

# Global Evolution of Research in Artificial Intelligence in Schooling: A Bibliometric Study

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## **Abstract:**

The application of Artificial Intelligence in Schooling (AIS) has extensive attention from scholars in recent decades. This study is intended to provide a global and historical picture of research concerning Artificial Intelligence in schooling. The 10029 papers were retrieved from the Web of Science TM (WOSTM) that were issued between 1985 and 2018. The descriptive analysis considered the collaboration of the papers, and authors and journals and countries. A global network of authors' keywords and content analysis of related scientific literature highlighted major techniques, including Virtual Reality (VR), Robotic, Artificial neural network, Artificial Intelligence (AI), Natural Language Processing (NLP). The number of expert systems related articles was the highest, followed by Intelligent Tutoring Systems (ITS), educational data mining, assessment and decision support systems. Moreover, there are few articles on evaluation of AI applications, which also hints at the direction of ai applications in the future. This study shows a comprehensive realistic picture of the research of Artificial Intelligence in schooling in the world, and suggests promoting a culture of data, and strengthening departmental/international cooperation, formulating relevant policies, so as to promote educational equity.

**Keywords:** *Bibliometric analysis; Artificial intelligence; Emerging technologies; Application; Science mapping.*

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## I. INTRODUCTION

Scholars have analyzed extensively on the benefits of AI applications in educational literature, stressing the role of artificial intelligence in promoting student learning [1]. With its Virtual Reality (VR) and machine learning capacity, AI have assisted teachers and educators in virtual teaching, predictive modeling, learning process surveillance and decision support in the domains of education information systems [2, 3, 4]. As artificial intelligence rapidly changes the teaching mode, learning method and evaluation mechanism of education, the number of studies on the application of artificial intelligence in the field of education is gradually increasing. It is necessary to make a comprehensive and detailed review of the research trend and hotspot of artificial intelligence application in education.

In the scholars thorough review article on teaching and studying, Katashi Nagao [5] give us a book about AI in education, a chapter is survey the literature on Artificial Intelligence in Education (AIE),

explain the advanced techniques(leaning analytics, deep learning and machine learning) and their applications(e-learning, ITS), and shows the challenges and breakthroughs in this field. Although this paper is one of the most recent attempts to elicit the use of educational AI at different stages, it has not yet mined the entire literature on AIE for some times. Therefore, in order to identify research gaps and promote clear and accurate translation of knowledge to better inform policy making, this study proposes the use of bibliometric analysis to explore research trends on ai topics in education.

Bibliometric analyze was a statistical method of books, articles, and other publications [6]. Bibliometric is the field of study which concerns itself with measuring and analyzing scientific literature. It uses databases of published literature as data sources to objectively assess the impact of research knowledge on educational issues. As the number of publications increases, the trends of related research topics and the network connections of researchers collaborating on different topics are reflected [7,8].

Bibliometrics are particularly useful, provide quantitative analysis in assessing global trends in scientific production and development, for example in educational research scientific production on mobile information literacy in higher education (2006–2017) [9],or effects of work environment and collaboration on research productivity in Vietnamese social sciences: evidence from 2008 to 2017 Scopus data [10],or road mapping towards sustainability proficiency in engineering education from 2013-2016[11], publication patterns and co-authorship in the Journal of Corporate Finance [12], Just a few examples. Through the review of AIS related research, this paper expounds the existing problems of the research trend core in this field, and puts forward the direction of future development. In brief, we review the research contents of artificial intelligence education and analyze the research patterns and trends in this field.

## II. DATA AND METHOD

### 2.1 Data Collection

Literatures was retrieved using a developed set of search terms from WOS<sup>TM</sup> from Thomson Reuters, focusing on (1) AI technology, and (2) schooling. We got the search terms based on prevailing literature on the topic, suggestions of AI experts' and discussions within our team. We defined synonyms for search terms and the differences between them.

Subject: "A" and "B".

A: "Artificial intelligence" OR "Deep learn\*" OR "Machine intelligence" OR "artificial neural network\*" OR "Machine learn\*" OR "Natural language process\*" OR "Robotic\*" OR "Agent" OR "data mining" OR "Virtual Reality".

B: educat\* OR Virtual Teaching OR intelligent robot OR MOOC OR online education OR Intelligent evaluation OR teaching game OR self-adaptive learn\* OR e-learn\* OR intelligent tutoring system OR expert system

Time: 1985-2018

Type: article

Language: English

## 2.2 Method of Analysis

VOSviewer software was a knowledge graph visualization software, and can use basic classification and clustering methods to help us get further information. a visualization software tool. These visualizing bibliometric networks may for instance include journals, researchers, or individual publications, and they can be constructed based on citation, bibliographic coupling, co-citation, or co-authorship relations[13]. VOSviewer collaborates important terms extracted from literature on the web through text mining.

A “Node” is a term. VOSviewer identify the record ID and label of a particular set of data beased on Node. In our study, the nodes are the article(s), author(s), and journal(s) and countries.

## III. RESULTS

### 3.1. The Publication Trend

There are 10,029 research results (9,067 Article and 959 reviews) were got from WOS<sup>TM</sup> published between 1991 and 2018. Do not include unmatched data (15,817research results), Fig.1.

Publication in 2019: 2;

Non-English articles:395;

Document types: 15420(Proceedings paper15104, Editorial material184, meeting abstract79, book chapter18, letter14, others21).

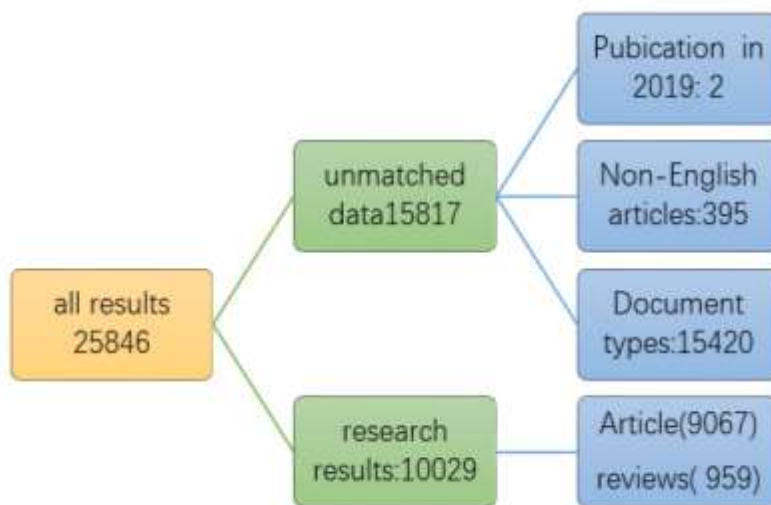


Fig 1: Selection of papers in the WOS™ database

Fig.2 is the visualization of annual change of the number of AI and AIS research in WOS™ in 1998-2018. It can be observed that AIS and AI have the same publishing trend. That is, the development of AI and its application research trend in the education field are consistent. But AIS research is relatively rare, accounting for 1.2% of AI in 1999 and 1.7% in 2018, with no significant growth.

The first paper related to “Artificial Intelligence in Education” of WOS was found in 1976[14]. The number of AIS publications has increased exponentially since 2005, and 76.9% of the papers were issued in 2008–2018. There are quantity of AIS surges upward dramatically in the amount of AIS research that happens around 2005-2006, 2016-2018 [15].

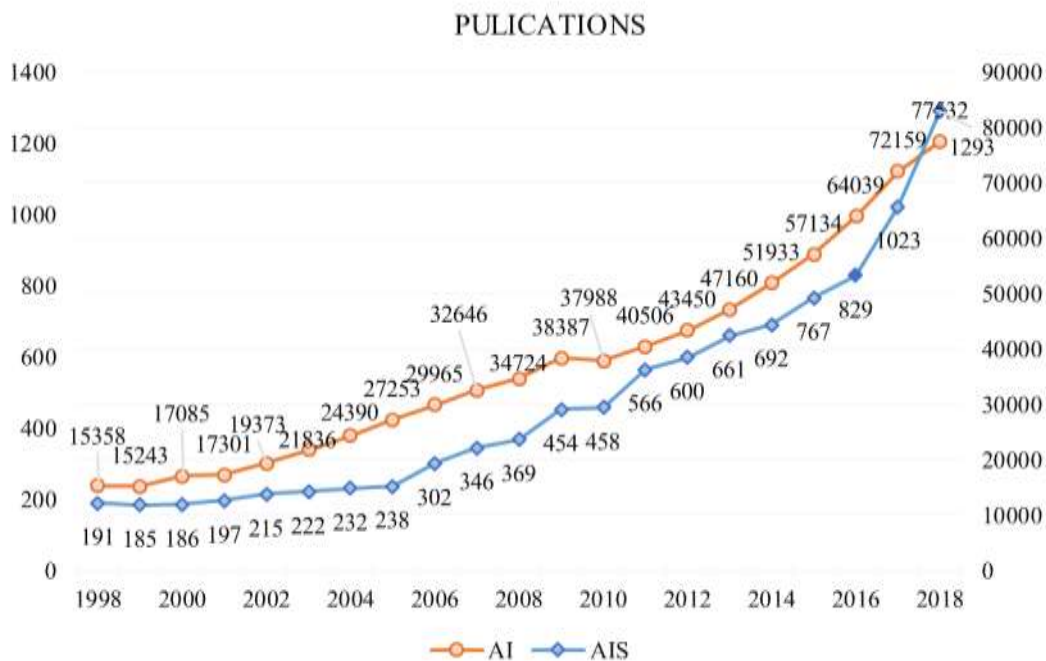


Fig 2: The publication of AI and AIS

76.7% of the papers were distributed over one (n = 4,205; 41.9%) or two (n = 3,487; 34.8%) subject categories, as shown in Table I.

TABLE I. Characteristics of subject categories

Number of subject categories	Number of publication	Percent
1	4205	41.9%
2	3487	34.8%
3	1870	18.6%
4	378	3.78%
5	83	0.83%
6	6	0.06%
>6	0	

2,555 journals published 10,029 research articles. “Expert systems with applications” (n=430; 4.29 %) was the most high-yield journal, deal with “Computer Science” or “Engineering” fields. Most literature of “COMPUTERS EDUCATION” (n=204; 2.04%) belongs to the field of “Computer Science” and “Education”. followed by Journal of SURGICAL ENDOSCOPY AND OTHER INTERVENTIONAL TECHNIQUES (n = 144; 1.44%), INTERNATIONAL JOURNAL OF ENGINEERING EDUCATION (n = 100; 1.00%), and Journal of COMPUTER APPLICATIONS IN ENGINEERING EDUCATION (n = 89; 0.89%). as shown in Table II. Among all topics, which was attracted the greatest concern in education, such as learn content, teaching methods, assessment [16].

**TABLE II. Characteristics of Journal**

	<b>Journal</b>	<b>Number</b>	<b>% of 10029</b>
<b>1</b>	EXPERT SYSTEMS WITH APPLICATIONS	430	4.29%
<b>2</b>	COMPUTERS EDUCATION	204	2.04%
<b>3</b>	SURGICAL ENDOSCOPY AND OTHER INTERVENTIONAL TECHNIQUES	144	1.44%
<b>4</b>	INTERNATIONAL JOURNAL OF ENGINEERING EDUCATION	100	1.00%
<b>5</b>	COMPUTER APPLICATIONS IN ENGINEERING EDUCATION	89	0.89%
<b>6</b>	JOURNAL OF SURGICAL EDUCATION	88	0.88%
<b>7</b>	ENGINEERING APPLICATIONS OF ARTIFICIAL INTELLIGENCE	73	0.73%
<b>8</b>	IEEE ACCESS	70	0.70%
<b>9</b>	IEEE TRANSACTIONS ON EDUCATION	68	0.68%
<b>10</b>	PLOS ONE	66	0.66%

### 3.2 Contribution by Author

55.9% (n = 5,601) of the papers were collaboration from two, three or four authors in Table III; 24.5% (n = 2,455) of the papers were published by two or three authors; 10.2% (n = 1,027) of the papers were published by seven or more authors and only 9.4% (n = 946) of literature were written by one author. The data show that much of the literature on AIS is co-authored. The teamwork refers to computer science,

education, management, psychology, statistics, specific disciplines, communication and so on. Research on AIS requires multidisciplinary connections among authors, which also illustrates the interdisciplinary nature of the field. The data showed that only 10.2% (n = 1027) of the papers had more than 7 authors. This suggests that having too many authors collaborate on international publications may not be effective; Two to four co-authors is the optimal number of team members.

**TABLE III. Characteristics of authors**

Number of authors	Number of publication	Number Percent
1	946	9.4%
2-4	5601	55.9%
5-7	2455	24.5%
>7	1027	10.2%

We visualized the global cooperation of authors whose collaborations exceed 5. The top three prolific authors are Kamran Ahmed (red cluster), Aggarwal R (orange cluster), and Lars Konge (cyan cluster). The largest set of connected authors consists of 69 in Fig. 3. Most of the prolific authors had strong collaborations with others and form a connecting center.

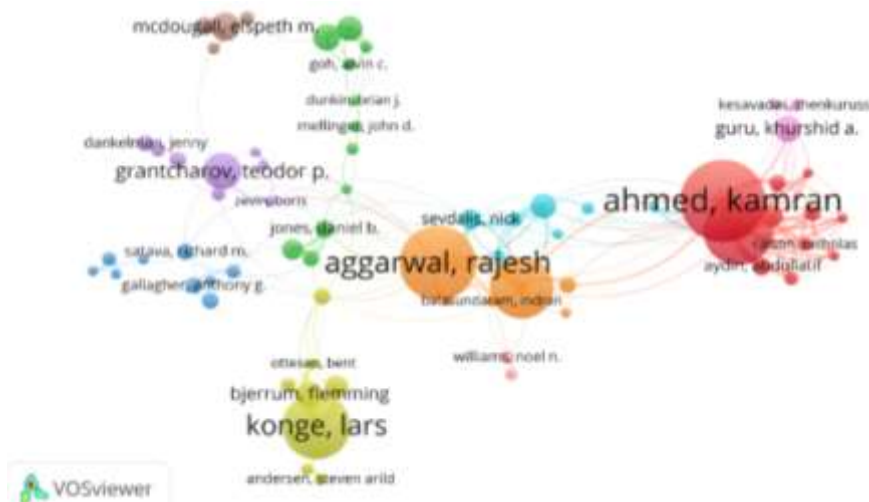


Fig 3: Characteristics of the prolific authors

At the same time, there are fewer papers by independent authors. The thickness of the lines indicates the strength of the relationship between the authors. The strength of these relationships was determined by the frequency of collaboration between authors. Their inclusion into different topic groups is based on their

clustering with specific term groups. Authors' position in the cluster represents the degree and frequency of their co-occurrence with other authors. This pattern has been confirmed by other bibliometric studies, as socially important and productive researchers tend to drive co-author productivity.

### 3.3 Collaboration by Country/Region

Table IV shows the productivity of AIS ranking of the top 10 countries/ regions in our dataset. In this table, the top three countries were USA, ENGLAND, PEOPLES R CHINA(CHINA). The country that produced the most papers was the USA (3,305 papers,33%), total citations (88,768 citations). The FRANCE at the top of Citations Per Paper (30%).

The main partners of the USA are Canada (161,11.2%), UK (129,9.0%), China (129,9.0%). The main partner of the ENGLAND are USA (129,13.2%), Germany (67,6.9%), Italy (67,6.9%). The main partner of the PEOPLES R CHINA are USA (129,27.8%) and Australia (45,9.7%) and the UK (37,8.0%).

**TABLE IV. Characteristics of country/region**

NO .	Country	Totalpapers	%Papers	Total Citations	Cite Rate	Cooperative Country	InternationalCollaboration
1	USA	3305	33.0%	88768	26.9	68	1439
2	ENGLAND	889	8.9%	26676	30.1	65	974
3	CHINA	810	8.1%	8777	10.8	51	464
4	SPAIN	650	6.5%	10486	16.1	57	449
5	CANADA	638	6.4%	20603	32.3	61	546
6	GERMANY	490	4.9%	16018	32.7	65	721
7	ITALY	418	4.2%	7794	18.6	62	632
8	AUSTRALIA	411	4.1%	12219	29.7	54	414
9	FRANCE	382	3.8%	14348	37.6	60	527
10	TAIWAN	376	3.7%	7315	19.5	32	135

After excluding countries with less than five papers. We got 82 countries/regions, visualizing the global cooperation in Fig.4. This chart shows international cooperation in the AIS field. USA (1439) has the most cooperation with other countries (68, 82.9%), including Canada, China, England, Germany. Take China as the highlight value of green, and Pakistan, Japan, Malaysia, Vietnam and South Korea cooperation meters



close. France, Italy and Germany as the highlight value of red, carry out extensive international cooperation.

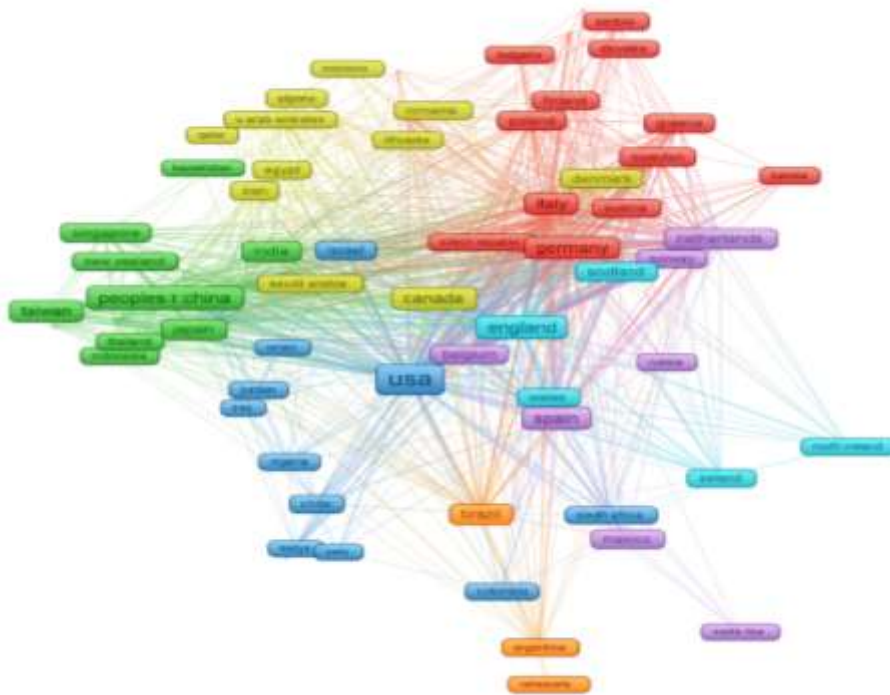


Fig 4: The global network of the 82 countries (at least five papers).

### 3.4 Collaboration by Journals/Source

All the articles were published in 2,555 journals in Fig. 5, This visualization also demonstrates the brighter the color, the more citations it gets. One is in the field of “expert systems with applications (8864, USA)” and “computers & education (8051, England)” as the core of AI technology and educational applications. The other it is distributed in “surgical endoscopy and other interventional techniques(4243,USA)” and “American journal of surgery(2296,USA), Critical care medicine(4458,USA).

### 3.5 Keyword and Text Analysis

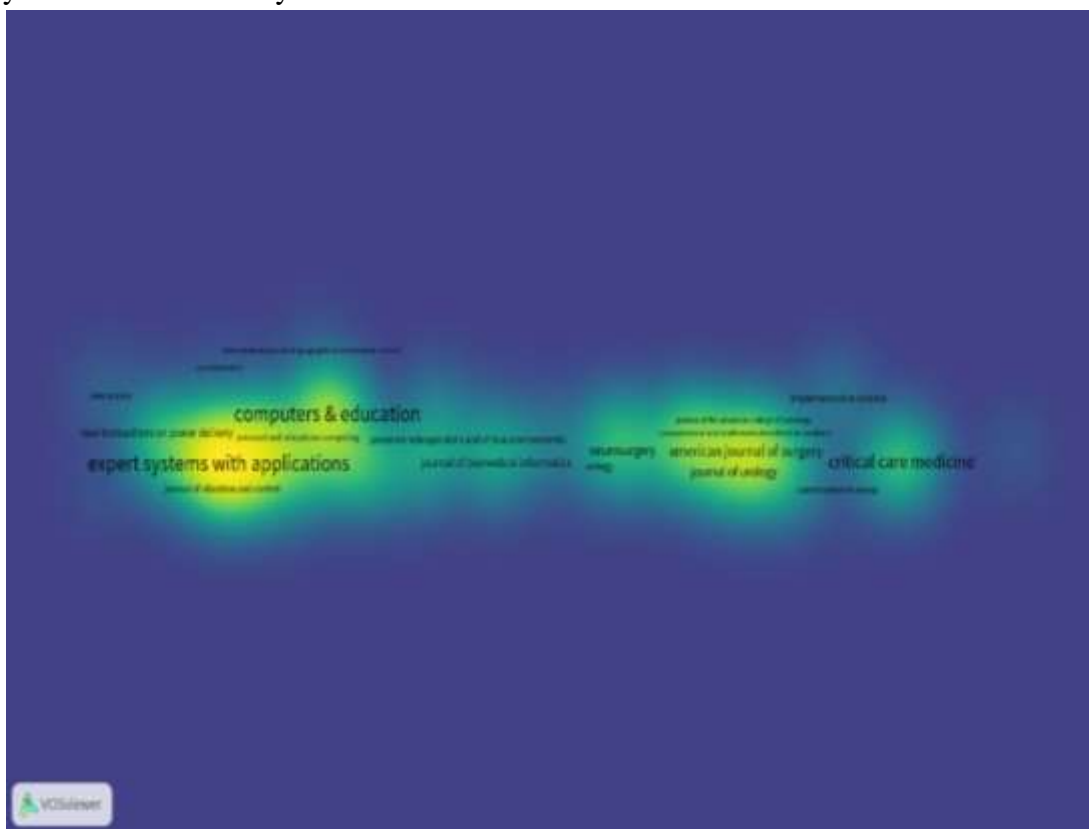


Fig 5: Density visualization of source

Delete the two key words of “artificial intelligence” and “education”, and select 555 keywords with clusters than 8 (see Fig. 6), divided the author’s keywords into two groups:

- (1) AI technology;
- (2) AI in schooling.

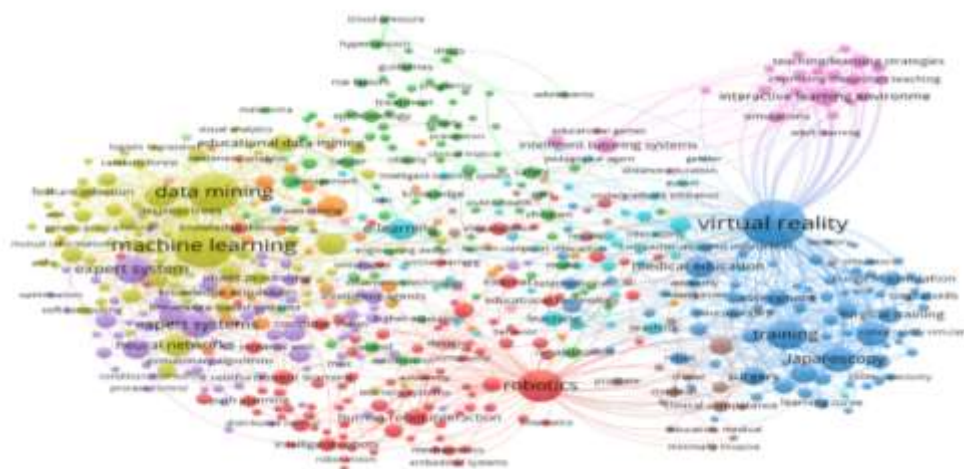


Fig 6: The co-occurrence of authors’ keywords

Types of AI: In the keyword of artificial intelligence technology class, appear most were Virtual Reality (occurrences: 676), “machine learning (403)”, data mining (436), “robotics (304)”, “deep learning (124)” and Natural Language Processing (122).

AI applications in education: For example, blue/pink represents “Virtual Reality (link:230, Total link strength:1077)” were used to support educational training (link strength :59,) and assessment (16), computer assisted instruction (8), interactive learning environments (54), teaching/learning strategies (19); distance education (3) and collaborative learning (4), medical education (21) and surgical (laparoscopy (40); dental education (16). Yellow represents “machine learning (241,770)” were used to support expert systems (link strength :42); Data mining (193,594) decision support systems (12), educational data mining (8), learning analytics (3); Red represents “robotics (184,449)” were used to support human-robot interaction (6), engineering education (5), Purple represents “Agent” and “big data” were used to support “e-learning”, expert systems, multi-agent systems. Orange represents “NLP (72,154)” were used to support text mining (6).

#### IV. CONCLUSIONS

This study is a comprehensive, visual and in-depth analysis of literature metrology using VOSviewer research on the global application of AIS.

AI technology is known as one of the cutting-edge science and technology that affect the development of today's society, which will have a profound impact on education[17]. In the past decade, due to the continuous growth of computing power and data storage capacity, the number of AIS literature has also increased rapidly, mainly from the United States, Europe and China. In this study, three players are also the biggest contributors who are attributed to the prolific output of research AI in education is United States, England and China (Fig. 4). Compare at the national level, this study proves that among the top 10 Cite Rate (Table IV), the number of citations per paper of China (10.8) is far below that of French (37.6), German (32.7), Canadian (32.3) researchers. China is relatively late to the game, which may be one reason. AIS papers are usually completed by 2 to 4 people and involve multiple disciplines, such as computer science, engineering, education, management, etc., which belong to interdisciplinary research.

Our research is showing that application of AI in education is (1). Self-adaptive learning (Virtual teaching, e-learning) AI provides technical assistance for self-adaptive learning, and gives students more freedom from space location, learning time and learning resources. The application of information technology AI in teaching enables teachers to better design personalized study plans for student according to their interests or hobbies. This will promote a variety of courses and learning styles and increase students' choice opportunities (2). Intelligent Tutoring system (or expert system) An intelligent tutoring system is a computer system that tutors students in some domain of study. A tutoring system interacts with a student, providing information about some domain and giving tests of the student's knowledge or performance. (3) Intelligent evaluation. Students can obtain learning resources through relevant software to realize the diversification of learning forms, and learn what they interest with the help of AI. As they learn

at their own pace using these specialized programs, their ability to correctly answer practice questions will be monitored. The time required for each question and the accuracy of the answer are recorded to form a progress report for the student. In conclusion, AI tools have been applied to many aspects of the educational process, including content development, resource sharing, assisted instruction, student evaluation of campus management, and communication between teachers and students. AI will collect students' learning process data for intelligent evaluation.

Compared with other application fields of AI, its application development in the field of education is relatively slow, mainly due to its specific characteristics of education, less international cooperation and lack of high-quality papers. It can be traced back to the lack of professional talents who is good at both education and AI, the lack of large-scale educational datasets, there are isolated islands of data, each system has its own data, but the data is not integrated, and the lack of relevant policy support.

Based on the above analysis, this study puts forward four suggestions: First strengthens the training and deep cooperation of teachers and technicians under the background of AI. Teachers play a very important role in the application of AIS. The application degree of AI technology in the field of education is inseparable from teachers' understanding of AI technology; Second, recommending ai for educational applications requires the collaboration of school stakeholders, including schools, the public and private sectors, to improve product research and development for AI applications in schooling. Most countries are still in the early stages of theoretical or practical exploration, practical exploration on the application of AI in the field of education. The birth of educational robot and intelligent tutoring system will promote the development of intelligent education; Third, developing countries should actively increase their investment in AIS research. China and India, in particular, are emerging as leaders in this field. Finally, in order to promote the integration of ARTIFICIAL intelligence technology and education and accelerate the application of ARTIFICIAL intelligence in the field of education, it is necessary to formulate relevant protocol planning or regulations to protect the security of educational data. (e.g. Artificial Intelligence Education Blue Book 2022 in China, AI Technology Strategy” industrial strategy: artificial intelligence industrial policy higher education artificial intelligence innovation action plan, Spanish artificial intelligence research development and innovation strategy.

There are some limitations in this study: in the language of literature selection, non-English articles are excluded, which is not objective for the analysis of some publications from non-English speaking countries. Only papers and reviews were analyzed in detail, and other publications, such as books, ai policies, and peer-reviewed publications, were not included. Of course, the adoption of keyword clustering, author coupling and keyword density visualization for a large number of publications has helped to promote the objectivity and comprehensiveness of the research.

Through bibliometrics analysis of 20 years of domestic and foreign literature, this study shows the development process and research field of artificial intelligence education application in a visual way, which is of great help to the technology developers and front-line teachers of artificial intelligence education application research. It can be expected that there will be more and more researches on the

application of AI in the field of education in the future, and its application scope will be broader and deeper. This article will lay a foundation for future researches. In short, with the increasingly mature concept, technology, teachers and policies of ARTIFICIAL intelligence, the research on the theory and application of artificial intelligence in the field of education will become an important topic and development trend in the new era, and the application of artificial intelligence in the field of education will be more and more extensive and in-depth in the future. We look forward to seeing how these technologies empower learners everywhere, promote educational equality, and provide rich, immersive interactive experiences for people of all ages and at all times.

### ACKNOWLEDGEMENTS

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