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Artificial intelligence applied to early childhood education: A focus for educational research?

María José Latorre-Medina and Samia Abdelmaula-Mesaud

University of Granada, Spain

Abstract

The study focuses on a currently emerging topic: artificial intelligence (AI). The impact of AI on the field of education is considerable. The possibilities and risks associated with its use are already well known, especially when the ethical and/or legal boundaries associated with it are crossed. However, the potential of AI as an emerging technology, in the field of education in general, and in early childhood education in particular, is yet to be realised. In this paper we consider what has occurred to date, and then focus the attention of researchers who have conducted studies in the field of early childhood education. To do this, we adopted a bibliometric study approach. This type of analysis has allowed us to consider the scientific activity carried out in the field of artificial intelligence as applied in early childhood education. As we note throughout this paper, this type of analysis is highly valued among the scientific community as a way of assessing the quality, productivity and scientific evolution of a subject of study. It provides academics with valuable information about research conducted in a particular area. Following the recommendations of experts in the field, in this paper we not only address the volume of publications (quantity), but also assess other scientometric indicators that measure their quality. The results of this study then can make a significant contribution to the field of research and work in early childhood education in the face of the new challenges presented by today's society.

Keywords: early childhood education, artificial intelligence, bibliometric analysis, scientific impact.

1. INTRODUCTION

In recent years, advances in artificial intelligence (AI) have transformed the world, permeating almost all sectors of society, including education. This has occurred to such an extent that AI has come to be considered the fourth revolution of technology in education (Cordón 2023; Prendes-Espinosa 2023). Given its unprecedented particularities (Ubal et al. 2023) to offer innovative and effective solutions to support teachers in their educational work (Aparicio 2023) AI is regarded as one of the most important aspects of education and schooling in contemporary society.

In the field of education, and in the educational discourse generated about it, the interest in AI has provoked various reactions and controversies: from recognition of AI's potential to make teaching and student learning more efficient and effective, to

apprehension about its possible overuse or misuse. In this regard, focusing on early childhood education, Wang et al. (2021) discuss how AI acts as a double-edged sword, presenting some of its positive effects (personalised learning, personalised interactive support and increased accessibility to broader learning experiences) as well as negative effects (overuse and misuse). In order to maximise the benefits and minimise the dangers associated with children's use of AI, it might be useful to apply frameworks to analyse the use of AI. One such framework is the POWER model (purposeful, optimal, wise, ethical, responsible) which encourages us to apply specific principles to children's AI literacy.

Focusing on its advantages, it is apparent that this emerging technology provides numerous applications that can be used by teachers to personalise teaching, assess student performance, generate educational content, create learning experiences and provide automatic feedback (Montiel & López 2023). Or as Ayuso-del Puerto & Gutiérrez-Esteban (2022) argue, AI applications can prepare young people for a changing labour market marked by new social demands.

The review of the academic literature has made us aware that most of the studies and experiences carried out on AI applications in the field of education have not focused on the early childhood years. Specifically, the authors Forero and Negre (2023) reveal that AI applications are mainly being used at the secondary and university levels, with some also being experienced in primary school, but they recorded none in the early childhood years.

For our part, convinced of the potential of AI as an emerging technology in the field of education in general, and in early childhood education in particular, we planned this colloquium to see what was being done in the field and to if possible consider the possibilities for researchers who have approached their study within the field of early childhood education, as this is our area of professional interest.

To this end, we carries out a bibliometric study. We felt that this type of analysis would allow us to assess the scientific activity carried out in the field of artificial intelligence in early childhood education. As justified throughout this work, this type of analysis is highly valued among the scientific community as a way of assessing the quality, productivity and the scientific evolution of a subject of study, providing academics with valuable information. Following the recommendations of experts in the field, in this article we will not only address the volume of publications, but also assess other scientometric indicators that measure their quality. In this sense, we trust that the findings might make a significant contribution to the field of research and work in early childhood education in the face of the new challenges presented by today's society.

1.1. Purpose of the study

The general purpose of this work is to identify the state of scientific productivity on the *use of AI in early childhood education* (AICHILED, from now on), by analysing the works developed in the field that are available on the Web of Science platform, currently one of the most prestigious online databases in the world.

The research questions guiding the study are as follows:

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RQ 1. Can the scientific evolution of AICHILED be characterised through the Web of Science?

RQ 2. What is the performance of scientific activity in AICHILED in the Web of Science?

2. METHOD

2.1. Bibliometric study

In the present work a bibliometric type of research was carried out. Authors such as Moed and Glänzel (2005) summarise it as a study of the quantitative aspects of the production, dissemination and use of published information in a field of knowledge and study. Following Reyes et al. (2016), we know that this type of study offers a number of publications, showing the scientific production as a tool to acquire in depth knowledge of a topic within a field, groups or areas of research, and classifying the selected indicators with the idea of verifying how their frequency is presented and how they are distributed in a discipline or scientific area.

More specifically, this article resorts to a bibliometric analysis of secondary sources, which is a type of analysis that allows researchers to identify general or specific concepts of specific areas of an academic field and subsequently visualise their evolution (López-Robles et al. 2019). Following authors such as Rey-Martí et al. (2016) and Rodríguez-Bolívar et al. (2018), it appears that this type of analysis is well valued as a means of assessing the quality, productivity and scientific evolution of a topic/field of study, providing scholars with valuable information in this regard.

Aleixandre et al. (2017) argue that bibliometrics assesses scientific activity through the use of bibliometric indicators extracted from publications considered as the final result of any research. The most common scientific production indicators include the number of papers published by an author, institution, country, journal or subject area. These data, generally after a normalisation process, are presented in static or dynamic form (Aleixandre et al. 2017b).

But knowing the volume of publications is not enough. Other indicators are also required to measure their quality, such as citation and impact (Aleixandre et al. 2017c, 2017d).

In this respect, the Web of Science platform has emerged as an essential source of information for bibliometric studies, overcoming the limitations found in other databases, such as PubMed/Medline.

2.2. Database selection

Authors such as Martínez et al. (2015) point out that the most prominent databases for this type of studies are Web of Science (WoS), Scopus and Google Scholar. However, given the greater access to academic literature, WoS seems to be the most accepted and commonly used platform for conducting bibliometric analyses within the area of science, social sciences, arts and humanities disciplines (Norris and

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Oppenheim 2007).

WoS, owned by Clarivate Analytics, is a web-based platform that integrates a large collection of bibliographic reference and citation databases of multidisciplinary scientific publications. It allows access to other databases such as Web of Science Core Collection (WOS Core Collection), Current Contents Connect, Derwent Innovations Index, Korean Journal Database, Medline, Russian Science Citation Index and Scielo Citation Index, indicating the documentary, thematic and chronological coverage for each of them. In turn, this platform provides access to other databases (located at the top of the web) that act as citation analysis tools, such as Journal Citation Reports, InCites or Essential Science Indicators (Lucas et al. 2018).

WoS access licences are managed through subscriptions made by the Spanish Foundation for Science and Technology (FECYT) directly with official scientific institutions, such as universities and public research organisations.

In line with this evidence, in the present study AICHILED data were collected through WoS, accessed through the University of Granada, Spain. We focus on the period between 2000 and 2023 to determine its evolution.

2.3. Procedure and data analysis

After the selection of the database, the research process was marked by the following steps: (a) choice of keywords (for this purpose, specialised thesauri, ERIC were consulted), (b) construction of a precise search equation to obtain meaningful results ("artifical intelligence" AND "childhood education") [TOPIC]), and (c) extraction of information on the documents containing these terms from the different metadata (title, abstract and keywords).

The first search identified 50 scientific publications, which was reduced to 34 by scanning exclusively through the education categories of the Web of Science (Education Educational Research). These 34 resulting papers were carefully analysed to eliminate possible duplicate records, those published before 2000 and those poorly indexed. After this, the unit of analysis remained at 34 publications, as a result of the configuration of the inclusion and exclusion criteria (Alexander 2020) (Table 1).

Table 1. Inclusion/exclusion criteria chosen to assemble the corpus of papers.

Inclusion criteria	Exclusion criteria
Studies identified using the search equation	Studies that do not meet the inclusion criteria
Studies identified through the WoS education categories	Studies that do not align with the topic under study
Studies published between 2000 and 2023	Poorly indexed studies in WoS
Studies published in different formats (articles, book chapters, etc.)	Repeated papers in WoS

Note. Prepared by the authors.

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To facilitate the understanding and visualisation of the different actions carried out, the following flow chart (Figure 1) has been drawn up in accordance with the protocols of the PRISMA-P matrix.

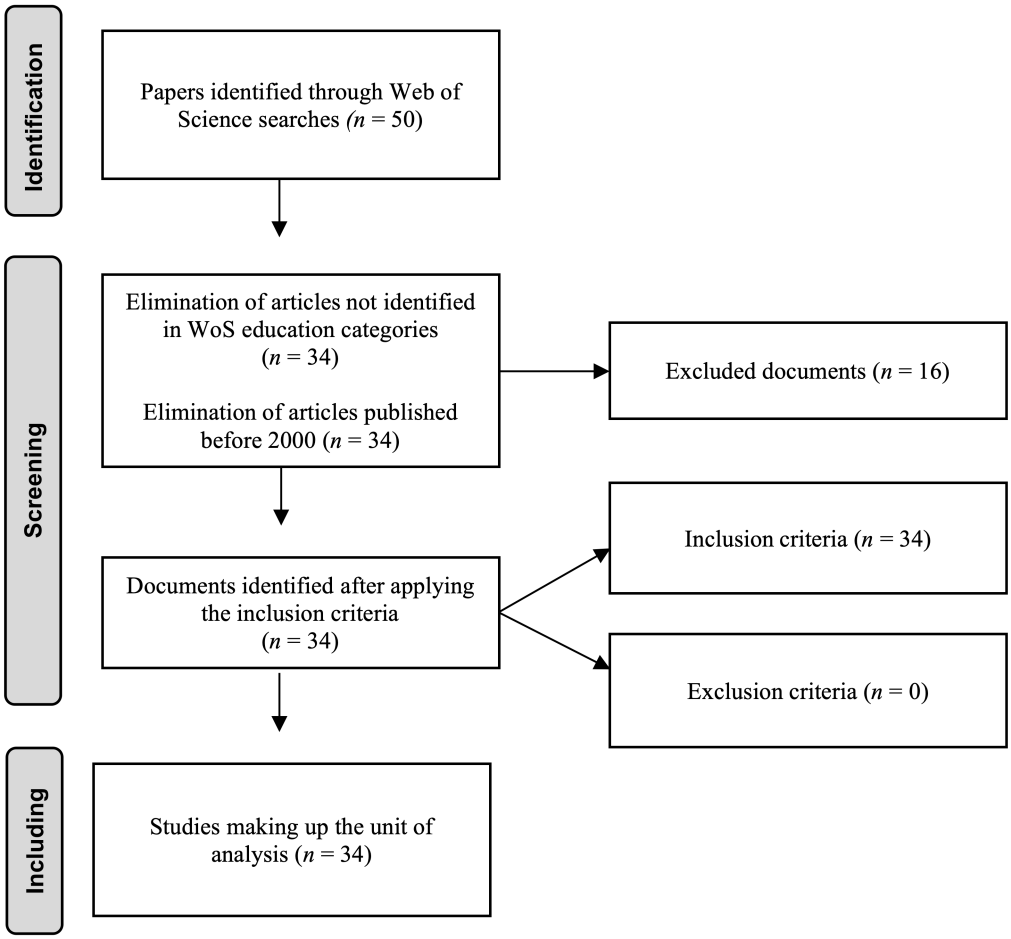

Figure 1. Flow chart according to the PRISMA Declaration.
Note. Prepared by the authors.

2.4. Data analysis tools

The two main tools used to carry out the bibliometric analysis were *Analyze Results* and *Creation Citation Report.* These two applications, which are part of the Web of Science Core Collection, have allowed us to discover and analyse the performance and existing scientific production in the field of artificial intelligence applied to early childhood education. Following Muñoz-Leiva et al. (2012) and Lucas et al. (2018), we know that, through the analysis of scientific output, we can qualitatively and quantitatively measure the contribution of topics and subject areas to the entire academic field, allowing us to identify the most prominent, productive and high-impact subfields.

Under these coordinates, in the present work these two tools have been used to obtain data on the year of publication, authorship, country, type of document, language, institution, source of publication, among other indicators of scientific production, as

well as to determine the most cited authors/works and their impact on the scientific community.

3. RESULTS

3.1. Scientific output and production

The evolution of scientific publications on the subject under study has been constant and continuous since 2010, when the first academic record was found in WoS. The pace of scientific production on AICHILED was slow until 2019, when there was an exponential growth experienced. The graph (Figure 2) shows the frequency of these publications per year and allows us to clearly visualise the marked growth of scientific production on AICHILED over the last four years. Some hypotheses that motivate this increase in recent publications in the field of early childhood education, as well as in other areas of knowledge and/or scientific disciplines, are related, on the one hand, to the state of technological revolution experienced worldwide and its impact on the world of education. Today, AI, is still regarded as an emerging technology, that is considered to have brought about the fourth technological revolution in education (Cordón 2023; Prendes-Espinosa 2023; Ubal et al. 2023); and, on the other hand, what is known as academic capitalism (Saura and Caballero 2021) which imposes a *publish or perish* scenario (Fernández-Cano 2021) among university teaching staff, also impacts is use and application.

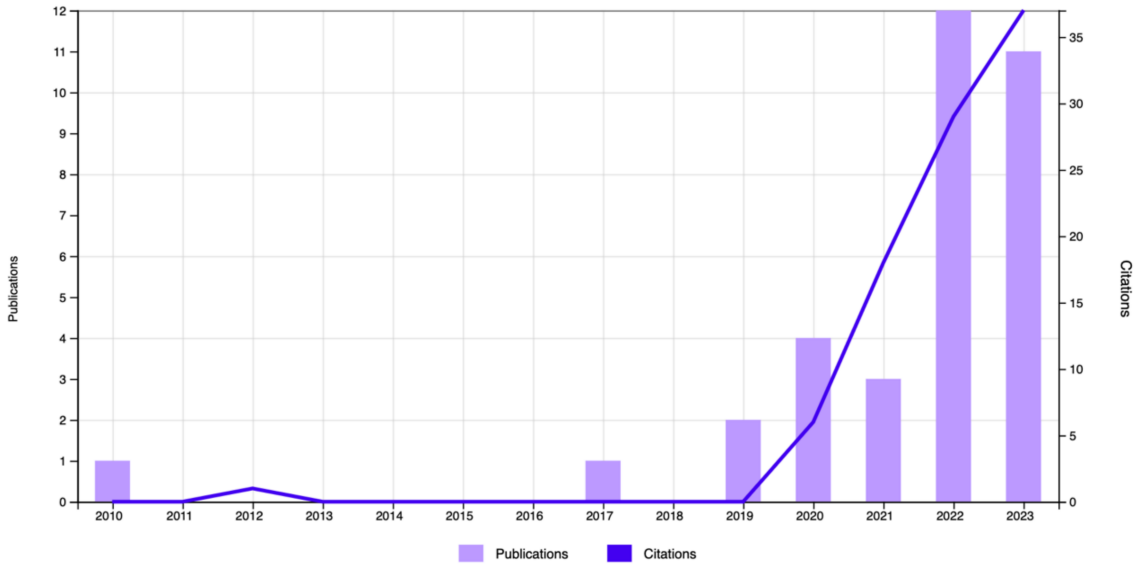

Figure 2. Number of papers per year collected from Web of Science.

Note. Data extracted from WoS.

3.1.1. Calculation of scientific output indicators focusing on the volume of publications

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Based on the data obtained through the *Analyze Results* tool, the following should be noted.

Most of the documents identified in this study are articles (28 documents, 82.35%), written in English (23 documents, 67.65%) and Korean (10 documents, 29.41%). Only two publications are found in Spanish. About a quarter of these documents are Open Access (9 documents, 26.47%).

In terms of country of publication, the country with the highest number of publications (7) is Peoples R China (20.59%), followed by Australia, China, India and USA with 3 each (8.82% in each case). Of the total of 15 countries, only those with two or more than two publications have been selected for this study (Table 2).

Table 2. Ranking of the number of publications by country.

Countries	Number of documents
Peoples R China	7
Australia	3
China	3
India	3
USA	3
England	2
Spain	2

Note. Prepared by the authors.

As for the authors who are established in the field, or who have approached research on AICHILED, Su Jh and Yang Wp stand out as the two most productive authors in the field of study, with four publications each (11.76%), followed closely by Wang X with two publications (5.88%). Of the total 146 authors, only those with two or more than two publications were selected in this study (Table 3).

Table 3. Ranking of number of publications by author.

Authors	Number of documents
Su Jh	4
Yang Wp	4
Wang X	2

Note. Prepared by the authors.

On the other hand, in terms of the main source of publication of papers on AICHILED, the journals "International Journal of Early Childhood Special Education" and "The Journal of Learner-Centred Curriculum and Instruction" are the most requested by authors. They occupy the first two positions in the ranking of number of publications per source and host three articles on AICHILED each (8.82%). They are

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closely followed by four other journals "Contemporary Issues in Early Childhood", "Interactive Learning Environments", "Journal of Computer assisted Learning" and "The Journal of Korea Open Association for Early Childhood Education" with two publications each (5.88%). In the ranking of the number of publications by source, it is worth noting that we only found 25 scientific journals among which only one Spanish journal appears, with a single publication by two Spanish authors (Ayuso-del Puerto & Gutiérrez-Esteban, 2022), the "Revista Iberoamericana de Educación a Distancia" (2.94%). In this study, only those sources with two or more than two publications have been selected (Table 4).

Table 4. Ranking of the number of publications by source.

Source	Number of documents
International Journal of Early Childhood Special Education	3
The Journal of Learner centered Curriculum and Instruction	3
Contemporary Issues in Early Childhood	2
Interactive Learning Environments	2
Journal of Computer assisted Learning	2
The Journal of Korea Open Association for Early Childhood Education	2

Note. Prepared by the authors.

Likewise, the analysis of the performance of scientific production informs us of the two higher education institutions that are leaders in AICHILED research: the *University of Hong Kong* and the *Education University of Hong Kong* (EdUHK). It is worth noting that only one Spanish university, the University of Extremadura, appears in the ranking of institutions by number of publications. However, in this study only those institutions with two or more publications have been considered (Table 5).

Table 5. Ranking of institutions by number of publications.

Higher education institutions	Number of documents
University of Hong Kong	5
Education University of Hong Kong (EdUHK)	4
Koneru Lakshmaiah Education Foundation	3
Sree Vidyanikethan Engn Coll Autonomous	2

Note. Prepared by the authors.

Finally, it should be noted that, of the total scientific production analysed, 24 documents are in the Web of Science Core Collection database (70.58%) and the rest in the KCI-Korean Journal Database (29.41%).

3.1.2. Calculation of scientific output indicators focusing on citation and publication impact

Following the recommendations of experts in the field (Lucas et al. 2018), in this work we not only focus on calculating and assessing the volume of publications in the field of AICHILED, but we also assess other scientometric indicators that measure their quality, such as citation and impact. Thus, according to the data obtained through the *Creation Citation Report* tool, the following should be highlighted.

The authors who have received the highest number of citations in the AICHILED field of study, and who have therefore been the "focus of attention" of the other authors and researchers who have approached their study, are shown in Table 6:

Table 6. Authors, number of citations and main research topic on the AICHILED field of study.

Authors	Number of appointments	Research topic	Implications of the study
Williams, R., Park, H. W. & Breazeal, C. (2019)	45	Development of a novel early childhood AI platform, PopBots, where preschool children train and interact with social robots to learn AI concepts.	Early AI education can enable early childhood learners to have a good knowledge and understanding of AI devices (typology, use, etc.), which are increasingly present in their lives.
Kewalramani, S., Kidman, G. & Palaiologou, I. (2021)	18	Use of interactive robotic toys with AI interface in early childhood settings to develop children's research literacy (creative, emotional and collaborative enquiry).	Appropriate integration of AI in student play and learning Need to improve teachers' skills in using AI robotic toys to engage children in new educational experiences.
Ganesh, D., Sunil, M., Venkateswarlu, P., Kavitha, S. & Sudarsana, D. (2022)	5	The process of design, development and improvement of a set of AI computational tools with kindergarten students is investigated.	Need for teachers, in collaboration with families, to foster children's ability to think creatively from an early age. Promote a curriculum that includes more AI content and experiences.
Ayuso-del Puerto, D. & Gutiérrez-Esteban, P. (2022)	4	Design and development of an e-learning programme to increase the knowledge of AI of future teachers.	The need to revise the syllabuses of subjects in the Bachelor's Degree in Early Childhood Education to include the use of AI in the initial teacher training process.
Wang, X., Yin, N. A. & Zhang, Z. N. (2021)	4	Designing smart companion toys that contribute to children's cognitive development	In addition to enriching research on smart toy design, this article also serves as a guide for professionals to design smart toys and contribute to children's cognitive development.

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Focusing our attention on this scientific production, another interesting bibliometric analysis was directed at the keywords of the most cited studies. To carry out this analysis, we entered all the keywords appearing in the selected research into a word frequency analysis programme based on tag clouds.

This analytical approach to the subject makes it possible to identify the key descriptors that identify the subject of study in the most cited scientific publications: "design of intelligent toys" and "children's literacy in AI" are among the priority lines of study (Figure 3).

Figure 3. Keyword analysis through tag clouds.
Source: own elaboration.

4. CONCLUSIONS

In the present article the following actions have occurred:

1. A bibliometric study has been carried out on the field of artificial intelligence applied to early childhood education to find out and assess the scientific activity carried out to date in the field.
2. For this purpose, the Web of Science (WoS) platform was selected as it is presented, among the scientific and academic community, as an essential source of information for carrying out bibliometric studies on any area of knowledge.
3. The bibliometric analysis has been carried out with the Web of Science Core Collection, making use of its two main tools: a) *Analyze Results,* and b) *Creation Citation Report*. Through these two tools:

    3.1. Indicators focused on the volume of scientific activity on AICHILED have been calculated and evaluated, such as: data relating to the year of publication, authorship, country, type of document, language, institution, source of publication and database in which it is located, given that WoS allows access to other databases.

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3.2. Indicators focused on the quality of scientific activity on AICHILED have been calculated and assessed, such as: data on the most cited authors/works and their impact on the scientific community, and the highlighting of key descriptors used in studies.

4. The results obtained from the bibliometric analysis carried out allow us to answer the two key questions that guided the research. By way of conclusion, a series of central aspects that provide answers to these questions are highlighted below.

RQ1. *Can the scientific evolution of AICHILED be characterised through Web of Science?*

The analysis of the scientific evolution of the subject under study reveals the stability of the line of research since the first academic record appeared in WoS in 2010, which has been progressively cultivated over time. In fact, there has been a considerable increase in scientific production over the last four years. This indicates that AICHILED is a topic that has been gaining more relevance over time, being a special focus of attention nowadays of those authors and researchers devoted to the subject, both nationally and internationally.

RQ2. *What is the performance of scientific activity on AICHILED in Web of Science?*

The Peoples Republic China, followed by Australia, China, India and USA had authors that produced the largest number of publications. The two leading higher education institutions in AICHILED research were found to be the *University of Hong Kong* and the *Education University of Hong Kong* (EdUHK). The data also reveal the great diversity of scientific journals publishing AICHILED-related articles. The international journals *International Journal of Early Childhood Special Education, The Journal of Learner centered Curriculum and Instruction* stand out in this regard. In addition, Su Jh and Yang Wp are listed as the most productive authors in the field of study. However, in terms of number of citations and impact in the field of study, Williams, Park & Breazeal (2019) and Kewalramani, Kidman & Palaiologou (2021) are the most cited. The work undertaken by these authors focuses on the development of innovative experiences based on the use of AI in early childhood settings.

In sum, the data obtained in this study allow us to conclude that AICHILED has been –and remains– the object of interest and study by numerous researchers from different institutions globally.

5. IMPLICATIONS AND LIMITATIONS OF THE STUDY

In recent years, there has been a growing trend towards the incorporation of technological applications and resources in early childhood education. In fact, the use of AI apps by early childhood teachers has grown. We are aware that the age of AI has –and it will have– a significant impact on society in the future. Therefore, we agree with Williams et al. (2019) when they argue that early AI education should enable early childhood learners to have a good knowledge and understanding of AI devices (e.g. typology, use), which are increasingly prevalent in their lives.

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Referring to AI, Prendes-Espinosa (2023) stated:

> AI is [...] the fourth technology revolution in education. It is here and it has come to change our institutions and our roles. We must take on the need to redefine our teaching role and understand how it has changed the learning ecology of our students, our way of teaching and their strategies for learning. This is a challenge for 21st century education (p. 13).

Achieving this will require, first and foremost, the training of teachers to ensure the optimal use of the educational applications offered by AI (Montiel & López 2023). "They should learn how the best AI techniques can be used for students' academic success" (Ganesh et al. 2022: 2289).

Only in this way will teachers be able to provide new and enriching learning situations in the early childhood education, effectively and ethically integrating the use of AI in teaching-learning processes, along the lines of the experiences developed by Kewalramani et al. (2021). This should also reflect the use of *responsible AI*, a novel concept of AI that enhances values desired by society such as fairness, reliability, privacy, security, inclusion, transparency and accountability (Díaz-Rodríguez et al. 2023; Marín & Tur 2024; Nguyen et al. 2023). Through this use, AI can indeed be a key approach to achieve the challenges set out in the 17 United Nations Sustainable Development Goals. That "education" (SDG 4) can cause a significant disruption, which has already been observed in recent times (Hwang & Wu 2021; Montes et al. 2021).

Despite what has been researched so far, there is still a need for further research on the mechanisms that allow for a harmonious integration of this emerging technology in the field of education. Authors such as Aparicio (2023) and Montiel and López (2023) suggest that more research needs to be conducted on the use of AI in education. It should consider the different cases, contexts and perspectives and reflect on what constitutes exemplary practices and recommendations. This will then allow for an effective and responsible implementation of AI in the classroom, that considers the ethics and privacy of the data used as a major issue.

Specifically, educators need to be alerted to the ethical and social relevance of achieving solutions that make it possible to integrate these technologies without compromising the quality of educational processes, Ubal et al. (2023) propose, as a future line of research that involves the creation of scientific communities and/or work teams to generate knowledge and strategies to understand and minimise the negative impact of AI on society in general, and in the field of education in particular.

Finally, by way of limitation, it should be noted that, in this study, only the WoS platform was used to determine the current state of research on AICHILED. Hence, a potential line of research is to replicate the bibliometric analysis using other impact databases such as Scopus and Google Scholar might occur. Likewise, following expert recommendations (Cascón-Katchadourian et al. 2020; Cobo et al. 2011; Montero-Díaz et al. 2018), it would be interesting to complement the analysis carried out with a scientific mapping generated from SciMat, a very specific software that would make it possible to identify the main topics, their conceptual evolution and the thematic areas of

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study that concentrate the research carried out on AICHILED over time. This then represents another open door for research.

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