

Artificial Intelligence for virtual learning: Bibliometric analysis

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Abstract: *The evolution of Artificial Intelligence has significantly influenced educational practices for students and teachers. For teachers, the importance lies in utilizing Artificial Intelligence to design assignments that help students enhance their knowledge. The students attempt to utilize Artificial Intelligence to complete assignments or to grasp certain concepts from the class. In this paper, we present a systematic analysis of scientific publications on the Web of Science that address the integration of AI in education. We are using bibliometric methods on a dataset of publications indexed in Web of Science to understand how this field evolved and the extent of interest in using Artificial Intelligence in education. The results show a significant increase in the number of publications in this field, as well as a rise in interest in how Artificial Intelligence can be applied in Education. Furthermore, the analysis identifies the leading countries and institutions driving research output and outlines the gaps that require further investigation. By providing a comprehensive quantitative overview of the scientific landscape, this study supports researchers and policymakers in understanding current directions and future opportunities in AI-enhanced education.*

Keywords: Artificial Intelligence, Education, Bibliometric analysis.

1. Introduction

In recent years, the accelerated development of artificial intelligence (AI) has produced significant changes in the educational system. Generative AI (GAI) systems, such as large language models, are increasingly being investigated for educational uses that include automated content generation, personalized feedback, support for adaptive learning, and assisting assessment processes. In this context, education system learning has consolidated itself as an essential framework for integrating these emerging technologies, using a rigorous analysis of existing research directions (Waltman et al., 2010). Recent specialized studies indicate a sharp rise in scholarly interest in the use of AI in education, particularly within higher education and online learning settings. Current research highlights the significant potential of these technologies to personalize learning pathways and enhance students' experiences in digital environments. At the same time, the literature points to important challenges, including ethical concerns, issues of

academic integrity, and possible effects on students' cognitive development (Irwanto et al., 2025). This accelerated development of research in artificial intelligence field has led to an extensive but fragmented literature, which makes it difficult to identify main trends and underexplored areas.

In this context, bibliometric analysis is an appropriate methodology for the systematic mapping of an emerging scientific field. Through the quantitative analysis of publications, citations and collaborative networks, the bibliometric approach allows the identification of influential authors, relevant scientific sources and main research topics. Recent bibliometric studies have demonstrated the usefulness of this method in investigating research on GenAI in education, providing valuable insights into the intellectual structure of the field (Zhang et al., 2025). However, many of the existing analyses treat virtual learning as a secondary context, without approaching it as a distinct analytical dimension. Given the central role of virtual environments in the implementation of GenAI applications, it is necessary to perform a statistical analysis of scientific publication mainly focused on this educational framework. The use of those tools, such as VOSviewer and Bibliometrix, facilitates the visualization of keyword co-citation and co-occurrence networks, contributing to transparent and reproducible analyses (van Eck & Waltman, 2010; Aria & Cuccurullo, 2017). Therefore, this study aims to carry out a bibliometric analysis of research on generative artificial intelligence in virtual learning, with the following objectives:

- (1) analysis of the chronological evolution of scientific publications;
- (2) authors identification, and affiliations identification with major influence this field.

This article aims to provide, through the proposed bibliometric approach, not only a quantitative synthesis of the existing literature, but also a framework for critical reflection of the relationships between institutional actors and publication dynamics. Those allow a better understanding of the field and the level of theoretical convergence. In this way, the results can serve as a reference point for future research, facilitating the development of empirically grounded pedagogical models and supporting the responsible and efficient integration of GAI technologies into contemporary virtual education.

2. Literature review

As previously mentioned, the emergence of **Generative Artificial Intelligence** represents a **qualitative shift** in both the conceptual and practical architecture of *Artificial Intelligence in Education* (AIED). Recent studies highlight the need for systematic examinations of the **evolution, structure, and dominant trends** within the field.

Bibliometric analyses have become essential tools for mapping research trajectories, identifying influential contributions, and highlighting emerging themes that can guide future investigations (Prahani et al., 2022). Several large-scale bibliometric studies have analysed AIED literature using major databases such as Scopus and Web of Science (WoS). For instance, Prahani et al. (2022) examined

457 highly cited publications over the past decade, revealing exponential growth in AIED research, particularly over the last five years. Peer-reviewed journal articles were the dominant document type, with China emerging as the most productive country. Trend mapping identified six key thematic areas: (1) student-centered AI applications, (2) AI integration in engineering education, (3) AI-supported teaching methods, (4) e-learning and digital education, (5) educational systems, and (6) curriculum-level AI integration.

Complementary analyses confirm the central role of educational technology journals in shaping AIED research dissemination. A WoS-based study covering 2,686 publications between 2001 and 2021 highlighted *Computers & Education* and the *International Journal of Emerging Technologies in Learning* as the most prolific outlets (Talan, 2021). A broader investigation of approximately 8,660 Scopus-indexed articles published between 2000 and 2019 employed CiteSpace and alluvial flow analysis to examine publication outputs, international collaboration, cluster structures, and research evolution (Song & Wang, 2020). Five core intellectual clusters were identified: intelligent tutoring systems, learning systems, students, labelled training data, and pedagogy (Cîrnu, 2015). Longitudinal analysis conceptualized AIED research into four stages: (a) technological foundation, (b) technological breakthrough, (c) intelligent application, and (d) symbiotic integration of AI technologies with educational practices.

More recently, Derinalp (2024) adopted an extended temporal perspective, analyzing 905 WoS-indexed studies published between 1989 and 2023. Using Biblioshiny, the annual growth rate of publications was estimated at 18.7%, reflecting sustained and accelerating interest. China, the United States, the United Kingdom, Australia, and Spain emerged as leading contributors, while themes of articles demonstrated the diversification and maturation of research topics over time.

Recent bibliometric studies indicate that, from 2022 onwards, GAI has become a **central driver of growth** in AIED research. Ng and Ho (2025), analyzing 3,808 Scopus-indexed publications, documented an exponential increase in GAI-related educational research, with the majority of contributions coming from the United States, China, and Hong Kong. This geographic distribution reflects well-established research ecosystems, supported by institutional investment, digital infrastructure, and national AI policies. Keyword evolution further suggests a conceptual shift from technology-focused studies toward research emphasizing learner experience, cognitive engagement, and medium- to long-term pedagogical outcomes. Bahroun et al. (2023) highlight the dominant role of tools like ChatGPT and stress the importance of algorithmic transparency, bias mitigation, and responsible AI use.

With this evolving landscape of Generative AI in mind, it is crucial to explore its **practical and conceptual implications** across multiple dimensions, to understand how GAI is reshaping education and highlighting areas where further research and careful governance are needed.

Ethical, Normative, and Institutional Dimensions: A defining feature of recent GAI literature is the emphasis on ethical considerations and institutional

governance. Unlike earlier phases of AIED, where ethics were marginal, GAI poses direct risks to academic integrity, assessment authenticity, and authorship responsibility. These challenges are amplified by the **hybrid, multifunctional nature** of GAI systems. A systematic review by Arista et al. (2024) shows growing interest in ethical policies in higher education, peaking in 2024. Ganjavi et al. (2024) document normative fragmentation among publishers and journals, highlighting inconsistencies in transparency requirements and reporting, which may create uncertainty for authors and affect scientific integrity.

Educational Impact and Pedagogical Efficiency: Xiao-yu et al. (2024) report that around 70% of empirical studies find positive effects of GAI on learning outcomes, especially through personalized feedback and adaptive support. However, over-reliance on GAI can hinder creativity and critical thinking, highlighting the need for **clearly defined pedagogical frameworks**. Sharma and Panja (2025) further confirm the transdisciplinary nature of GAI research and its relevance for evidence-informed educational policies.

GAI, Sustainability, and Future Directions: Nikolopoulou (2025) emphasizes GAI's potential to support sustainability in higher education by optimizing educational resources, fostering inclusion, and promoting development-focused education. Nonetheless, most contributions remain theoretical, underscoring the need for **empirical and longitudinal studies** to assess GAI's real-world impact on institutional and educational sustainability.

Although the field of AI in education has grown rapidly and produced a wealth of studies, several gaps remain that point to promising directions for future research. Most notably, the bulk of recent work has focused on the period between 2022 and 2025 and largely on generative AI, leaving earlier phases of AIED and other types of AI—such as adaptive, predictive, or assessment-oriented systems—less explored. Furthermore, while these AI types often overlap in practical applications, research tends to examine them in isolation, limiting our understanding of how hybrid AI systems operate in diverse educational contexts.

3. Methodology

Before and after the widespread adoption of artificial intelligence, there has always been a significant interest in applying certain artificial intelligence techniques to assist either teachers or students in the educational field, especially for universities or schools with a large number of students. The accelerated growth in recent years of the use of artificial intelligence has also led to an increase in the number of articles addressing this issue. Therefore, we consider it necessary to perform bibliometric analyses that systematically present the evolution of the number of publications in the field of education for the use of artificial intelligence.

To carry out this analysis, metadata was collected regarding articles published and indexed in the Web of Science that contain the terms AI or Artificial Intelligence and the term education in the title. In this way, 21,665 articles that meet these conditions were identified. This metadata was sanitized and prepared for processing.

Python was used in this bibliometric analysis mainly to ensure reproducibility and to allow the study to be extended and explored in greater depth in the future. Working with scripts means that every step of the process data cleaning, filtering, calculating indicators, and creating visualizations is clearly documented, transparent, and easy to repeat or adjust. Unlike tools with fixed interfaces, this approach makes it possible to gradually build on the analysis by adding new datasets, time periods, variables, or methods without starting over, which increases both the flexibility of the methodology and the overall scientific reliability of the research.

The analysis aims to highlight the distribution of publications over time, identify the authors with the highest number of contributions, as well as institutions with intensive activity in the field.

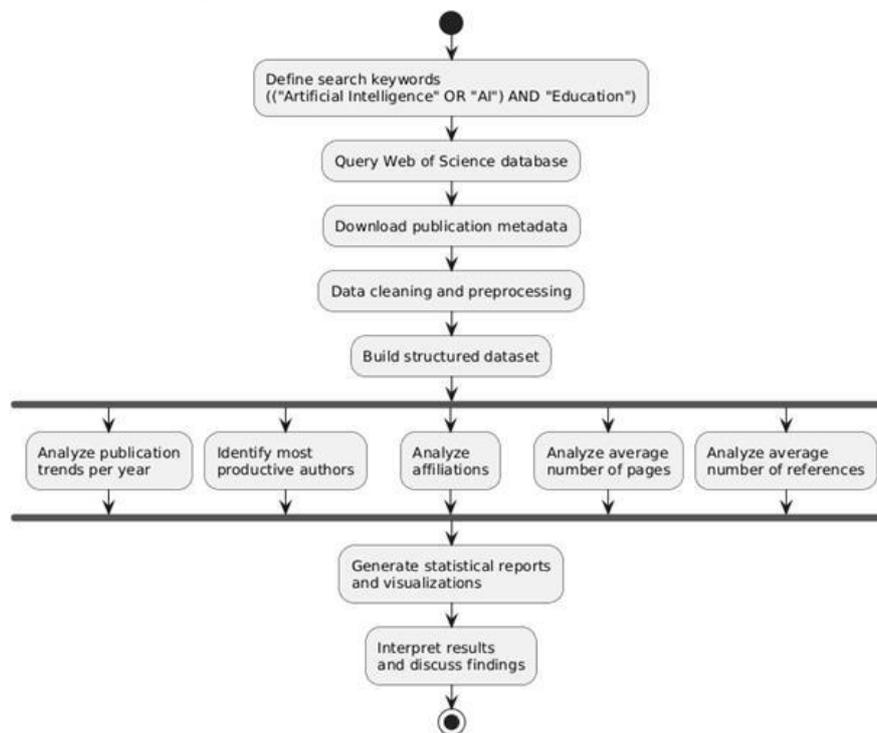


Figure 1. Methodology process

The general process of the methodology is schematically illustrated in Figure 1, which presents the stages of data collection, preprocessing, bibliometric analysis and reporting of results.

The analysis of institutional affiliations is relevant because it allows highlighting universities and research centers that invest in the development and application of Artificial Intelligence in education. In this way, active scientific communities and potential academic collaboration networks can be identified. In addition, the study includes the analysis of complementary indicators, such as the

average number of pages per article, the average number of references used and their evolution over time.

4. Results

The bibliometric analysis conducted for the works identified on the Web of Science that address the use of Artificial Intelligence in education highlighted an increase in the number of pages for the articles published recently. Although the dynamics of the average number of pages per article may suggest an increase in research complexity, this indicator is strongly influenced by editorial policies and publication formats. Still, it may show a deepening and growing interest of the scientific and academic community for the application of artificial intelligence in the educational environment, Figure 2.

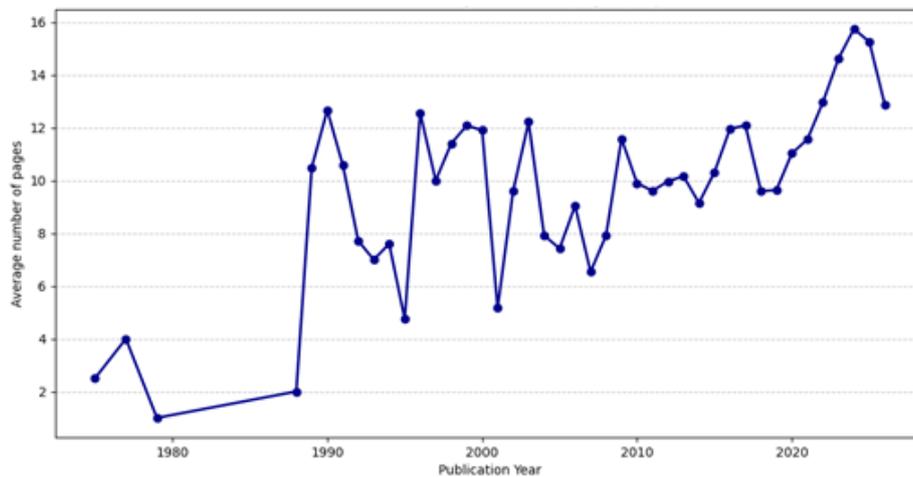


Figure 2. Evolution of the average number of pages per year

The average number of citations per article has increased significantly in recent years. This reflects the authors' concerns for a solid foundation of research in the field and for its integration into the existing literature. This increase over time also shows the consolidation of the field with a significant number of research and publications, Figure 3. This increase also highlights a gradual maturation of the field of Artificial Intelligence in Education.

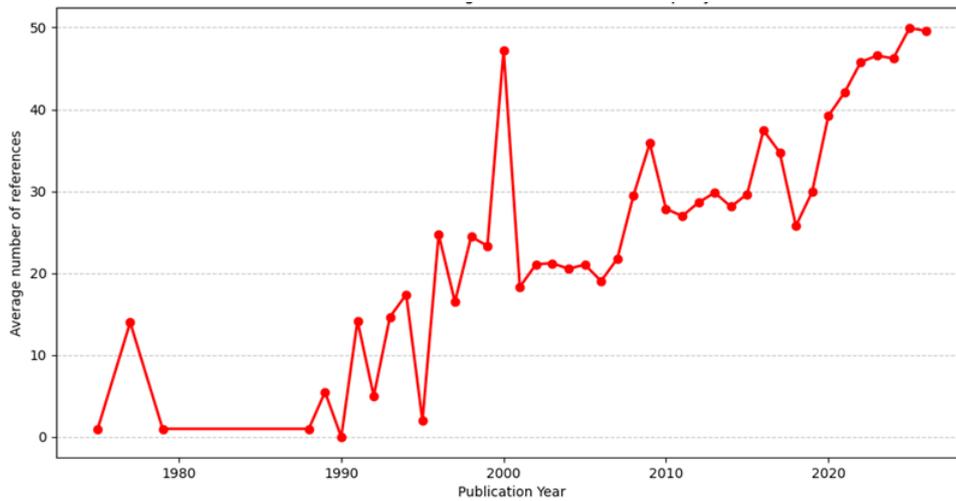


Figure 3. Evolution of the average number of references per year

The rise in citations around the year 2000 marked the moment AI in education truly found its place, moving from isolated lab experiments to validated pedagogical models. This phase of maturation laid the groundwork for the exponential explosion we witnessed after 2020, as Figure 4 shows. While the early 2000s were dedicated to refining the theory behind intelligent tutoring systems, the 2020 turning point - fueled by the convergence of Deep Learning, Big Data, and the global necessity for remote learning - transformed these concepts into scalable, everyday technologies. We can view the dynamics of 2000 as the field's 'conceptual birth,' whereas the post-2020 marks its global revolution—the point where AI stopped being just a research topic and became an essential infrastructure for modern education.

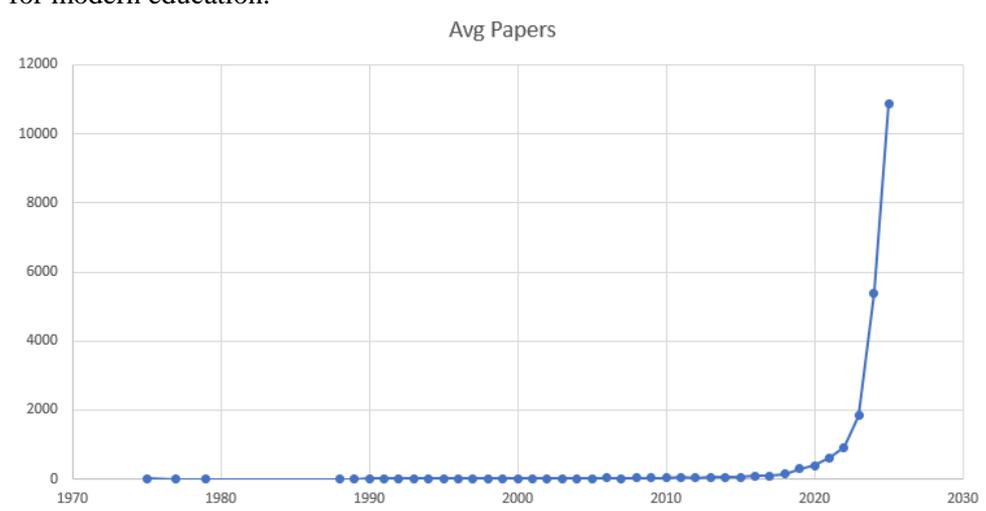


Figure 4. Evolution of the number of articles per year

This bibliometric analysis of publications dedicated to Artificial Intelligence in Education provides a clear overview of the evolution and structure of this emerging field. The results highlight a significant increase in the scientific community's interest in integrating AI-based technologies into educational processes, reflected in the upward dynamics of the number of published papers and the thematic diversity addressed.

Regarding the authors who have published in this field, the bibliometric analysis highlighted the top 20 authors with the highest number of published articles, indicating the existence of opinion leaders in this field of publication for the use of artificial intelligence in education, Figure 5.

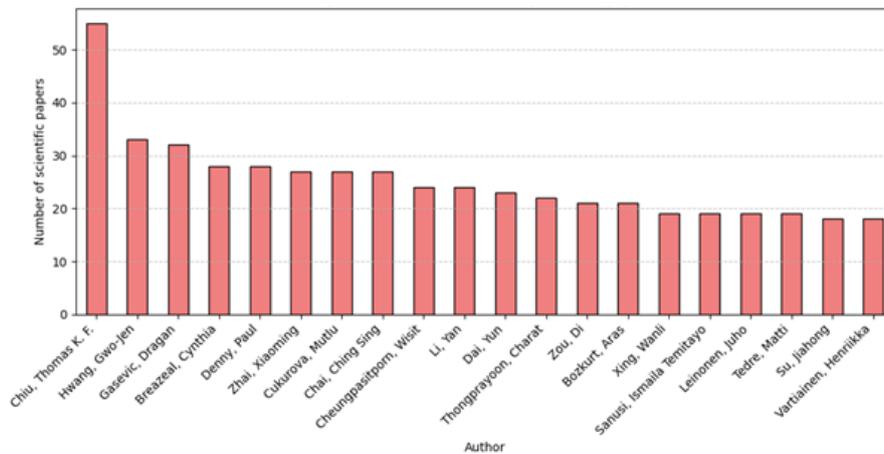


Figure 5. Top 20 authors with the most published papers

The institutional affiliations of the authors (Figure 6) of the analyzed publications show that universities mainly actively invest in the development, use and application of AI in education, contributing to the strengthening of scientific communities and research infrastructure in this field.

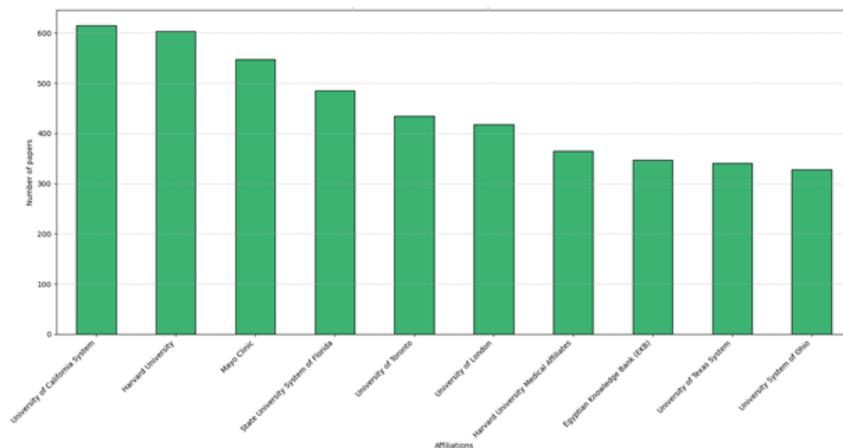


Figure 6. Top 10 affiliations with the most published articles

5. Conclusions

Overall, the bibliometric findings show that Artificial Intelligence in Education (AIED) has moved beyond being a narrow research niche and has developed into a well-established and fast-growing field. The steady rise in the number of publications, together with the increase in article length and the higher average number of citations, suggests not only more research activity but also greater depth and stronger connections with existing educational and technological studies. While factors such as journal requirements can influence structural aspects like article size, the combined trends in publication and citation patterns clearly reflect a growing and sustained interest from the scientific community, as well as the gradual strengthening of theoretical frameworks, research methods, and practical applications in education.

At the same time, the presence of highly productive authors and frequently cited works highlights the formation of a recognizable research community with key contributors and stable collaboration networks. This indicates that the field is maturing, as foundational theories, intelligent tutoring systems, learning analytics, and more recent data-driven and generative AI approaches are now part of a shared research landscape. The strong acceleration after 2020 further suggests a shift from mainly conceptual and experimental work toward broader, real-world implementation. In this context, AI is no longer seen only as an innovative topic of study, but increasingly as a core component of modern educational systems and future research directions.

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