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EDUCATIONAL REVOLUTION: THE IMPACT OF ARTIFICIAL INTELLIGENCE ON TEACHER TRAINING

William Niebles[1], Hernán Guzmán[2], José Torres[3]

[1]Doctor en Ciencias Gerenciales, Universidad de Sucre,
[2]Doctor en Ciencias de la Educación, Universidad de Sucre,
[3]Doctor en Economía y Empresas, Doctor en Estudios Políticos, Universidad de Sucre,

williamniebles@yahoo.com.mx[1]
hernan.guzman@unisucre.edu.co[2]
jose.torres@unisucre.edu.co[3]

ABSTRACT
This bibliometric review analyzed 166 documents related to the impact of artificial intelligence in teacher training published in 2014-2024, using R Studio and VOSviewer. The analysis proves that artificial intelligence is revolutionizing the education and training of teachers according to scientific production. Lecture Notes in Computer Science is the most relevant source with 23 publications, while production by country is led by China with 295 documents; The most productive institution comes from there, Central China Normal University with 25 publications contributed. Among the key terms with the greatest impact found are "Artificial intelligence", "Teacher training", "Adversarial machine learning", among others.

Keywords: Artificial intelligence, Teacher education, Teacher training, Machine learning, Bibliometrics

1. Introduction

Artificial intelligence (AI) has quickly changed several fields, including education, creating new possibilities and problems for teacher preparation (Pham & Sampson, 2022). Understanding how AI-driven technologies and approaches affect teacher training and professional development is essential as educational institutions progressively include them. The worldwide conversation on artificial intelligence in education has mostly been on its possibilities to improve individualized instruction, automate administrative processes, and offer real-time analytics for student development (Alam, 2021). Still, its impact on educators' pedagogical abilities is understudied, especially from a bibliometric perspective.

Historically, mostly through university-based programs, teacher preparation has been focused on pedagogical theories, classroom management practices, and subject-specific methods (Howard & Milner, 2021). The paradigm change brought about by artificial intelligence calls for the incorporation of technical capabilities into teacher preparation (Atibuni et al., 2022). Artificial intelligence-driven platforms like virtual reality simulations, automated grading tools, and intelligent tutoring systems have started to rethink teaching strategies and evaluation techniques (Murdan & Halkhoree, 2024). Although these developments have great benefits, they also raise questions about teachers' readiness to make good use of these tools (Park & Son, 2022).

Though artificial intelligence is becoming more and more common in the classroom, studies on its particular influence on teacher preparation are still scattered. Emphasizing their ability to offer adaptable learning opportunities and support ongoing professional growth, several studies show the advantages of AI-enhanced training programs (Gedrimiene et al., 2024). AI-powered analytics, for example, may provide teachers with insights on how well they teach, therefore supporting data-driven instructional changes (Nazaretsky et al., 2022). On the other hand, other academics warn against depending too much on artificial intelligence as it can dehumanize

teacher-student relationships and compromise important features of human-led learning (Arantes, 2024). Furthermore raising ethical questions concerning data privacy, algorithmic biases, and the digital divide is how fair use of artificial intelligence in teacher education (Nguyen, et al., 2023) is discussed.

Examining the scientific debate on artificial intelligence in teacher preparation may be done methodically using a bibliometric study. This approach helps scholars to spot important fieldwork topics, trends, and significant works (Ramírez et al., 2023); bibliometric analysis provides insightful analysis of the direction of knowledge creation by mapping the development of AI-related research in teacher education, therefore revealing areas of interest and possible research gaps. Moreover, this analytical method helps to clarify how various areas and organizations add to the conversation, therefore guiding local and international policy and practice.

Previous bibliometric research in the more general subject of artificial intelligence in education have mostly concentrated on student-centered applications, thereby lacking knowledge about AI's consequences for teacher preparation (Donmez, 2024). Filling in this void, our study seeks to give a thorough summary of the body of current research, therefore clarifying the degree of effect artificial intelligence has had on educational approaches. We specifically try to address the following study questions: (1) In AI-related teacher training research, what are the main trends and themes? (2) Which areas and establishments have led front stage in this intellectual debate? (3) Based on the literature, what main potential and difficulties related to artificial intelligence integration in teacher preparation come to light?

2. Method

This bibliometric analysis focuses on investigating the most important aspects of scientific publications in relation to the impact of artificial intelligence on teacher training. This study was carried out by systematically reviewing the literature using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology to ensure a strict and systematic selection procedure. It was used the Scopus database, known for its extensive, high-quality academic literature and organizational approach that simplifies bibliometric analysis (Umar et al., 2022).

The analysis was carried out in February 2025 and included specific terms related to the topic since they were previously standardized, through the keyword normalization process. This approach ensures the inclusion of a large number of relevant publications, reduces bias and improves data comparability. Data investigation was carried out using R Studio and VOSviewer, tools often used in bibliometric studies as they can visually display co-author networks, keyword coexistence, and cooperation between institutions (Shen et al., 2023).

The research was based on a descriptive documentary approach (Heras et al., 2021), which facilitated the characterization of scientific production in this field based on indicators such as the growth rate of publications, to assess the progression of academic interest in the subject, geographical distribution and national productivity, identifying the regions with the most study on the effect of artificial intelligence on teacher training, the most prominent authors and institutions, through the study of co-authorship networks and institutional affiliations, and also the most influential journals.

On the other hand, Bradford's law determines the most influential group of sources in a field of research, Lotka's law tests the productivity of authors and can evaluate the concentration of scientific results in a limited group of researchers (Onyancha & Ocholla, 2022; Nandeesha & Begum, 2023). Finally, the dissemination and impact of the knowledge generated in the

academy can be analyzed. To identify the main trends, bibliometric network analysis methods were used, such as the identification of research groups and the term co-occurrence study, which facilitated the identification of rising topic areas within the study area.

Table 1

Keywords standardization.

Variable	Descriptor
Teacher training	"Teacher education", "Pedagogical instruction", "Teacher professional development"
Inteligencia Artificial	"Cognitive computing", "Automated learning", "Cognitive technology", "Machine learning", "Artificial neural networks"

Based on the identification of these elements, the following search equation was formulated in the Scopus database: "(TITLE-ABS-KEY ("Teacher training") OR TITLE-ABS-KEY ("Teacher education") OR TITLE-ABS-KEY ("Pedagogical instruction") OR TITLE-ABS-KEY ("Teacher professional development") AND TITLE-ABS-KEY ("AI") OR TITLE-ABS-KEY ("Cognitive computing") OR TITLE-ABS-KEY ("Automated learning") OR TITLE-ABS-KEY ("Cognitive technology") OR TITLE-ABS-KEY ("Machine learning") OR TITLE-ABS-KEY ("Artificial neural networks") AND PUBYEAR > 2013 AND PUBYEAR < 2025". This equation allowed us to recover publications from the last ten years (2014-2024), ensuring the inclusion of recent and relevant studies for understanding the impact of artificial intelligence on teacher training. Furthermore, the analysis focused on studies indexed in high-impact journals, guaranteeing the quality and reliability of the data obtained.

3. Results

Table 2

Main information of the data obtained from Scopus.

MAIN INFORMATION ABOUT DATA	
Timespan	2014:2024
Sources (Journals, Books, etc)	317
Documents	547
Annual Growth Rate %	78.04
Document Average Age	1.93
Average citations per doc	8.901
References	0
DOCUMENT CONTENTS	
Keywords Plus (ID)	1776
Author's Keywords (DE)	1421
AUTHORS	
Authors	1561
Authors of single-authored docs	74
AUTHORS COLLABORATION	

Single-authored docs	78
Co-Authors per Doc	3.36
International co-authorships %	21.76
DOCUMENT TYPES	
article	278
book chapter	42
conference paper	183
conference review	14
data paper	1
editorial	2
erratum	2
note	2
review	22
short survey	1

Table 2 identifies the general components related to scientific production in this field of study, showing an increase of 78.04% in recent years, with a total of 317 sources, 547 articles and 1561 authors identified among all the publications found. Likewise, the increase in scientific production can be seen more clearly in Figure 1, where the year 2024 stands out with 316 documents produced, 2023 with 107 documents produced and 2022 with 54 documents produced, which are the years with the highest annual production.

This exponential increase in science production shows the growing importance of artificial intelligence in teacher education and its strengthening as a top-level research field. From a bibliometric point of view, this growth pattern coincides with Price's model of the exponential growth of science, which indicates that developing fields typically experience an accelerated increase in publications as they develop and gain greater scholarly interest. Furthermore, the distribution of production over time indicates the presence of events that drive debate and research in this field. The increase in the number of publications in the last three years could be conditioned by the effect of the COVID-19 pandemic, which promoted the incorporation of digital technologies in education and promoted a growing interest in the implementation of Artificial Intelligence in teacher training.

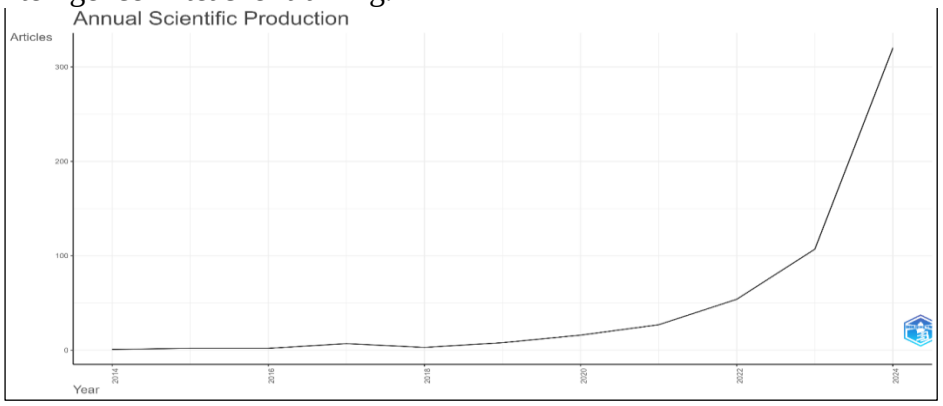

Fig. 1. Annual scientific production.

3.1 Laws of bibliometric productivity

Lotka's law facilitates the analysis of scientific production in relation to the number of authors, which helps to better understand the impact of authors on an area of knowledge [18].

Figure 3 illustrates that most authors have published only one paper, a pattern characteristic of Lotka's law.

As the number of published papers increases (2, 3, etc.), the percentage of authors contributing those papers rapidly decreases.

In the case of authors who have published 2 documents, the percentage is significantly lower, and for those with 3 documents, it is almost insignificant. The curve suggests that very few authors are responsible for the majority of publications, while the vast majority of authors only contribute one or a few papers. This is the foundation of Lotka's law.

Table 3

Lotka's Law.

Documents written	N. of Authors	Proportion of Authors
1	1372	0.876
2	140	0.089
3	39	0.025
4	13	0.008
5	2	0.001
7	1	0.001

From a theoretical perspective, the usefulness of Lotka's law in this context suggests that this area of research is characterized by an ecosystem of irregular collaborators, who may be researchers from different disciplines studying the connection between artificial intelligence and teacher training, but without a single commitment (Nandeesha & Begum, 2023). However, only a small number of authors who have published three or more articles suggest that researchers can play a key role in consolidating the field, creating more organized research directions, and promoting professionalization. This is very important for the development of knowledge in this field, since the continuity of scientific production contributes to the accumulation of evidence, the formation of more robust theoretical frameworks and the creation of more stable collaboration networks.

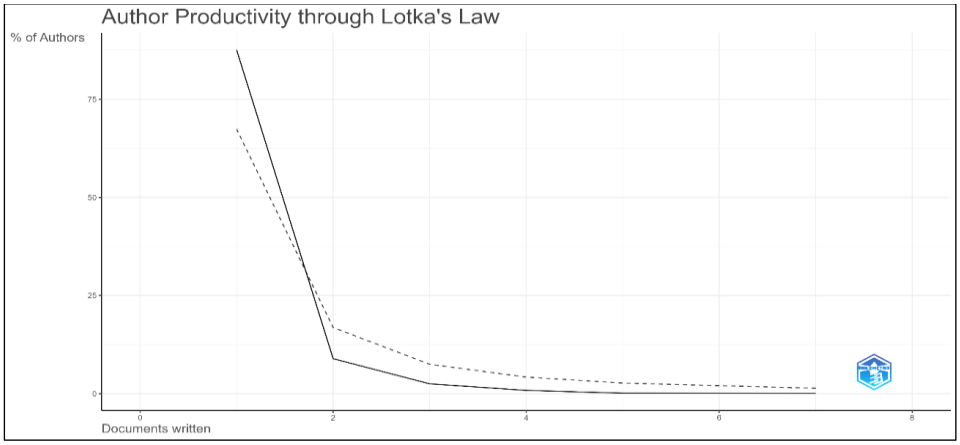

Fig. 2. Lotka’s Law.

The main sources are listed by publication frequency by topic and in percentiles according to Bradford's law, which divides journals into three areas of activity, where the number of journals increases but the proportion of articles remains relatively constant. Table 4 shows the

quotas allocated to each Bradford Law zone. Zone 2 stands out with 33.82%, followed by Zone 1 with 33.27% and Zone 3 with 32.91%, being the zone with the lowest number of documents.

Table 4
Bradford's Law.

Zone	No. Magazines	No. Titles	Percentages
Zone 1	22	182	33.27%
Zone 2	115	185	33.82%
Zone 3	180	180	32.91%

These results clearly demonstrate the diffusion principle of Bradford's law, which states that a small number of core journals represent a significant proportion of academic output, while an increasing number of peripheral journals contribute an equal amount of scientific literature (Onyancha & Ocholla, 2022). In this context, the fairly balanced distribution between the three regions shows that, although the research material on the relationship between artificial intelligence and teacher education (zone 1) is highly specialized, research on this topic can also be found in several journals from different disciplines, suggesting an interdisciplinary approach in the field.

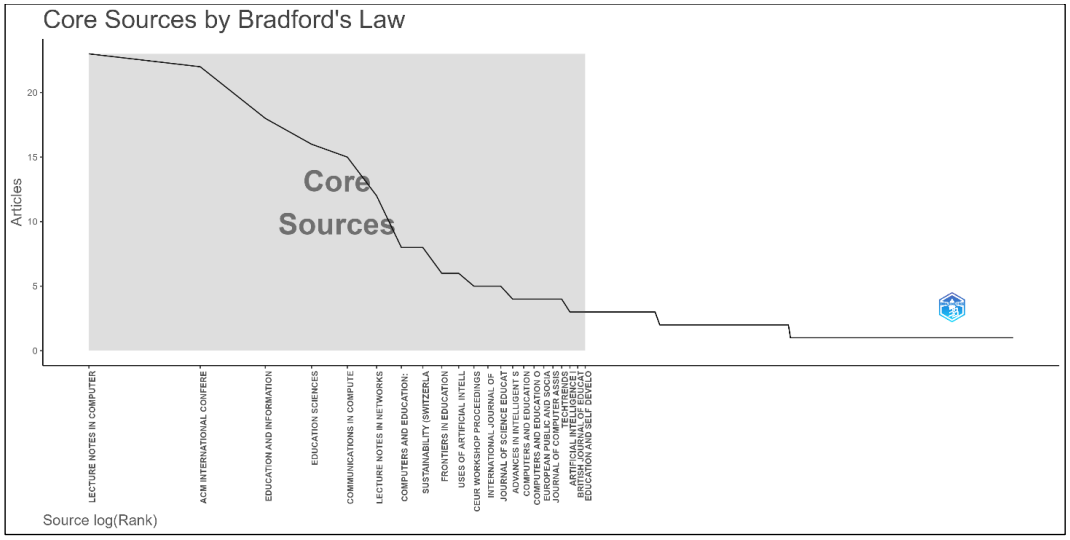

Fig. 3. Bradford 's Law.

3.2 Bibliometric indicators

Table 5 shows the main publication sources in the study area. Lecture Notes in Computer Science (including its subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) tops the list with 23 publications, followed by ACM International Conference Proceeding Series with 22 publications and Education and Information Technologies with 18 publications. These three sources are consolidated as the main references in scientific production on the research topic.

Regarding publication sources, the findings show that they are distinguished by their specialization in artificial intelligence and educational technology, which suggests that research in this field focuses on highly technological and innovative areas. Likewise, the appearance of publications such as Sustainability (Switzerland) indicates that there is increasing focus on the confluence between artificial intelligence and sustainability in the educational field. In contrast,

the publication of studies such as Frontiers in Education and Uses of Artificial Intelligence in STEM Education indicates that research also focuses on the use of artificial intelligence in the instruction of specific areas, especially in science, technology, engineering and mathematics (STEM).

Table 5
Most relevant sources.

Sources	Articles
LECTURE NOTES IN COMPUTER SCIENCE	23
ACM INTERNATIONAL CONFERENCE PROCEEDING SERIES	22
EDUCATION AND INFORMATION TECHNOLOGIES	18
EDUCATION SCIENCES	16
COMMUNICATIONS IN COMPUTER AND INFORMATION SCIENCE	15
LECTURE NOTES IN NETWORKS AND SYSTEMS	12
COMPUTERS AND EDUCATION: ARTIFICIAL INTELLIGENCE	8
SUSTAINABILITY (SWITZERLAND)	8
FRONTIERS IN EDUCATION	6
USES OF ARTIFICIAL INTELLIGENCE IN STEM EDUCATION	6

Instead, Figure 4 shows the findings of the bibliometric analysis, showing a contrast between scientific production among the countries with the greatest number of publications. China has a notable leadership in this production with 295 documents, the United States follows with 255 and Germany with 113. Several countries such as Spain, India and Indonesia show an average production in relation to the former.

The observed distribution in scientific production by country suggests that nations with greater investment in technology and education are leading research in the field. China's supremacy is due to its policies to promote artificial intelligence and its intense drive in technological advancement related to education. On the other hand, nations such as Spain, India and Indonesia exhibit average production, which signals a gradual increase in their participation

in the industry. These findings could be related to government strategies to promote artificial intelligence in education and the formation of international research network.

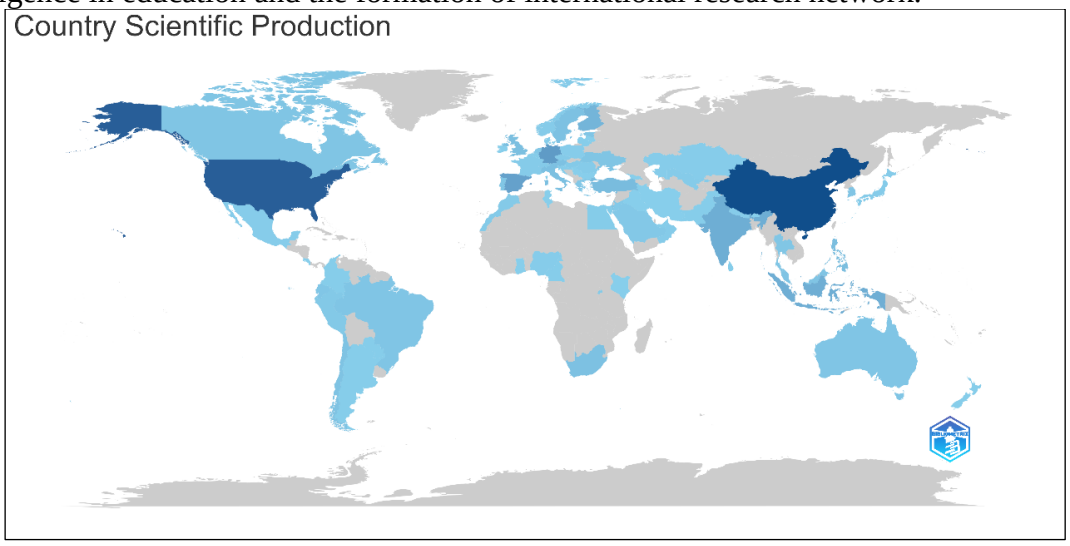

Fig. 4. Scientific production by country.

Following this study approach, figure 5 shows the institutions that have contributed the most to the topic under analysis. Central China Normal University leads the list with 25 publications, followed by Florida State University and South China Normal University, both with 19 publications each. In sum, these three entities constitute 11.58% of the total documents disclosed, which demonstrates their influence on scientific production related to this matter. Regarding the relevant institutions and authors, it can be stated that the presence of two Chinese universities in the top positions reaffirms China's supremacy in artificial intelligence research in the educational field.

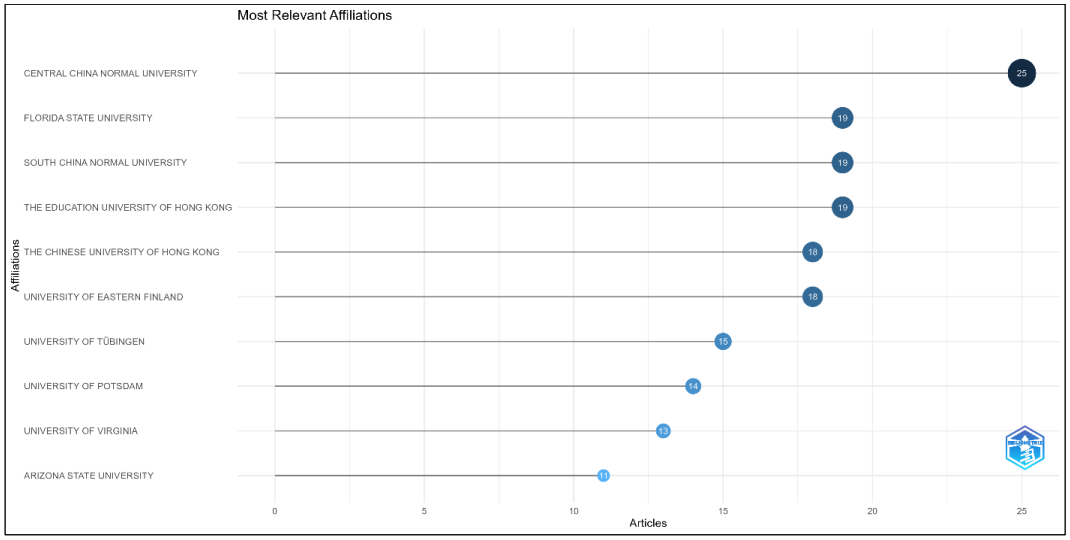

Fig. 5. Most relevant affiliations.

In another order of ideas, productivity per researcher is evaluated using the frequency index. As seen in Figure 6, CHIU TKF leads with 7 publications, followed by ROMEIKE R and SANUSI IT, who have contributed 5 publications each. These results highlight the influence of these researchers on scientific production within the topic of study; The influence of specific

authors who have focused their careers on this area of research is highlighted, establishing themselves as essential reference points.

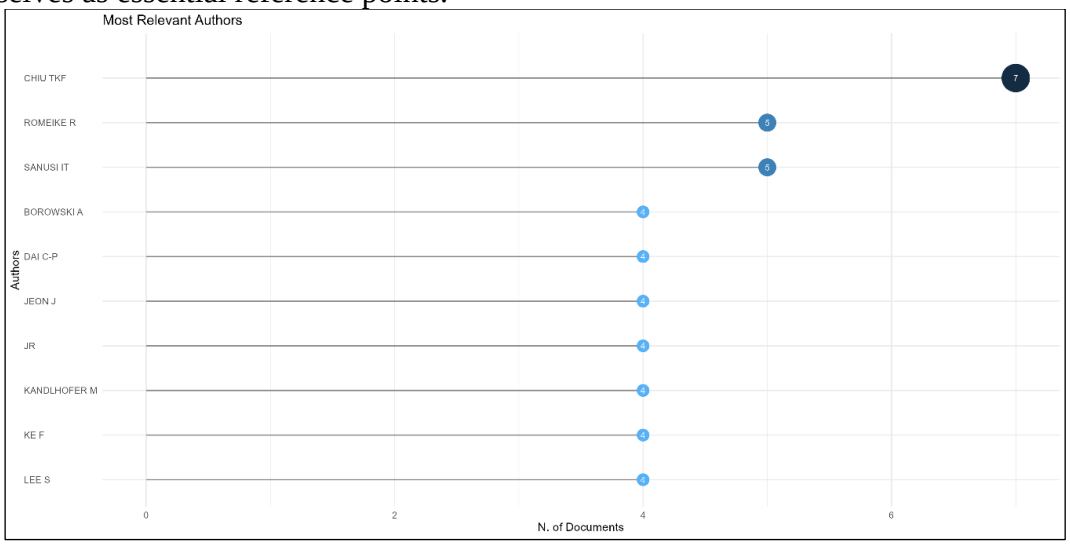

Fig. 6. Most relevant authors.

Finally, Table 6 shows the twenty articles related to the topic of study that have the most citations; The three most representative are: LUAN H, 2020, FRONT PSYCHOL, with 264 citations in total, in second place, CELIK I, 2022, TECHTRENDS, with 224 citations and finally CELIK I, 2023, COMPUT HUM BEHAV with a total of 195 citations. The study of the most mentioned articles makes it possible to recognize the articles with the greatest influence in the field of study.

The large number of references to these articles indicates that they have played a crucial role in the theoretical and methodological progress of the discipline. Furthermore, the existence of multiple recent publications with a high number of standardized citations suggests that the issue has gained importance in recent years, evidencing a growing interest in the use of artificial intelligence in the educational field, paying special attention to teacher training.

Table 6

Most cited articles.

Articles	Total Citations	TC per Year	Normalized TC
LUAN H, 2020, FRONT PSYCHOL	264	44.00	7.76
CELIK I, 2022, TECHTRENDS	224	56.00	10.28
CELIK I, 2023, COMPUT HUM BEHAV	195	65.00	16.16
CHIU TKF, 2020, SUSTAINABILITY	167	27.83	4.91
GONZÁLEZ-CALATAYUD V, 2021, APPL SCI	161	32.20	6.53
LUCAS M, 2021, COMPUT EDUC	156	31.20	6.32
NAZARETSKY T, 2022, BR J EDUC TECHNOL	149	37.25	6.84
CHIU TKF, 2022, IEEE TRANS EDUC	143	35.75	6.56
CHIU TKF, 2024, INTERACT LEARN ENVIRON	139	69.50	53.11

GOLDBERG P, 2021, EDUC PSYCHOL REV	129	25.80	5.23
IMRAN M, 2023, CONTEMP EDU TECH	119	39.67	9.86
SU J, 2022, COMPUT EDUC	103	25.75	4.73
MISHRA P, 2023, J DIGIT LEARN TEACH EDUC	94	31.33	7.79
VAN DEN BERG G, 2023, EDUC SCI	85	28.33	7.04
FLORES-VIVAR J-M, 2023, COMUNICAR	85	28.33	7.04
SALAS-PILCO SZ, 2022, EDUC SCI	81	20.25	3.72
VAZHAYIL A, 2019, PROC - IEEE INT CONF TECHNOL EDUC, T4E	79	11.29	2.89
ZHANG C, 2023, INT J EDUC TECHNOL HIGH EDUC	70	23.33	5.80
SANUSI IT, 2023, EDUC INF TECHNOL	68	22.67	5.64
WILSON RC, 2019, NAT COMMUN	68	9.71	2.48

3.3 Analysis of relationships and co-occurrences

Finally, the cluster study using VOS VIEWER shows the terms with the greatest impact grouped by co-occurrence. Figure 7 shows keywords such as “Artificial intelligence”, “Teacher education”, “Teacher training”, “Adversarial machine learning”, “Machine learning”, among others. The study of keywords through co-occurrence not only facilitates the identification of thematic trends in the area of study, but is also an essential instrument to understand the conceptual structure and the progression of knowledge in the field (Narong & Hallinger, 2023). From a theoretical point of view, this study is based on the assumption that the most common terms and the connections between them represent the main research approaches and the connections between different subfields.

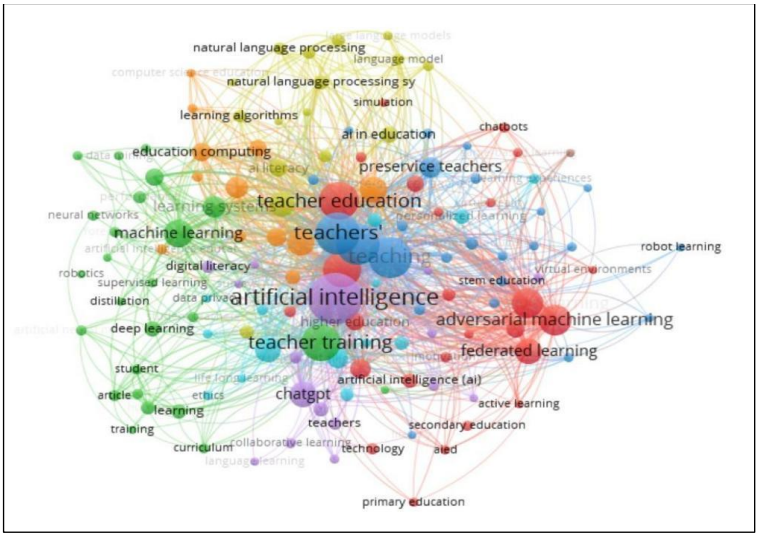

Fig. 7. Co-occurrence of keywords.

The existence of concepts such as "Artificial Intelligence" and "Machine Learning" suggests that artificial intelligence is a main core in the literature examined, while the incorporation of concepts such as "Teacher Education" and "Teacher Training" indicates an emphasis on the use of these technologies in teacher training. Additionally, the term “Adversarial Machine Learning” highlights the interest in the challenges and weaknesses of machine learning models, which indicates a growing line of research aimed at increasing the security and robustness of these systems. Therefore, co-occurrence analysis not only facilitates the current mapping of knowledge in the field, but also provides a foundation for detecting research gaps and future exploration routes.

4. Conclusions

The findings of the bibliometric study carried out demonstrate a rapid increase in academic interest in the use of artificial intelligence (AI) in teacher training, especially in the last three years. This exponential increase, with 78.04% in science production in recent years, indicates that Artificial Intelligence is establishing itself as an essential technology for innovation in the educational field. Furthermore, the volume of publications indicates that the COVID-19 pandemic could have functioned as a driver for the integration of digital technologies in education, fostering new interest in research in Artificial Intelligence and teacher training.

In terms of scientific productivity, the study based on Lotka's Law shows that the majority of writers have contributed a single article, while a small group of highly specialized researchers is promoting the constant progress of the discipline. This pattern indicates that, although research in Artificial Intelligence in teacher training is growing, it has not yet achieved total consolidation with a solid core of specialists who lead the creation of knowledge.

Furthermore, the implementation of the Bradford Law has facilitated the identification of the most relevant publication sources in this field. The fairly balanced distribution between the three areas of Bradford indicates that research in Artificial Intelligence and teacher training is not only concentrated in specific publications, but also spreads across works from different disciplines. This strengthens the interdisciplinary nature of the topic, which could promote closer cooperation between researchers from various disciplines.

In relation to the contributions of the research and future areas of study, this bibliometric analysis provides a complete perspective of the current state of studies on artificial intelligence in teacher education, facilitating the identification of evolution patterns, essential participants and the main ways of propagation of knowledge. The discoveries can serve as a starting point for future research that attempts to explore in depth the impact of Artificial Intelligence on teaching processes, as well as for the development of evidence-based educational policies.

Based on the results achieved, various routes for future studies are suggested. For example, research on how Artificial Intelligence tools affect the strengthening of pedagogical skills and the learning process of students. On the other hand, studies could be carried out focused on examining the obstacles and facilitators in the application of Artificial Intelligence in teacher training. On the other hand, it is proposed to explore how training programs for teachers can effectively integrate AI into their curricular schemes, in addition to analyzing regional variations in the adoption of AI in teacher education and its effect on educational equity. Finally, it is proposed to investigate the use of Artificial Intelligence to optimize evaluation systems for academic performance and student learning.

Artificial intelligence is dramatically revolutionizing teacher education and training, and the exponential increase in research in this field indicates continued and growing interest. However,

there is still much to investigate to more deeply understand the challenges and possibilities that this technology offers to future education.

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