Trends and Challenges of AI Integration in Basic Education: Insights from a Bibliometric Study

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Abstract. *This article reviews 43 publications (2021-2024) on Artificial Intelligence (AI) in Basic Education, using Guedes' (2018) methodology. A global increase in interest is noted, with China and the USA leading contributions. Prominent research areas include "Education," "Technology," "Teacher Perceptions," and "Ethics," categorized into: AI perceptions, factors in teacher adoption, and professional development. While AI has the potential to personalize learning, teacher concern and uncertainty require continuous training in technical and pedagogical skills, focusing on critical thinking and curriculum integration. The study emphasizes educational leadership and suggests future research on student-centered and adaptive learning models.*

1. Introduction

Artificial Intelligence (AI) is a field of computer science dedicated to the development of systems that simulate human reasoning and autonomous decision-making. According to [RUSSELL and NORVING 2013], these systems, based on the information they receive, generate predictions, recommendations, or decisions that can influence physical or virtual environments.

Over the years, AI has consolidated as a transformative force in various sectors of society, including education, and in basic education it has been no different. There has been a growing advancement of AI in basic education, with the potential to revolutionize teaching and learning methods. AI in education encompasses a wide range of applications, from intelligent tutoring systems to automated assessment resources and adaptive learning [SOUZA et al. 2023].

According to the authors, these technologies use advanced natural language processing algorithms to interact with users, providing answers and performing specific tasks. It is worth noting that AI has the potential to address some of the biggest challenges in education today, such as learning assessment and the provision of personalized support for students [HOLMES et al. 2019]. This view is corroborated by researchers, who argue that AI can be a powerful tool to combat educational inequalities in the country; however, the implementation of AI in Basic Education is not without its challenges [SANTOS and SILVA 2022].

In the global context, countries such as the United States, China, and the United Kingdom have led the implementation of AI in education. In Brazil, although adoption is slower, there is a growing interest in the use of AI in education [SALAS-PILCO and YANG 2022]. According to a survey conducted by the Brazilian Education Innovation Center (CIEB) in 2024, some experiences are underway in Brazil, such as in the state of Piauí, which has promoted teacher training on the subject and introduced curricular components dedicated to AI in Basic Education.

Teacher training for the use of AI in education is essential to ensure that teachers can effectively and ethically integrate these technologies into their teaching practices [DUQUE et al. 2024]. With the increasing presence of AI in classrooms, educators face the challenge of developing skills that allow them to use these tools and understand their impact on the learning process. Proper training enables teachers to select appropriate resources, personalize teaching, and promote an inclusive learning environment where all students can benefit from technological innovations [MOREIRA 2024].

This article is the result of a research based on a Bibliometric Literature Review, seeking to answer the following questions (1) *What are the patterns, trends, and geographic distribution of research on AI in Basic Education between 2021 and 2024?* and (2) *What are the main thematic categories addressed by these studies? The research results identified patterns, trends, and geographic distribution, in addition to developing an analysis of the current scenario.*

While previous studies, such as that of [SALAS-PILCO and YANG 2022], focused on the application of AI in Latin American higher education, this article differs by focusing its analysis exclusively on Basic Education in a global scope, investigating a more recent period (2021-2024) and the specific perceptions and challenges faced by educators at this level of education. Thus, this article is organized as follows: introduction, methodology, in addition, an analysis of the results is carried out and, finally, the final considerations are presented.

2. Methodology

This research used the methodological approach of the Bibliometric Review of Literature (RBL), as proposed by [GUEDES 2018], as it is suitable for the objective of mapping the general panorama of scientific production, identifying quantitative patterns and thematic trends. Unlike a systematic review, which seeks to synthesize evidence for a clinical or very specific question, our focus is to provide a broad and exploratory view of the field of AI in Basic Education.

2.1. Bibliographic Study

This RBL investigates how scientific articles address Artificial Intelligence (AI) in Basic Education. The study categorizes these approaches and begins with database searches using the term "Artificial Intelligence in Basic Education." In Brazil, Basic Education covers Early Childhood, Elementary, and Secondary Education, and is compulsory and free from ages 4 to 17. In addition, other variants of Basic Education were used (Table 2) [1], such as: K-12, Key Stages, Elementary and Secondary Education, Primary and

[1]It's important to note that the terms listed in Table 2 were used to broaden the scope of the initial search and ensure the inclusion of studies from different educational systems.

Secondary Education, and Basic and Secondary School. Below, Table 1 is presented with the search strings to facilitate understanding.

Table 1. Search strings with adopted logical operators

(Artificial Intelligence) AND ((Basic Education) OR (K-12) OR (Key Stages) OR (Elementary and Secondary Education) OR (Primary and Secondary Education) OR (Basic and Secondary School))

Table 2. Reference terms for basic education in different countries

Country	Term in Portuguese	Term in English
Brazil	Educação Básica	Basic Education
United States	Jardim da infância ao 12º ano	K-12
United Kingdom	Estágios-chave	Key Stages
Canada	Educação Elementar e Secundária	Elementary and Secondary Education
Australia	Educação Primária e Secundária	Primary and Secondary Education
Estonia	Escola Básica e Secundária	Basic and Secondary School

The databases selected for this literature review were chosen based on criteria, prioritizing their level of credibility and their ability to be exported to a reference manager. The following databases were chosen: ERIC, IEEE Xplore, ScienceDirect, and Scopus, due to their consolidated reputation in the academic field, indexing of reputable journals, free access to materials, and organization/management of bibliographic references. The results of the searches in each database were exported and organized in the Zotero tool. In this phase, the files were organized into folders, resulting in 59 files from the ERIC database, 136 files from IEEE Xplore, 136 from ScienceDirect, and 31 from Scopus, totaling 362 files, with a time frame from 2021 to 2024.

Subsequently, the pre-selection phase of publications was initiated, predefining the inclusion and exclusion criteria. The inclusion criteria were based on: journal Article and conference papers in open access; publications containing the terms “Artificial Intelligence” AND “Basic Education” or variations thereof in any of the following sections: Title/Keywords/Abstract. In addition, only articles published between 2021 and 2024 were considered. The exclusion criteria were articles that did not meet the inclusion criteria, i.e., that were not available in open access; did not address Basic Education; and duplicate articles were also excluded, as can be seen in Table 3.

Table 3. Number of pre-selected publications in the databases

Database	Publications located	Pre-selected publications
ERIC	59 publications	19 publications
IEEE Xplore	136 publications	11 publications
ScienceDirect	136 publications	14 publications
Scopus	31 publications	11 publications
Total	362 publications	55 publications

After the initial pre-selection phase, the publications were read to understand their content, the titles and abstracts were reread, and the documents were thoroughly scanned. During this process, it was detected that 12 publications did not fit the research topic. For example, articles related to higher education, despite the initial criteria established. Therefore, after the exclusion of the articles, a total of 43 publications are presented for the study, illustrated in Table 4 below.

Table 4. Research corpus

Database	Selected publications
ERIC	14 publications
IEEE Xplore	10 publications
ScienceDirect	12 publications
Scopus	7 publications
Total	43 publications

Thus, the 43 articles were analyzed in depth to identify patterns, trends, and results. The understandings built are presented in the later section of the Bibliometric Literature Review, which allowed for the inferences and conclusions obtained from the analysis of the articles.

3. Results

In this section, the results of the analyses and summaries of information obtained through bibliographic searches conducted in the ERIC, IEEE Xplore, ScienceDirect, and Scopus databases are presented. These results represent a compilation of the selected data, providing an overview of the topic in question.

3.1. Patterns, trends, and geographical distribution

In recent years, we have seen a significant increase in the number of studies investigating the potential of AI in basic education. This growth trend is clearly illustrated in Figure 1, which presents the number of publications by year. It is worth noting that the data for 2024 is partial, as it reflects the works published up to the initial date of the research.

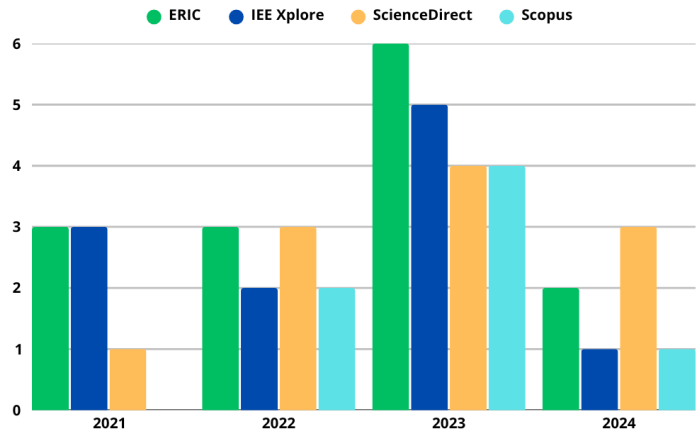

Figure 1. Number of publications per year

In addition to analyzing the time, we also sought to understand which specific categories within the application of AI in Basic Education have been the subject of investigation. Categorization is the process of classifying the elements of a set, differentiating them, and then grouping them according to similarities, based on previously established criteria [BARDIN 1977]. Figure 2 illustrates the main categories of interest identified.

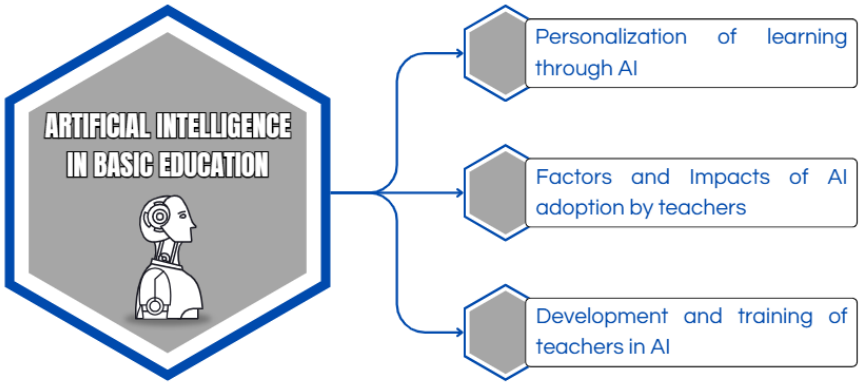

Figure 2. Themes of Artificial Intelligence in Basic Education

Upon examining the emerging categories in more detail, it is evident that perceptions about the integration of AI in education have been an area of great interest. The reviewed articles highlight how AI tools, such as intelligent tutoring systems and adaptive learning, allow for the personalization of educational content according to the needs and skills of each student.

The adoption of AI by teachers does not happen automatically, but depends on a number of key factors, most notably teachers' confidence in using AI in the classroom and their perception of its relevance and applicability to their teaching practice. However, there are important barriers that hinder this process, such as the lack of adequate and specific training. To overcome these obstacles and prepare teachers, investment in continuous professional development and research into AI-based teaching methodologies is essential.

The analysis of the articles in this review reveals a worldwide distribution, with 125 authors from 29 countries on 6 continents (Figure 3). China leads the list with 36 authors, linked to the following educational institutions: The Hong Kong Polytechnic University, The Chinese University of Hong Kong, Beijing Normal University, Minnan Normal University, followed by the United States (16), where their productions are linked to Central Missouri University, Purdue University, Virginia Commonwealth University, University of Florida, Indiana University, North Carolina State University, Mississippi State University.

In Brazil, there are 9 authors with productions from the Federal Technological University of Paraná and the Federal University of Bahia, which highlights the involvement of these nations in research. This concentration suggests the existence of centers of excellence and significant investments in research and development.

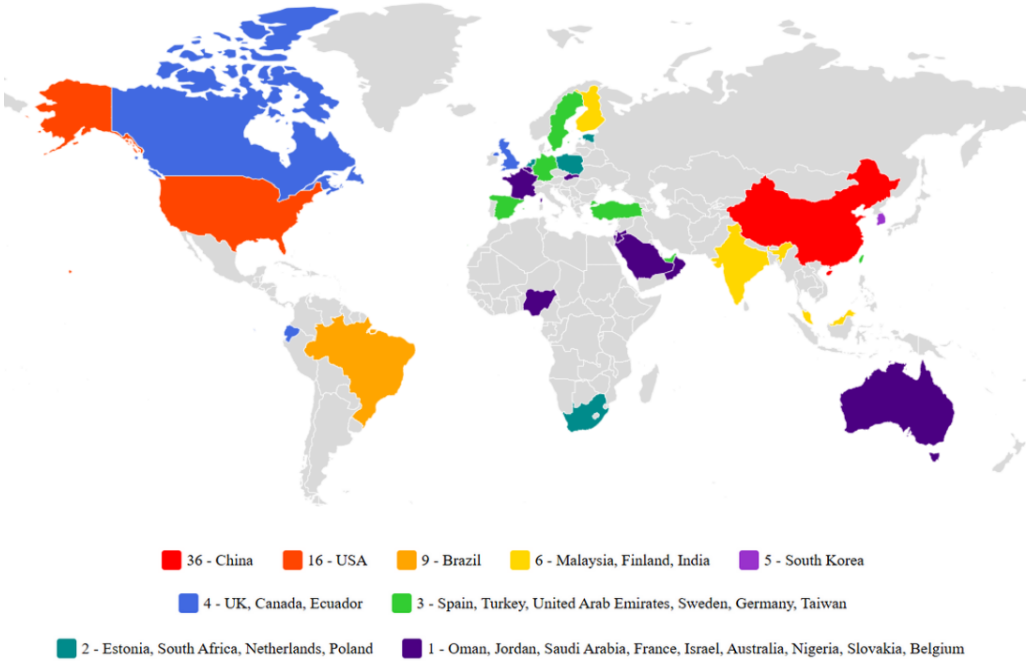

Figure 3. Geographical distribution

Europe proves to be a consistent hub for research on the topic, with significant contributions from several countries. Finland stands out with 6 authors, linked to institutions such as the University of Eastern Finland and Jamk University of Applied Sciences. The United Kingdom (4), Germany (3), and Sweden (3) also reinforce the European presence, with productions from renowned universities like the University of Cambridge, the Dresden University of Technology, and the Karlstad University. This participation from established academic centers underscores the maturity of research on Artificial Intelligence in basic education on the continent.

The research's global scope is enriched by contributions from the Middle East and other nations with less historical association with the topic, such as Estonia (2), Oman (1), Jordan, and Ecuador. This demonstrates that interest in the subject is not limited to traditional academic powerhouses. While continents like Africa and Oceania have a more limited representation with a combined total of 4 authors, the presence of countries like South Africa, Nigeria, and Australia is a crucial indicator of growth potential. This initial participation suggests a fertile ground for future research and collaborations, pointing to an opportunity to further expand and diversify the global panorama of studies on AI in education.

When analyzing the articles, several central themes were identified. Among the most recurring are "Artificial Intelligence", followed by "Teacher's Perceptions", "Ethics", "Academic Performance", and "Professional Preparation". In addition, references to "Training", "Learning Experience", "Curriculum" and "School Implementation" were observed. Figure 4 shows a word cloud containing the themes found in the selected articles, using the Claude.AI platform and the following prompt on August 8, 2024 [*Let's create word clouds to better visualize the most frequent keywords in each cluster*].

Figure 4. Word cloud of keywords found in the selected publications

Therefore, the analysis of the selected articles reveals a worldwide distribution of authors from different countries, which indicates the existence of centers of excellence and significant investments in research and development. In addition, the most frequent keywords reflect the main areas of interest in studies related to Artificial Intelligence in Basic Education.

3.2. AI and basic education: analysis of the current situation and future perspectives

The integration of AI in basic education is a complex and multifaceted topic with great potential to transform pedagogical practices and the learning experience. This text presents an analysis of the current situation, exploring the perceptions of various actors, the factors influencing the adoption of AI by teachers, and relevant research on teacher development and training.

3.2.1. Personalization of learning through AI

A critical analysis of current literature reveals a paradoxical scenario, where enthusiasm for AI's transformative potential coexists with significant apprehension and a clear gap in practical knowledge. This duality is not merely an obstacle to be overcome, but a fundamental aspect that must shape technological implementation strategies in education.

Among faculty, the predominant perception is one of cautious optimism. Teachers envision AI as a supportive tool capable of enhancing pedagogy, as pointed out by studies such as those by [CHOUNTA et al. 2022] and [GARCÍA PEÑALVO et al. 2024]. They recognize its potential to personalize teaching, offering individualized feedback and adapting to each student's needs an advantage particularly valued in fields like mathematics [WARDAT et al. 2023]. However, this optimism is directly confronted by a crucial barrier: the lack of practical knowledge on how to apply these tools effectively.

The research by [CHOUNTA et al. 2022], for example, highlights that while they see AI as a support for challenges like accessing multilingual content, teachers require substantial support to become efficient. This gap between perceived potential and actual readiness reveals a systemic flaw.

The arrival of generative AI tools, such as ChatGPT, has intensified this dynamic, acting as a catalyst for discussions and concerns. A survey conducted by [HAYS et al. 2023] with North American teachers precisely captured this tension: an acknowledgment of the tool's potential for effective learning, side-by-side with anxieties about its overall impact on education. Given this context, the conclusion that consistently emerges from the literature is the urgency of teacher training. It becomes imperative, as underscored by [ROVIRA-COLLADO et al. 2024], to invest heavily in initial and continuous training, so that educators can not only use these technologies but also critically and innovatively integrate them into their pedagogical practices.

Surprisingly, an equally complex and ambivalent view is found among students. A study with elementary school students in Sweden [SHIN et al. 2024] revealed that children recognize the practical value of AI as an aid in their studies. However, this utilitarian perception is accompanied by a critical awareness of the technology's social and ethical dilemmas, such as the possibility of job loss and privacy issues—concerns also observed by [CAMARGO et al. 2025]. The presence of these concerns in such a young audience is a powerful indicator of the need to incorporate AI ethics into the curriculum from the earliest grades, preparing citizens for a future where these technologies will be ubiquitous.

3.2.2. Factors and Impacts of AI adoption by teachers

The effective integration of AI into teaching practice transcends mere technological availability, constituting a complex phenomenon mediated by a web of human, pedagogical, and institutional factors. An in-depth analysis of recent literature reveals that the success of this implementation does not depend on isolated elements, but on a confluence of perceptions, skills, and structural conditions that truly empower educators and transform the learning environment.

A common thread in the research points to teachers' performance expectations and self-confidence as the main drivers of adoption. The intention to use AI is directly linked to the perception that it can, in fact, improve teaching and learning. Studies such as [AN et al. 2023] reinforce that performance expectations are a significant predictor. This idea is corroborated by [JATILENI et al. 2023] and [AYANWALE et al. 2022], who identified the perceived relevance of technology and teachers' confidence in their own abilities as pillars for the intention to teach with AI. It is therefore clear that teachers must first and foremost believe in the practical value of the tool and feel confident in using it.

However, this individual disposition is strongly influenced, and can be undermined, by institutional and psychological barriers. Research by [HAO et al. 2021] with school principals expands this view, showing that the intention to adopt is positively impacted by facilitating conditions, such as infrastructure and technical support, and by social influence within the school. On the other hand, the perception of risks, such as data security and loss of autonomy, in addition to the anxiety that the technology itself can generate, act as powerful brakes. This demonstrates that even the most well-intentioned individual initiative can fail if the school ecosystem does not offer the necessary support and proactively address educators' insecurities.

It is at this point that the discussion transcends the technical aspect and enters the pedagogical domain. The successful integration of AI is not just about knowing how to operate software, but knowing how to integrate it meaningfully into content and teaching. The analysis by [AN et al. 2023], using the TPACK model, is categorical in pointing out that the fusion of AI knowledge with pedagogical and content knowledge (AI-TPACK) is a differentiator. This need for broader and more critical AI literacy is echoed in studies on basic education [YETISENSOY and RAPOPORT 2023, CASAL-OTERO et al. 2023]. The ultimate goal of this integration, as pointed out by the research by [JAISWAL and ARUN 2021], is to transform the educational system, using AI to offer personalized learning and adaptive assessments that meet the individual needs of students and provide teachers with valuable analysis.

Interestingly, the perspective is reversed when analyzing student interaction with the tool. The study by [XIA et al. 2023] on the use of an AI chatbot for self-regulated learning brings an important nuance: the student's prior knowledge of the content (in this case, English) was more decisive for success than their prior knowledge of AI itself. This suggests that, in certain applications, AI works best as an enhancer of existing knowledge, rather than as an isolated starting point. In order for teachers to design strategies that take advantage of this potential, it is also essential to understand the motivational factors of the students themselves, such as those identified by [LIN et al. 2021], which include intrinsic motivation, perceived relevance, and confidence.

3.2.3. Development and training of teachers in AI

Teacher training is a crucial element for the effective integration of AI in education. Professional development programs and research exploring new pedagogical approaches are essential to prepare educators for the challenges and opportunities of AI in the classroom. [CONDE-ZHIGRE et al. 2022], in a study on AI's impact on basic education in Ecuador, highlight both the challenges and opportunities of its integration. They emphasize the need to adapt educational systems and teacher training to effectively use AI, supporting the development of future-ready citizens. Artificial Intelligence in education offers a range of possibilities for both the teacher and the student in the teaching-learning process [CONDE-ZHIGRE et al. 2022].

[SAMPAIO et al. 2023] evaluated the use of machine learning (ML) in a Brazilian municipal school, using TinyML and Arduino boards with 8th and 9th grade students. The research sought to analyze the impact of the workshop on students' 21st-century skills, but noted that one option for beginning to master ML concepts is during high school. As this is a Brazilian production, it is worth mentioning that the Ministry of Education (MEC) aims to integrate computing into all levels of basic education, preparing students for the challenges and opportunities of the digital world. This stems from Resolutions CNE/CP 02/2017; CNE/CP 04/2018 and CEB 01/2022.

[LIU et al. 2022] proposed a differentiated training program for primary school mathematics, leveraging AI and big data to personalize teaching. The approach uses AI to analyze student data, provide feedback, and guide pedagogical interventions. While empirical evidence is still limited, the study contributes to the debate on using AI to individualize instruction and foster meaningful learning.

Several initiatives aim to integrate AI into elementary and secondary education, promoting computational thinking and preparing teachers for future technological demands [ANTONENKO and ABRAMOWITZ 2022, KIM et al. 2022]. This brings us to the heart of the matter: the nature of teacher training. When analyzing the body of work on the integration of AI in basic education, a paradoxical picture emerges. On the one hand, there is almost unanimous consensus and a declared urgency that teacher training is the crucial element for the success of this endeavor. On the other hand, the way in which this training is discussed in the literature reveals a profound disconnect between the rhetoric of innovation and the complex and unequal reality of educational systems, generating a cycle of promising proposals with limited practical impact.

It's not enough to simply assert the need to train teachers. It is imperative to ask: what kind of training? One that teaches how to use tools or one that empowers teachers to question algorithmic biases, protect student data privacy, and make pedagogical decisions about when AI actually adds value? As long as research and policy focus more on adoption drivers and perceptions than on critical impact and the systemic conditions for ethical and equitable implementation, we will continue to celebrate the potential of AI without ever fully realizing it in the classroom.

4. Final Considerations

Returning to the central objective of this study, which is to investigate how scientific articles address the role of Artificial Intelligence (AI) in Basic Education and how these contents can be categorized. The bibliometric analysis of the 43 selected publications reveals a growing field of research, but focused on understanding the preconditions for the implementation of AI, rather than the consequences and real impact of these technologies on learning.

The findings were classified into three main categories: perceptions about the integration of AI, factors that influence its adoption by teachers, and teacher development and training. One of the main results is the notable centrality of the literature on the figure of the teacher, whose concerns, uncertainties and need for training are recurring themes. While on the one hand this shows that the teaching staff is correctly identified as the main actor in the process of technological integration, on the other hand it reveals a significant gap regarding the student's perspective.

Furthermore, although the "Ethics" dimension emerges as a prominent keyword, its discussion in the analyzed studies tends to be superficial, treating it more as a challenge to be mentioned than as a central pillar for pedagogical planning. Future research should delve deeper into the ethical implications, addressing critical issues such as algorithmic bias in assessment tools, the privacy and security of student data, equity in access to AI technologies, and the need to develop ethical and digital literacy in teachers and students. Successful implementation cannot focus solely on adoption factors but must prioritize the conditions for ethically responsible and socially just integration.

5. Acknowledgment

The authors gratefully acknowledge the support and contributions of their colleagues to this research. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001.

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