	How does the implementation of robotics in primary education differ in various cultural and geographic contexts? Are there common patterns or significant differences?
	(b) Study of barriers and facilitators in different regions.	Identifying the obstacles and factors that facilitate the implementation of robotics in primary education in various regions would contribute to more adapted strategies.	What are the common barriers that schools in different regions face when implementing robotics programs in primary education?
Interdisciplinary gaps	(a) Evaluation of interdisciplinary training for teachers.	Interdisciplinary teacher training is essential to address the complexity of robotics teaching, but its effectiveness and challenges need more attention.	How can interdisciplinary training for teachers in the field of educational robotics in primary education be improved? What methodologies are most effective?
	(b) Collaborative research between educators and robotics experts.	Interdisciplinary collaboration can enrich robotics teaching; however, there is a need to explore how to foster and maintain such collaborations.	What are the most effective approaches to foster collaboration between educators and robotics experts in interdisciplinary educational projects?
Temporal gaps	(a) Long-term evaluation of the impact of robotics.	Most studies focus on immediate impacts, making it essential to investigate how these impacts evolve over time in primary education.	How does the impact of robotics instruction on student performance and attitude change over several years?
	(b) Monitoring the adaptation of teachers to new technologies.	Teachers' continued learning in the use of emerging technologies such as robotics should be the subject of further investigation to inform professional development strategies.	How do teachers' attitudes and skills toward teaching robotics change as new technologies and methods are introduced?

The concept of "constructionism," which is emerging in the fields of elementary education and robotics, underscores the significance of students constructing their own knowledge through active involvement in projects and hands-on experiences. Future research could investigate how constructionist approaches to teaching robotics influence the cognitive development and problem-solving abilities of primary education students. Similarly, research could be conducted on the integration of constructionist principles into curricular programs, with the aim of maximizing the educational potential of robotics.

The inclusion of the "emotional learning companion" underscores the increasing emphasis on the emotional aspect in primary education and robotics. Future research could be focused on elucidating the impact of robots and emotional learning companions on students' emotional well-being within the context of robotics education. Additionally, there is a need to investigate the design and enhancement of these companions to enhance their capacity for emotional support and their influence on the learning process.

The term "health" within the context of primary education and robotics indicates a growing awareness of the importance of addressing health-related aspects in the implementation of robotics programs. Future research could explore the impact of robotics programs on the physical and mental health of students in primary education. Additionally, specific interventions could be developed that utilize robotics as a tool to promote healthy habits and general well-being in the student population.

"Computer programming" remains a pivotal subject in the context of elementary and robotics education. Future research should concentrate on elucidating the impact of early computer programming instruction on the development of cognitive abilities and preparedness for subsequent academic challenges. Additionally, the efficacy of diverse pedagogical strategies for teaching programming in the context of primary education should be investigated, with particular emphasis on the adaptability and accessibility of the methodologies employed.

"Program evaluation" in the context of primary education and robotics underscores the necessity for systematic and ongoing assessment of the efficacy of implemented programs and strategies. Future research may focus on the development of specific evaluation methods and models to gauge the impact of robotics programs in primary education. Similarly, one could investigate how assessments can be adapted to more accurately reflect not only academic outcomes but also the socio-emotional benefits and skills acquired by students.

The concept of learning remains a fundamental tenet in the context of both primary and robotics education. Future research could enhance our comprehension of the particular learning processes that are facilitated by the incorporation of robotics in educational settings. Additionally, longitudinal studies could be established to assess the impact of early learning experiences related to robotics on cognitive and academic development over time in primary education.

The term "STEM education" denotes a comprehensive focus area encompassing science, technology, engineering, and mathematics. While the relevance of this approach is already established, future research may benefit from exploring how STEM methodologies in primary education can be optimized through the integration of robotics. It would be beneficial to design studies to evaluate the effectiveness of specific STEM programs that incorporate robotics in comparison to more traditional approaches. This would allow for the identification of optimal practices and strategies to enhance primary STEM education.

The evaluation of the impact and effectiveness of the implementation of robotics in primary education remains a crucial element in this field of study. Future research could focus on the refinement and development of specific assessment models to measure not only academic outcomes but also social-emotional aspects and preparation for 21st century skills. Additionally, assessments could be adapted to more accurately reflect not only academic results but also the socio-emotional benefits and skills acquired by students. **Figure 9** shows the research agenda.

CONCLUSION

The bibliometric analysis of primary education and robotics has yielded significant conclusions that address the research questions posed. Firstly, it is evident that the most pertinent years in terms of interest in this topic were 2020, 2021, and 2022, which reflects a growing recognition of the significance of robotics in primary education. Moreover, the examination of the growth in the number of scientific articles indicated a cubic polynomial trend, suggesting a notable surge in the production of scientific literature within this domain. In conclusion, the identified research references, such as Zhong, B. C., Pizarro, C., and Pérez-Marín, D., together with the prominent journals and leading countries, provide a solid foundation for future research and guide the development of knowledge at the intersection of primary education and robotics.

The thematic evolution in the field has undergone a substantial change, evolving from an initial focus on compilers towards a contemporary orientation that focuses on key concepts such as educational technology, teaching, teaching programming, and computer programming. In conclusion, this change reflects an adaptation to the demands and advances in the fields of education and technology. Moreover, the identification of thematic clusters, most notably the cluster comprising programming, thematic analysis, and constructionism, underscores conceptual coherence within the literature and suggests areas of interconnection that warrant further investigation.

The emergence and growth of keywords provide insight into the evolving landscape of the field, where established concepts such as secondary education, teacher training, teaching programming, and Scratch represent areas of significant focus. Concurrently, novel concepts such as the emotional learning companion, constructionism, and steam emerge, indicating promising new avenues for research. In conclusion, these results underscore the necessity to strike a balance between maintaining continuity in fundamental themes and exploring new dimensions at the intersection of primary education and robotics.

Finally, the formulation of a research agenda highlights the significance of delving into the pivotal concepts identified to inform future studies. The consolidation of these findings provides academics, educators, and policymakers with invaluable guidance for the strategic planning of research that contributes to the advancement and continued integration of robotics in primary education.

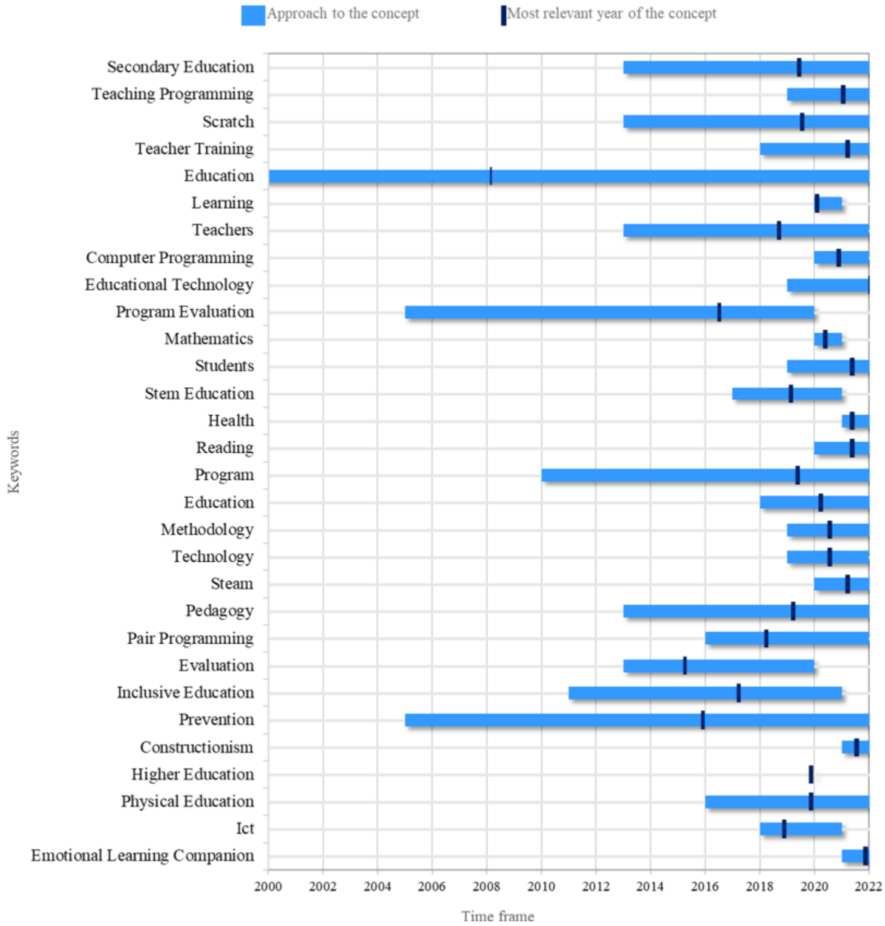

Figure 9. Research agenda (the authors' own elaboration based on Scopus and Web of Science)

Author contributions: EM-R, AV-A, MHV-C, JMB-G, EA-C, MLB-A, & LV-M: conceptualization and study design; **EM-R, MHV-C, & JMB-G:** data curation; **AV-A, EA-C, & MLB-A:** formal analysis; **LV-M:** writing – original draft, writing – review & editing. All authors reviewed and approved the final version of the manuscript.

Funding: No funding source is reported for this study.

Ethical statement: The authors stated that the study does not require approval from an ethics committee since it was based on existing literature.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

REFERENCES

Abeles, T. P. (2016). Call for articles: Education at a tipping point scenarios and narratives. *On the Horizon, 24*(2), 137-140. https://doi.org/10.1108/OTH-03-2016-0007

Amador-Terrón, S., Carvalho, J. L., & Melo, L. (2022). Enseñanza de matemáticas con el apoyo de la robótica: Opinión de futuros/as docentes de educación primaria [Teaching mathematics with the support of robotics: Opinion of future primary school teachers]. *Revista Prisma Social*, (38), 114-136.

Bolarín Martínez, M. J., Porto Currás, M., & Lova Mellado, M. (2019). Implementation of bilingual programs in primary education: Teaching and evaluation strategies. *Elia: Estudios de Lingüística Inglesa Aplicada, 1 Monográfico*, 207-234. https://doi.org/10.12795/elia.mon.2019.i19.09

Bottino, R., Chioccariello, A., & Freina, L. (2023). Developing computational fluency via multimedia stories. In T. Keane, A. E. Fluck (Eds.), *Teaching coding in K-12 schools: Research and application* (pp. 63-79). Springer. https://doi.org/10.1007/978-3-031-21970-2_5

Caballero-González, Y., & García-Valcárcel, A. (2020). Learning with robotics in primary education. A means of stimulating computational thinking. *Education in the Knowledge Society, 20*(10), 1-15. https://doi.org/10.14201/eks.22956

Caputo, A., & Kargina, M. (2022). A user-friendly method to merge Scopus and Web of Science data during bibliometric analysis. *Journal of Marketing Analytics, 10*(1), 82-88. https://doi.org/10.1057/s41270-021-00142-7

Collado-Soler, R., Alférez-Pastor, M., Torres, F. L., Trigueros, R., Aguilar-Parra, J. M., & Navarro, N. (2023). A systematic review of healthy nutrition intervention programs in kindergarten and primary education. *Nutrients, 15*(3), Article 541. https://doi.org/10.3390/nu15030541

Cruz García, I., Martín García, J. A., Pérez Marín, D., & Pizarro, C. (2021). A proposal of programming didactics in primary education following a gamified approach with educational videogames. *Education in the Knowledge Society, 22*, Article e26130. https://doi.org/10.14201/eks.26130

Dorouka, P., Papadakis, S., & Kalogiannakis, M. (2020). Tablets and apps for promoting robotics, mathematics, STEM education and literacy in early childhood education. *International Journal of Mobile Learning and Organisation, 14*(2), 255-274. https://doi.org/10.1504/IJMLO.2020.106179

Durak, H. Y., & Guyer, T. (2019). Programming with Scratch in primary school, indicators related to effectiveness of education process and analysis of these indicators in terms of various variables. *Gifted Education International, 35*(3), 237-258. https://doi.org/10.1177/0261429419854223

Durieux, V., & Gevenois, P. A. (2010). Bibliometric indicators: Quality measurements of scientific publication. *Radiology, 255*(2), 342-351. https://doi.org/10.1148/radiol.09090626

Fernández-Martín, F. D., Romero-Rodríguez, J. M., Marín-Marín, J. A., & Gómez-García, G. (2021). Social and emotional learning in the Ibero-American context: A systematic review. *Frontiers in Psychology, 12*. https://doi.org/10.3389/fpsyg.2021.738501

García-Carrillo, C., Greca, I. M., & Fernández-Hawrylak, M. (2021). Teacher perspectives on teaching the STEM approach to educational coding and robotics in primary education. *Education Sciences, 11*(2), Article 64. https://doi.org/10.3390/educsci11020064

Hijón-Neira, R., Pérez-Marin, D., Pizarro, C., & Connolly, C. (2020). The effects of a visual execution environment and Makey Makey on primary school children learning introductory programming concepts. *IEEE Access, 8*, 217800-217815. https://doi.org/10.1109/ACCESS.2020.3041686

Iskrenovic-Momcilovic, O. (2019). Pair programming with scratch. *Education and Information Technologies, 24*, 2943-2952. https://doi.org/10.1007/s10639-019-09905-3

Keats, A. (2018). Women's schooling, fertility, and child health outcomes: Evidence from Uganda's free primary education program. *Journal of Development Economics, 135*, 142-159. https://doi.org/10.1016/j.jdeveco.2018.07.002

Manera, L. (2020). STEAM and educational robotics: Interdisciplinary approaches to robotics in early childhood and primary education. In *Proceedings of the Human-Friendly Robotics 2019: 12th International Workshop* (pp. 103-109). Springer. https://doi.org/10.1007/978-3-030-42026-0_8

Manso, J., & Garrido-Martos, R. (2021). Formación inicial y acceso a la profesión: Qué demandan los docentes [Initial training and access to the profession: Teachers' demands]. *Revista de Educación, 393*, 285-310. https://doi.org/10.4438/1988-592X-RE-2021-393-494

Minsky, M. (1970). Form and content in computer science (1970 ACM Turing lecture). *Journal of the ACM, 17*(2), 197-215. https://doi.org/10.1145/321574.321575

Monjelat, N., & Lantz-Andersson, A. (2020). Teachers' narrative of learning to program in a professional development effort and the relation to the rhetoric of computational thinking. *Education and Information Technologies, 25*(3), 2175-2200. https://doi.org/10.1007/s10639-019-10048-8

Muñoz, L., Villarreal, V., Morales, I., Gonzalez, J., & Nielsen, M. (2020). Developing an interactive environment through the teaching of mathematics with small robots. *Sensors, 20*(7), Article 1935. https://doi.org/10.3390/s20071935

Ocaña, J. M., Morales-Urrutia, E. K., Pérez-Marín, D., & Pizarro, C. (2023). About gamifying an emotional learning companion to teach programming to primary education students. *Simulation & Gaming, 54*(4), 402-426. https://doi.org/10.1177/10468781231175013

Ocaña, J. M., Morales-Urrutia, E. K., Pérez-Marín, D., & Pizarro, C. (2020). Can a learning companion be used to continue teaching programming to children even during the COVID-19 pandemic? *IEEE Access, 8*, 157840-157861. https://doi.org/10.1109/ACCESS.2020.3020007

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hrobjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *International journal of surgery, 88*, Article 105906. https://doi.org/10.1016/j.ijsu.2021.105906

Perales, R. G., Ruiz, A. P., Parra, E. L., & García, M. I. M. (2023). Avaliação do ensino em programação matemática em alunos do 5º ano do Ensino fundamental em centros educacionais Espanhóis [Evaluation of teaching in mathematical programming in 5th grade students of primary school in Spanish educational centers]. *Ensaio: Avaliação e Políticas Públicas em Educação, 31*(120), 729-753. https://doi.org/10.1007/978-3-319-51380-5

Pérez-Marín, D., Hijón-Neira, R., Bacelo, A., & Pizarro, C. (2020). Can computational thinking be improved by using a methodology based on metaphors and scratch to teach computer programming to children?. *Computers in Human Behavior, 105*, Article 105849. https://doi.org/10.1016/j.chb.2018.12.027

Rich, P. J., Browning, S. F., Perkins, M., Shoop, T., Yoshikawa, E., & Belikov, O. M. (2019). Coding in K-8: International trends in teaching elementary/primary computing. *TechTrends, 63*, 311-329. https://doi.org/10.1007/s11528-018-0295-4

Rodgers, S., & Zhang, W. (2022). Evaluating reliability of Google Scholar, Scopus, and Web of Science: A study of faculty in US advertising and public relations programs. *Journalism & Mass Communication Educator, 77*(3), 292-307. https://doi.org/10.1177/10776958211064687

Ruiz Vicente, F., Zapatera Llinares, A., & Montés Sánchez, N. (2020). "Sustainable city": A steam project using robotics to bring the city of the future to primary education students. *Sustainability, 12*(22), Article 9696. https://doi.org/10.3390/su12229696

Sáez López, J. M., & Cózar Gutiérrez, R. (2017). Programación visual por bloques en educación primaria: Aprendiendo y creando contenidos en ciencias sociales [Visual block programming in primary education: Learning and creating content in social sciences]. *Revista Complutense de Educación, 28*(2), 409-426. https://doi.org/10.5209/rev_RCED.2017.v28.n2.49381

Sapounidis, T., Tselegkaridis, S., & Stamovlasis, D. (2022). Educational robotics and STEM in primary education: A review and a meta-analysis. *Journal of Research on Technology in Education, 56*(4), 462-476. https://doi.org/10.1080/15391523.2022.2160394

Silva, M. P. D., & Barbosa, F. D. C. (2022). Mathematics and physics in free robotics experiments: Exploring the ultrasonic sensor. *Texto Livre, 14*. https://doi.org/10.35699/1983-3652.2021.29629

Socratous, C., & Ioannou, A. (2021). Structured or unstructured educational robotics curriculum? A study of debugging in block-based programming. *Educational Technology Research and Development, 69*, 3081-3100. https://doi.org/10.1007/s11423-021-10056-x

Topali, P., & Mikropoulos, T. A. (2023). Scratch-based learning objects for novice programmers: Exploring quality aspects and perceptions for primary education. *Interactive Learning Environments, 31*(7), 4219-4234. https://doi.org/10.1080/10494820.2021.1956546

Tselegkaridis, S., & Sapounidis, T. (2022). Exploring the features of educational robotics and STEM research in primary education: A systematic literature review. *Education Sciences, 12*(5), Article 305. https://doi.org/10.3390/educsci12050305

van Eck, N., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics, 84*(2), 523-538. https://doi.org/10.1007/s11192-009-0146-3

Vicente, F. R., Zapatera Llinares, A., & Montes Sanchez, N. (2021). Curriculum analysis and design, implementation, and validation of a STEAM project through educational robotics in primary education. *Computer Applications in Engineering Education, 29*(1), 160-174. https://doi.org/10.1002/cae.22373

Vivas, L., & Sáez, J. M. (2019). Integration of educational robotics in primary education. *RELATEC, 18*, 107-129. https://doi.org/10.17398/1695-288X.18.1.107

Zhong, B., Wang, Q., & Chen, J. (2016). The impact of social factors on pair programming in a primary school. *Computers in Human Behavior, 64*, 423-431. https://doi.org/10.1016/j.chb.2016.07.017

Zhong, B., Wang, Q., Chen, J., & Li, Y. (2016). An exploration of three-dimensional integrated assessment for computational thinking. *Journal of Educational Computing Research, 53*(4), 562-590. https://doi.org/10.1177/0735633115608444

Zhong, B., Wang, Q., Chen, J., & Li, Y. (2017). Investigating the period of switching roles in pair programming in a primary school. *Journal of Educational Technology & Society, 20*(3), 220-233.