



The Evolution of Educational Technology Implementation in Elementary School

A Bibliometric Analysis of Scopus Publications from 2010 to 2025

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ABSTRACT

The increasing integration of technology in primary education has led to a rapid growth of scholarly publications on educational technology implementation across diverse contexts. However, this expanding body of literature remains fragmented, as it has not been comprehensively examined from an educational technology perspective. The absence of systematic mapping limits a holistic understanding of global research trends in this field. Therefore, this study aims to analyze trends in the implementation of educational technology in primary schools using a bibliometric approach based on Scopus-indexed publications. This study employs a bibliometric research design to systematically map long-term developments over a 25-year period (2000–2025). The methodological framework follows five stages: data retrieval, eligibility screening, data cleaning, bibliometric mapping, and statistical as well as network analysis. Data were collected using the keywords “educational technology” AND “elementary school” and analyzed using VOS viewer (version 1.6.20) and the Bibliometrics R package (version 5.0), with term harmonization applied to ensure analytical consistency. The findings reveal a steady increase in publications, with an annual growth rate of 6.08% and a high coefficient of determination ($R^2 = 0.849$), indicating that the field is in a growth phase approaching maturity. A total of 6,125 authors contributed, with an average of 3.74 co-authors per document and an international collaboration rate of 13.55%. Recent keywords highlight digital and AI technologies, while long-standing themes emphasize learning enhancement.

Keywords

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Introduction

Advances in educational technology have become a central issue in the transformation of the global education system, in line with the demand for 21st-century skills such as digital literacy, critical thinking, creativity, and collaboration. The integration of technology in learning is no longer viewed merely as the use of digital devices, but rather as a system encompassing instructional design, pedagogical strategies, and the management of learning environments that support the achievement of educational goals [1], [2], [3]. In this context, educational technology plays a crucial role in enhancing the quality of learning and expanding access to diverse learning resources. The implementation of educational technology at the elementary school level presents distinct characteristics and challenges compared to other levels of education. Elementary school students are at a stage of cognitive and social development that requires a concrete, contextual, and experience-oriented approach to learning that fosters meaningful learning experiences [4], [5], [6]. Therefore, the use of educational technology in elementary schools must be aligned with principles of child development and student-centered pedagogy, so that technology functions as a facilitator of learning, not merely a tool for delivering content [2], [7]. Inappropriate application of technology, however, risks undermining the effectiveness of learning and the goals of elementary education.

As interest in the use of technology in elementary education grows, the number of scientific publications discussing the implementation of educational technology in elementary schools has also shown a significant upward trend. These studies cover a wide range of topics, such as the use of interactive multimedia, game-based learning, mobile learning, learning management systems, and the application of artificial intelligence and augmented reality [8], [9]. However, the diversity and growth of research in this area need to be examined comprehensively from the perspective of educational technology. Partial mapping can result in incomplete data and a limited understanding of the global dynamics of research on the implementation of educational technology in elementary schools.

The bibliometric approach offers a more systematic and objective alternative for mapping research trends through quantitative analysis of scientific publications. The Scopus database was selected because articles published in this index undergo a rigorous evaluation process to ensure that the uploaded scientific content is credible and influential and because of its broad coverage of educational sources [10], [11], [12]. Therefore, the Scopus database serves as an ideal data source for the purposes of this study. With this approach, research dynamics can be analyzed in greater depth and on a data-driven basis.

Nevertheless, bibliometric studies that specifically focus on the implementation of educational technology in elementary schools remain relatively limited. Therefore, there is a need for research that comprehensively maps the development of themes, key actors, and research directions over a longitudinal period, with a more specific focus [13], [14]. This gap highlights the need for studies capable of providing a complete picture of research trends in the field of educational technology.

Based on the above discussion, this study aims to analyze trends in the implementation of educational technology in elementary schools using Scopus data through a bibliometric approach. The results of this study are expected to provide a theoretical contribution to the development of educational technology as a field of study and to serve as a reference for researchers, practitioners, and policymakers in designing and implementing relevant and effective educational technology in elementary schools.

Material and Methods

This study employs a bibliometric design to map and analyze trends in educational technology in elementary schools over a 25-year period. It examines the development of educational technology in elementary schools using the " " of research articles published in Scopus from 2000 to 2025. The methodological flow of this study is adapted from the approach used by Passas [15] which consists of five sequential stages: (i) data collection, (ii) screening and eligibility assessment, (iii) data cleaning and preparation, (iv) bibliometric mapping, and (v) statistical and network analysis. Data collection used the keywords "*Educational technology*" OR "*Instructional technology*" OR "*Learning technology*" OR "*Technology-Enhanced Learning*" AND "*elementary school*" OR "*primary school*" NOT "*primary school teacher education*" AND "*primary school teacher*". The search covered the period from January 1, 2000, to November 2025, limited to works in the "English" language and restricted to the literature types "articles" and "proceedings of international conferences." A total of 6,500 articles were identified. Next, the entire dataset was sorted using the keywords that appeared on the search results page in Scopus. The keywords selected were: "*elementary school*," "*primary school*," "*elementary education*," "*primary education*," "*elementary student*," "*primary school student*," "*K-12 education*," "*educational technology*," "*technology-enhanced learning*," "*technology integration*," and "*technology education*." Keywords other than those listed were not selected. Irrelevant publications, such as news articles, conference call for papers, announcements, and books, were excluded from the analysis. The search yielded a total of 1,978 documents. All bibliometric data was downloaded on November 29, 2025. To avoid inconsistencies in data counts due to potential updates to the database, the entire search and download process was conducted on the same day

Complete data records were downloaded from Scopus in two formats: CSV and Bib. Data analysis was performed using VOS-Viewer (version 1.6.20) and the Bibliometrix R Package (version 5.0). During the analysis process, terms that were different but had the same meaning were standardized and normalized to ensure more accurate and consistent bibliometric analysis using the thesaurus file function. Data in CSV format were processed and analyzed using VOS-Viewer, while Bib data were processed and analyzed using the Bibliometrix R Package (version 5.0). VOS-Viewer was used to process data and perform visualizations using co-occurrence analysis and the *full-counting* method [16] to generate keyword clustering and visual keyword network maps illustrating thematic relationships among publications. Meanwhile, the Bibliometrix R Package was used to perform various visualization analyses, including institutional collaboration networks, journal publication trends, and emerging research hotspots each year. These visualizations were analyzed descriptively to identify research trends, dominant keywords, and opportunities for developing research topics on educational technology in elementary schools in the future.

Results

A. Key Information

Table 1 below presents a summary of key information from all the analyzed documents. The publication period spans from 2000 to 2025, with a total of 1,978 documents from 621 different sources. This research field has an average annual growth rate of 6.08%, indicating positive yet moderate growth. The research topic of educational technology in elementary schools is in the *growth-stabilization* phase, not the early (*emerging*) phase, and has not yet reached saturation [17]. The average age of the analyzed documents is 5.80 years, indicating that the research topic is contemporary and dynamic, not a fully established classical study. Each document received an average of 14.87 citations per article, indicating a good citation rate, especially when considering the documents' relatively young age. This indicates healthy academic visibility.

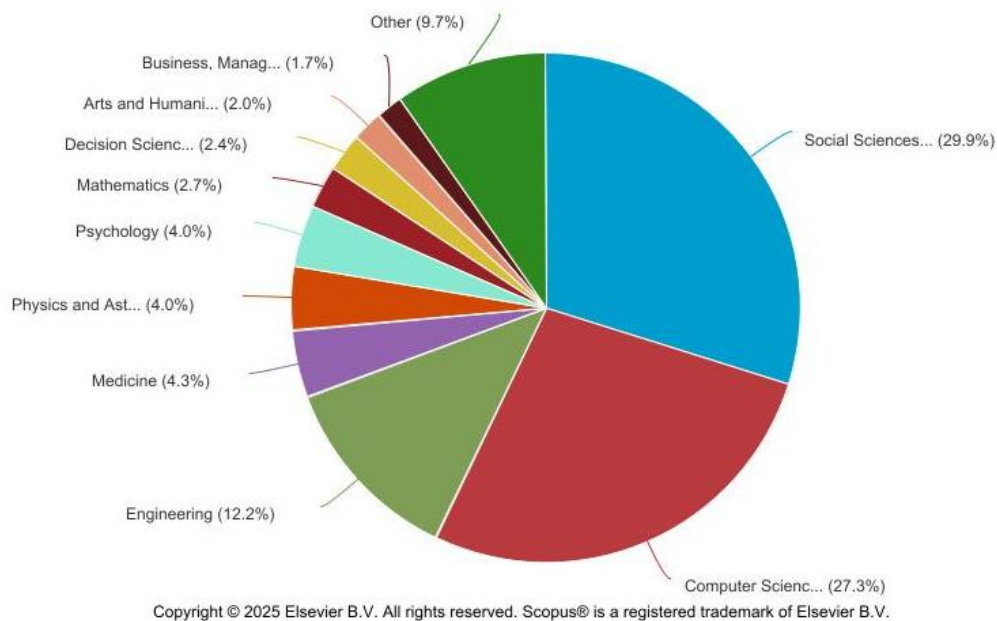
The distribution of articles across 621 journals and conference proceedings, spanning 1,978 documents, indicates that research on educational technology in elementary schools is interdisciplinary in nature. From the total data, 6,125 authors were involved in these publications, with 210 of them writing articles individually. These findings suggest that while some research is still conducted independently, co- on among authors is a prominent trend. Additionally, each article is authored by approximately 3.74 co-authors, yet only 13.55% of writing collaborations involve international cooperation. This data indicates a strong tendency toward collaboration, particularly at the domestic level, while international collaboration has not yet become widespread.

Table 1. Overview of Key Information

Documents and citations	Results	Authors and collaboration	Results
Time Range	2000–2025	Author	6125
Source (Journal, Proceedings)	621	Author Keywords (DE)	4389
Documents	1978	Documents written by a single author	210
Annual Growth Rate %	6.08	Documents written by a single author	228
Average Document Age	5.80	Co-authors per Document	3.74
Average Citations per Document	14.87	International co-authorship %	13.55

Source: results of analysis using the Bibliometrix R Package (version 5.0)

Based on the distribution of research fields, studies on educational technology in elementary schools have been examined from various perspectives, ranging from social sciences, computer science, engineering, and health to psychology, management, and business (Fig. 1). The three fields with the highest percentages are social sciences (29.9%), computer science (27.3%), and engineering (12.2%). Among this overall distribution, no single field dominates with a percentage exceeding 50%. These data indicate that the research perspectives on elementary school educational technology are spread across several disciplines in Fig. 1.

**Fig. 1.** Distribution of Documents by Field of Study

B. Annual Publication Trends

An annual trend analysis was conducted for publications on educational technology in elementary schools from January 1, 2000, to November 29, 2025, as shown in Fig. 2. The results of the analysis indicate that the number of publications each year has a coefficient of determination (R^2) of 0.849. The analysis of the annual publication lifecycle reveals a consistent and structured growth pattern. The value of the coefficient of determination ($R^2 = 0.849$)

indicates that 84.9% of the variation in the annual number of publications can be explained by the growth model used, so this field of study can be categorized as being in a stable growth phase toward maturity. If this coefficient of determination score is correlated with the *Annual Growth Rate* and the *Document Average Age*, it can be interpreted that this research field is in the *growth phase toward maturity*, not the early (*emerging*) phase, and has not yet entered the *decline* phase in Fig. 2.

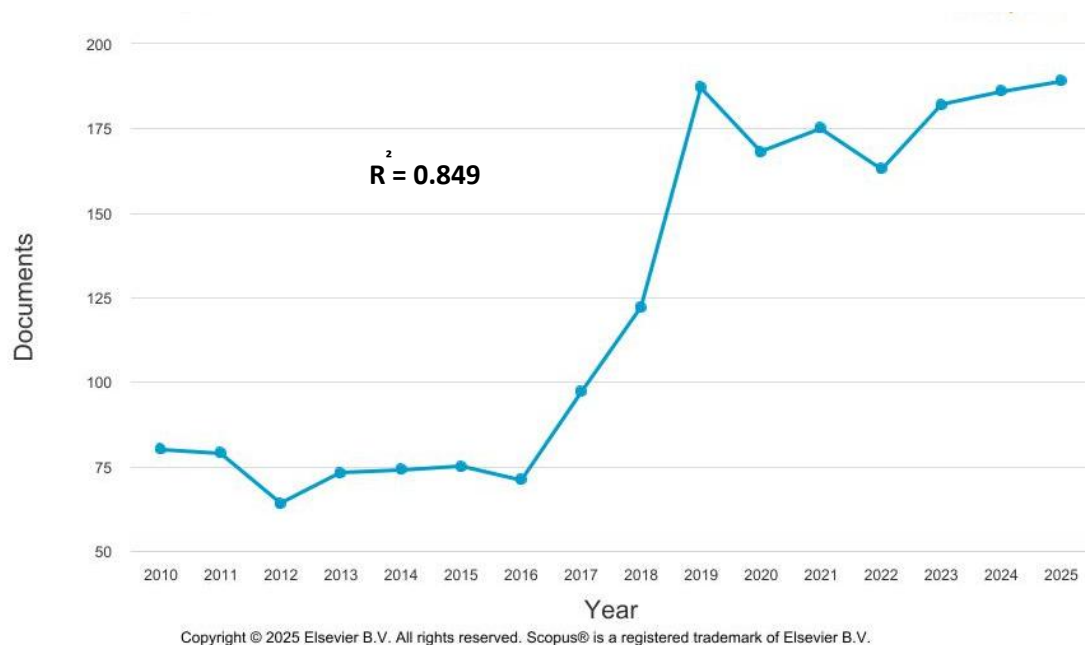


Fig. 2. Distribution of Documents by Field of Study

C. Country/Region Analysis

Among all countries researching educational technology in elementary schools, China and the United States are the two most productive. The eight other countries with the highest number of research studies on educational technology in elementary schools are Indonesia, Spain, South Korea, Turkey, Greece, Malaysia, the United Kingdom, and Canada. All ten countries with the highest number of publications on educational technology in elementary schools engage in cross-national research collaboration, as shown in the complete data in Fig. 3.

D. Keyword Analysis

The purpose of *co-occurrence* analysis is to identify the relationships between topic clusters formed from keywords and how frequently those keywords appear together. Keywords serve as brief summaries that describe the content of a document, thereby facilitating the identification of emerging research topics and trends within an academic field [18]. This analysis also helps provide a clearer picture of major themes and high-interest research areas, as well as predict future research directions and determine strategic focuses that need to be developed.

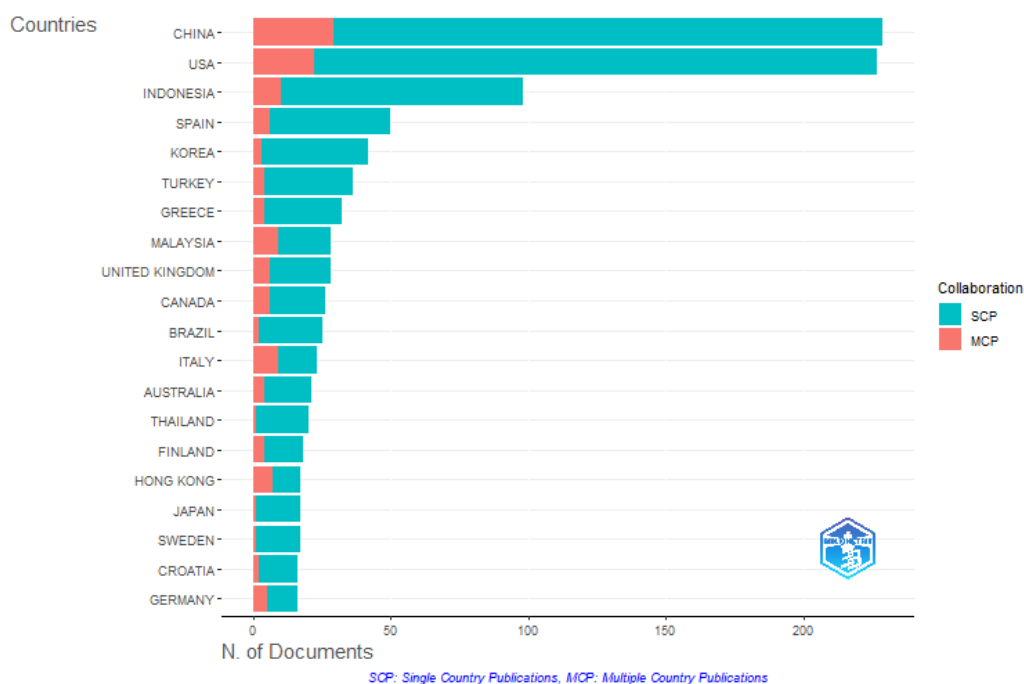


Fig. 3. Cross-National Research Collaboration Among the Top Ten Countries

Keywords were analyzed using *a thesaurus* to merge keywords with synonyms or duplicates, with a minimum occurrence threshold of five times. The selected keywords were all those provided by the author. This process yielded 228 keywords out of a total of 4,368. In Fig. 4, *node* size indicates the frequency of keyword occurrence within the topic of *educational technology in elementary schools*. The clustering process was performed using the VOS clustering algorithm with 20 random starts and 30 iterations. This clustering activity, utilizing the random starts and iterations algorithm, serves to ensure that the resulting data grouping process is not only accurate but also robust against variations in the data [19], [20]. Clustering in VOSviewer aims to identify structures or patterns within a network that help map interrelated concepts or topics.

Based on data analysis using VOS Viewer, keywords appearing in more than 50 documents/articles (excluding the terms "*elementary school*" and "*educational technology*") were identified: *Education*, *student*, *augmented reality*, *technology*, *ICT*, *STEM*, and *computational thinking*. All keywords were divided into 16 groups/clusters. The keywords in each cluster are shown in Fig. 4.

The sixteen cluster themes are listed in Table 2 below. Of the sixteen clusters identified, seven are specifically related to digital learning aspects. The other eight clusters are not specifically digital-AI based. This indicates a balanced distribution between topics based on digital-AI technology and general learning topics that are not specifically digital-based.

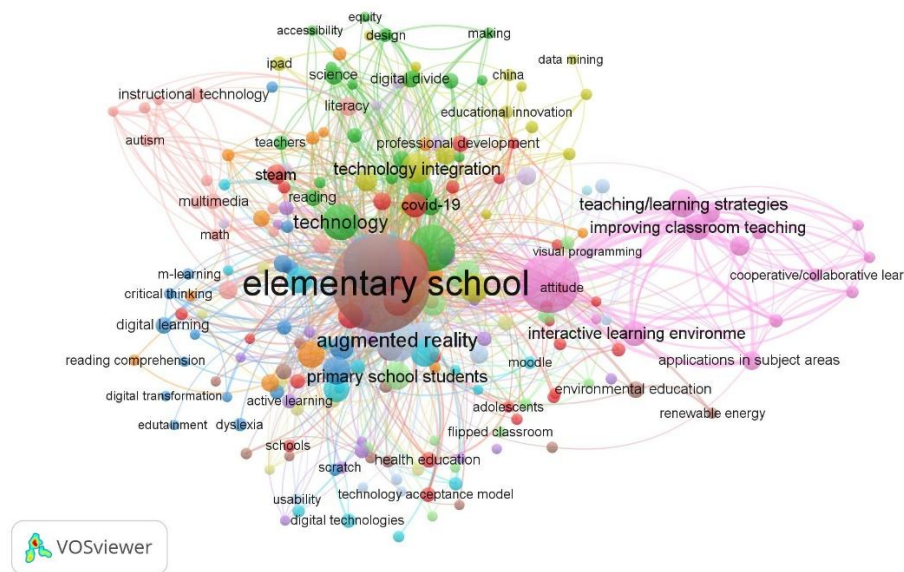


Fig. 4. Visualization of keyword clusters in elementary school educational technology research

Table 2. Sixteen clusters of educational technology research in elementary schools

Cluster	Thematic Label
1	Interactive Learning and General Pedagogy
2	Access & Educational Inclusion
3	Digital Learning & Learning Tools
4	STEM and Technology Integration
5	Creative and Critical Skills
6	Social media & Digital Well-being
7	Inclusive Learning & Assistive Technology
8	AI, STEM & Immersive Learning
9	Instructional Design & Implementation
10	Student Characteristics & Learning Context
11	Digital Learning Strategies & Assessment
12	Adaptive & AI-Based Learning
13	Cognitive & Gender Factors in STEM
14	STEM & Collaborative Approaches
15	Sensory & Interactive Technologies
16	General Topics & Others

This demonstrates equity and balance between digital-based and non-digital-based educational technology research topics in elementary schools. This aligns with the research by [21], which emphasizes the need for *a balanced approach* between the use of technology in education and humanistic values (e.g., interpersonal skills, ethics, student learning experiences) to prevent the neglect of the very essence of education itself in Fig. 5.

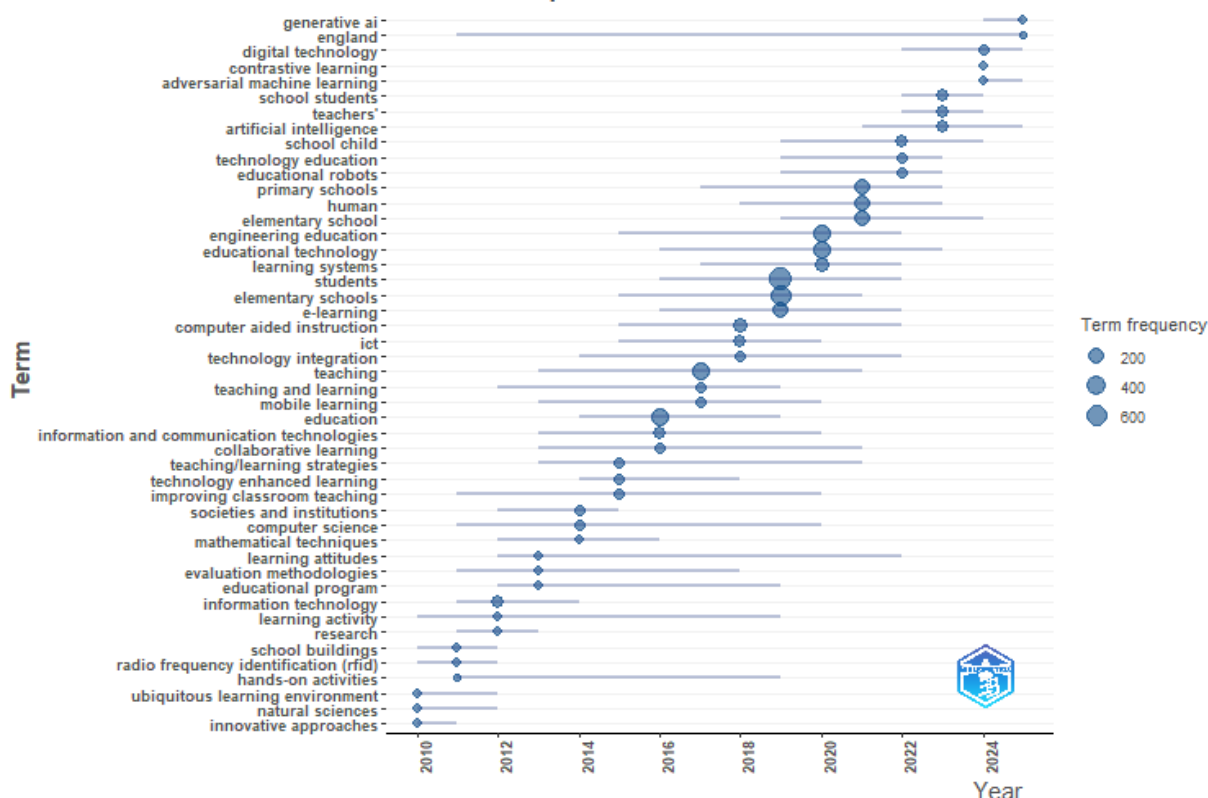


Fig. 5. Bibliometric Analysis of Emerging Themes

The temporal evolution of research *hotspots* related to educational technology in elementary schools was analyzed using the Bibliometrix R-package, as shown in Fig. 5. Specifically, the most frequently appearing topics over the past four years are as follows: *educational robots*, *technology education*, *schoolchildren*, *artificial intelligence*, *teachers*, *school students*, *adversarial machine learning*, *contrastive learning*, *digital technology*, *England*, and *generative AI*. The topics most frequently studied specifically in 2025 are: *generative AI*, *England*, *digital technology*, *adversarial machine learning*, and *artificial intelligence*. Based on this data, there has been significant development in the field of educational technology in elementary schools over the past few years. As research findings [22], [23] indicate, advancements in digital technology and AI have transformed the learning landscape in elementary schools, introducing interactive media such as mobile computing, online platforms, augmented reality (AR/VR), and software-based learning tools.

In the context of the development of elementary education, *contrastive learning* and *adversarial machine learning* serve as advanced AI techniques to support digital technology-based adaptive learning. *Contrastive learning* helps learning systems identify differences in students' levels of understanding and learning patterns more accurately, while adversarial machine learning strengthens the resilience of learning applications against data bias and invalid student responses. Both approaches contribute to the development of AI-based learning systems

that are inclusive, reliable, and aligned with the learning characteristics of elementary school-aged children [24].

In addition to topics that emerge annually, several topics consistently appear year after year. Nine keywords have appeared consistently for nine years or more and with a high frequency. These keywords are England (15 years), learning attitudes (11 years), improving classroom teaching (10 years), learning activity (10 years), computer science (10 years), hands-on activities (9 years), technology integration (9 years), collaborative learning (9 years), and teaching/learning strategies (9 years). The consistent appearance of these nine main keywords indicates that educational technology research in elementary schools is not dominated by fleeting technological trends, but rather by a long-term focus on integrating technology into active and collaborative classroom learning strategies. The emphasis on learning attitudes, hands-on activities, and basic computer science instruction underscores a strong pedagogical and developmental orientation.

Discussion

This study is based on the assumptions that research on educational technology in elementary schools (1) has experienced significant growth, (2) shows a shift toward digital-based themes and artificial intelligence (AI), and (3) demonstrates an increasing pattern of collaboration. The results of this study strongly support all three assumptions.

First, the consistent increase in the number of publications, with an annual growth rate of 6.08% and a high coefficient of determination ($R^2 = 0.849$), indicates that the field of educational technology in elementary schools is developing in a structured and sustainable manner. This finding aligns with previous research stating that the integration of digital technology in education has accelerated significantly over the past decade, particularly alongside the digital transformation of learning systems [22], [25]. Furthermore, Zawacki-Richter et al. (2019) emphasize that educational technology research has shifted from an exploratory phase toward a more systematic and evidence-based approach, reinforcing the field's position as it moves toward maturity.

Second, the hypothesis regarding a shift in themes toward digital-based learning and artificial intelligence was also confirmed. Keyword analysis reveals the dominance of topics such as augmented reality, artificial intelligence, STEM, and computational thinking. These findings align with recent research indicating that immersive technologies and AI are critical components in creating adaptive and personalized learning [23], [27], [28]. Specifically, AI-based learning systems have been shown to enhance student engagement and learning outcomes through adaptive feedback and data-driven analysis [29], [30].

However, the findings of this study also indicate that non-digital pedagogical themes such as collaborative learning, instructional design, and student characteristic continue to emerge consistently. This suggests that the development of educational technology is not solely driven by technological innovation but remains grounded in pedagogical principles. These findings align with Kohler et al. [2] who assert that the effectiveness of educational technology heavily depends on the implementation of student-centered pedagogy. Additionally, Schindler et al. ([31] state that meaningful learning occurs when technology is integrated with active learning strategies, rather than merely replacing pedagogical interactions.

Third, regarding the collaboration pattern hypothesis, the research results indicate a high level of collaboration, with an average of 3.74 authors per article. However, the still-low percentage of international collaboration (13.55%) suggests that research remains dominated by national or regional networks. This finding aligns with global bibliometric studies showing that educational research, particularly at the elementary school level, is heavily influenced by local curriculum, cultural, and policy contexts, thereby limiting cross-national collaboration [32], [33]. Nevertheless, international collaboration remains crucial for expanding knowledge exchange and the development of a globally oriented educational technology framework.

A key theoretical implication of this study is the identification of a balance between technological innovation and pedagogical foundations. While new topics such as generative AI, adversarial machine learning, and contrastive learning are emerging, the persistence of topics like learning strategies, hands-on activities, and collaborative learning indicates that the primary goal of education remains focused on enhancing the quality of the learning process. These findings reinforce the social constructivist perspective, which emphasizes that learning is an interactive and contextual process, where technology serves as a supporting tool rather than the central focus of learning [27].

Furthermore, the emergence of AI-based themes in recent years indicates a paradigm shift toward intelligent and adaptive learning systems. Research in reputable journals shows that AI can support differentiated instruction, predict student performance, and enhance the effectiveness of formative assessment. However, these developments also present challenges, such as ethical issues, algorithmic bias, and the readiness of teachers and students to adopt such technologies [25], [27].

From a practical perspective, the results of this study indicate that the development of educational technology should not focus solely on technological innovation but must also consider contextual factors such as teacher competence, student readiness, and institutional support. This aligns with Tondeur (2020) who emphasize that effective technology integration

requires a holistic approach encompassing pedagogical aspects, infrastructure, and teacher professional development.

Overall, this study confirms that the development of educational technology in elementary schools is multidimensional, involving the interaction between technological innovation, pedagogical strategies, and the educational context. The findings not only support the initial hypothesis but also expand upon previous research by providing a comprehensive bibliometric overview of the direction of development in this field. These findings also underscore the importance of integrating AI-based technology with robust pedagogical practices to create meaningful and equitable learning in elementary schools

Conclusion

The research results show that: 1) the number of publications per year continues to increase, with an average annual growth rate of 6.08% and a coefficient of determination (R^2) of 0.849. This indicates that this research field is in the *growth phase toward maturity*, not the early (*emerging*) phase; 2) there were 6,125 authors involved in these publications, with 210 of them writing articles individually. The average number of co-authors per document was 3.74, and 13.55% of the documents were co-authored internationally. This indicates a strong tendency toward collaboration in authorship, particularly at the domestic level, while international collaboration has not yet become widespread. 3) Six of the 11 most frequently appearing keywords over the past four years are specific to digital-AI. 5) Keywords that have persisted for more than nine years are those related to strengthening and improving the quality of learning processes, whether computer-based or not.

Based on the findings, the following recommendations are made for future research: 1) Researchers studying educational technology in elementary schools should not focus solely on the terminology of technological devices but also on all aspects related to improving the quality of learning. 2) Since research on educational technology in elementary schools follows developments in digital and AI topics, future research related to digital and AI should be conducted on more specific topics. 3) Develop cross-cluster research to build a more holistic model for the implementation of educational technology in elementary schools. 4) Strengthen contextual and sustainable research that considers the readiness of elementary schools, teachers, and students.

Conflict of Interest

The authors declare that there are no conflicts of interest related to this study. The authors confirm that the research was conducted in the absence of any commercial, financial, or personal relationships that could be construed as a potential conflict of interest. Furthermore, no

funding or external support was received that could have influenced the outcomes of this research.

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