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Bibliometrics Analysis of AI Integration in Mathematics Teaching

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Abstrak

Studi literatur ini bertujuan untuk menganalisis tren penelitian dengan menggunakan analisis bibliometrik yang terkait dengan Kecerdasan Buatan (AI) dalam pengajaran matematika. Pentingnya AI dalam pengajaran matematika tidak sesuai dengan banyaknya penelitian tentang hal tersebut. Sehingga penelitian ini disusun dengan tujuan untuk mengidentifikasi penelitian berkaitan dengan integrasi AI dalam pengajaran matematika selama 10 tahun terakhir. Kata kunci yang digunakan untuk mengumpulkan artikel adalah "artificial intelligence" dan "mathematics teaching" dan diperoleh 460 dokumen di database scopus. Penelitian ini dilakukan dengan membatasi jumlah dokumen tergantung pada tahun, bahasa, dan jenis artikel. Batas tahun pada tahun 2014 hingga 2024, bahasa dibatasi hanya bahasa Inggris, dan dokumen dibatasi hanya pada jenis artikel. Jumlah dokumen dalam dekade terakhir meningkat dari 6 dokumen menjadi 26 dokumen. Zhongda Sun, yang berkecimpung dalam kecerdasan komputer, adalah penulis yang paling banyak dikutip. Negara paling produktif adalah Tiongkok yang menyalip jumlah publikasi Australia pada tahun 2021. Kecerdasan buatan dalam pengajaran matematika populer dalam ilmu sosial dan ilmu komputer dengan topik yang paling populer adalah siswa, kecerdasan buatan, dan guru.

Kata Kunci: Kecerdasan Buatan; Pengajaran Matematika; Bibliometrik.

Abstract

This literature study aims to analyze research trends by using bibliometrics analysis that related to Artificial Intelligence (AI) in mathematics teaching. The impact of AI in mathematics teaching did not match to the number of mathematics teaching research. So, this bibliometric study conducted in order to identify AI integration in mathematics teaching in last decade. Article gathered by two keywords, which are "artificial intelligence" and "mathematics teaching"and found 460 documents in scopus database. This study conducted by limiting the number of documents depend on years, language, and article type. The years limit in 2014 to 2024, languages limit to english only, and the documents limit to article type only. The number of documents in the last decade is increasing from 6 documents into 26 documents. Zhongda Sun, that concern in computer intelligence, is the most cited author. The most productive country was China that overtake Australia's number of publications in 2021. Artificial intelligence in mathematics teaching was popular in social science and computer science and the most popular topics are students, artificial intelligence, and teacher.

Keywords: Artificial Intelligence; Mathematics Teaching; Bibliometrics.

I. INTRODUCTION

Over last fifty years, artificial intelligence (AI) has driven a variety of technologies that generate machines to do things that according to human intelligence, such as observe, reason, learn, and interact (Almasri, 2024). AI took important role social and educational environment, and anyone with access to the Internet can use it. Some experts state that by 2023, AI will be the initiator of major changes that will have a major impact on teaching and learning methods. AI has transformative potential in education, which requires deception (Vintere et al., 2024).

Human computer interaction (HCI) is examined in designing and developing of interfaces that allow humans and computers interaction. AI ability to process large amounts of data and complex tasks in a few seconds correctly was The most significant impacts to human life (Chen & Chang, 2024). Development of research on artificial intelligence in education (AIED) was increase rapidly in recent years. Understanding these research trends and advances is critical to innovation and the application of technology in education. There are many applications of AI in education, and research has shown the true effects and benefits of this technology. Students are allowed to personalized and get instant feedback on their learning performance with AI-powered tools. Students experience learning according to their unique characteristics (Guo et al., 2024).

Teaching and learning process that has been supported by AI will becoming new trend in current development (Widyatama & Pratama, 2022; Saputro et al., 2024). With the rapid development of technology, society has entered a new era of intelligence (Dewi & Afriansyah, 2022; Warsito et al., 2023). The aim of assisting teaching and learning with AI is to lead deep educational reform and construct a new interconnected paradigm, unify theory and practice, and make education more flexible (Yang, 2024). Learning, teaching, assessment, and administration processes have all benefited from the widespread usage of technologies developed by the artificial intelligence in education (AIED) group. Skills, comprehension, engagement, test scores, course grades, and associated outcomes have all increased as a result of our approach (Ocumpaugh et al., 2024).

DigComp (2022) modifying its framework to accept AI technology to help teachers proposes six categories to improve (1) professional interactions with various parties using AI, (2) educators' pedagogical capabilities including digital resource management, (3) teaching and learning, (4) assessment, and (5) teaching strategies that encourage students to use AI, and (6) enable students to learn to use AI. This framework helps educators, researchers, and governments design appropriate learning strategies and programs to prepare students to become digitally competent in AI knowledge, skills, and attitudes. Additionally, this facilitates comprehension and application of AI literacy instruction (Vuorikari et al., 2022). Based on the COACTIV model, (Sun et al., 2023) it describes three components of artificial intelligence teaching ability that are closely related to the way teachers teach artificial intelligence: knowledge, skills, beliefs (self-efficacy).

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AI can also supply symbolic formulas for particular data sets. To create a symbolic formulation that corresponds to the data, predefined symbols are combined with algorithms, utility, and cost functions. This general approach uses a combination of these. Many times, combining multiple symbols is a difficult problem to solve. Therefore, the researchers came up with an innovative solution to help the algorithm in exploring various hypotheses. There are many subareas within the large field of mathematics. For the purpose of simplicity, we should assume that these activities are associated with symbols and ideas through established norms. It involves deduction, induction, abduction, creativity, intuition, patterns, axioms, theorems, proofs, logic, and communicating with other mathematicians (Alonso-Diaz, 2024).

Research on bibliometrics conducted by (Hwang & Tu, 2021) According to research findings, a number of factors related to artificial intelligence (AI) in mathematics education research are taken into account by using technology-based learning models. These factors include application domains, participants, techniques, adopted technologies, issues, the function of AI, and citation and co-citation relationships. Thus, advances in AI in mathematics education research are discussed, and possible research topics for future study are suggested. Research was also carried out by (Guo et al., 2024) At AIED, research primarily leverages machine learning, decision tree, deep learning, speech recognition and computer vision technologies. Educational robots, automated assessments, recommender systems, learning analytics, and intelligent tutoring systems are some of the major applications of AI .

Bibliometrics review research tend to find top-cited articles, most productive country and keyword trends (Prahani et al., 2024). That research present the last 20 years of researches that conducted creativity scientific litterature. In the other hand, other research present bibliometrics study on the use of eye movement technology in education (Suprapto et al., 2024). In methematics education, there is bibliometrics study that discussing artificial intelligence (Hwang & Tu, 2021). The limitation of that study doesn't concern on implementation and integration in teaching mathematics using AI.

The impact of AI in human activity (especially in mathematics teaching) did not match to the number of mathematics teaching research. The number of mathematics teaching research involving AI should be increased. Depite of this constraint, Bibliometrics study in the last 20 years did not map artificial intelligence with mathematics teaching. Therefore, this study uses bibliometric analysis to visualize and map the research profile and emerging trends in artificial intelligence-based mathematics teaching.

The aim of this research is to provide valuable insights for researchers, educational institutions, teachers, and librarians regarding future research trajectories in artificial intelligence-based mathematics teaching. They can use these research findings to inform their research agenda and aid continued progress in the

field. Additionally, policymakers can use the results of this research to make decisions that encourage and support research into artificial intelligence-based mathematics teaching, as they will have a better understanding of the research that has been conducted on this topic so they can continue to improve their knowledge. The research questions are listed below:

1. The number of publications on AI integration in mathematics teaching in the last ten years,
2. The most cited AI integration in mathematics teaching researcher in the last ten years,
3. The country with the highest AI integration in mathematics teaching publication in the last ten years,
4. The trend of publishing articles on AI integration in mathematics teaching in the last ten years.

II. METHOD

This research was conducted using a literature study method and analyzed using a bibliometric approach. Using bibliometric methodology, this research discovered and mapped research trends in the field of artificial intelligence-based mathematics teaching. Scopus, one of the largest curated databases for citations and abstracts, is the best for conducting bibliometric research because it can provide information about titles, authors, abstracts, keywords and references of scientific publications. It boasts extensive coverage of global and regional books, conferences and scientific journals (Prahani et al., 2024). The keywords used in this research are: "(TITLE-ABS-KEY (mathematics AND teaching) AND TITLE-ABS-KEY (artificial AND intelligence)) AND PUBYEAR > 2013 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE ," ar")) AND (LIMIT-TO (LANGUAGE , "English"))". Data collection was carried out on the 20th July 202 4 which covers a full year.

The data used for this bibliometric network analysis were collected from the leading scientific database Scopus, which is renowned for having extensive coverage of scientific literature across various disciplines. A comprehensive set of keywords was used for searches in the field of artificial intelligence-based mathematics teaching, keyword selection to find relevant publications. Then, the files are analyzed descriptively according to the research questions. To visualize the data, bibliometrics B software was used. Quantitative descriptive analysis was carried out to determine main information, source titles, top countries, and affiliations in artificial intelligence-based mathematics teaching research. An overview of the article selection process is depicted in Figure 1.

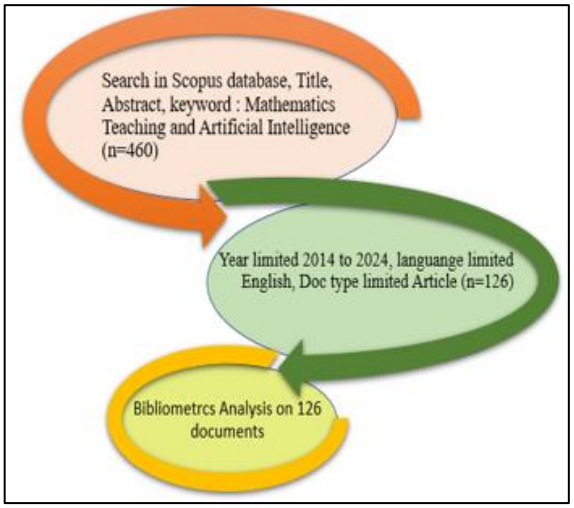

Figure 1. Articles Selection Process

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III. RESULT AND DISCUSSION

The last ten years publication involving artificial intelligence in mathematics teaching had several types of documents. The variation of publication types has shown in Figure 2.

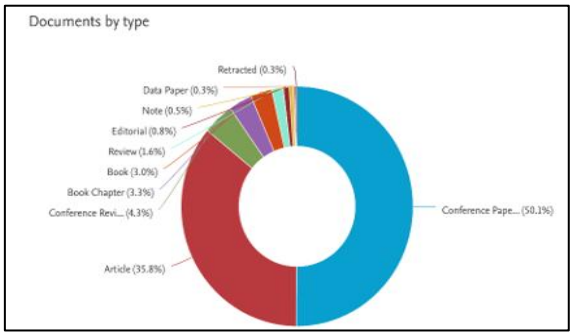

Figure 2. Percentage Documents by Type

The Most type of publication documents is Conference paper and it's followed by article. So, the results of this research are limited to article type of publication.

A. The Year Distribution of Artificial Intelligence In Mathematics Teaching

Look at Figure 3 below.

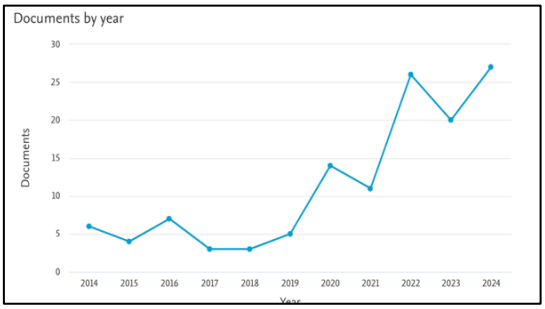

Figure 3. Documents Overtime During 2014-2024

Base on Figure 3, the year distribution of Artificial intelligence in mathematics teaching documents is fluctuated between 2014 until 2017. The number of documents increased gradually in 2017 to 2020. In 2020 to 2024, it had extremely fluctuation. Figure 3 show that the number of documents decreased in 2020 to 2021 but it increased significantly in 2021 to 2024. Generally, the number of documents in the last decade is increasing from 6 documents into 26 documents.

Phase of artificial intelligence in mathematics teaching during 2014 to 2020 is fluctuated and increase significantly during 2021 until nowadays. In 2014, research on artificial intelligence in mathematics teaching has been started by implementation AI in higher education course (Cabada et al., 2014). It means that, there are several researches about AI integration in mathematics teaching but the researches didn't scope in higher education. So, this state that development of this topic is constrained to higher education. This condition is supported by other research that state technology integration in mathematics education has limitation especially in 2016 (Borba et al., 2016). Publication on this topic start to increase significantly during 2020 to 2024. The needs, of technology in education During 2020 to 2024, were supported by pandemic situation. COVID-19 Pandemic forces technology in education to be implemented. Solution of this revolution era was AI integration on education, especially on mathematics education (Shin, 2020). In addition, the effectiveness of AI implementation in education was positive (Zheng et al., 2023).

B. Author Production and Top Cited in Artificial Intelligence in Mathematics Teaching Documents

Look at Figure 4.

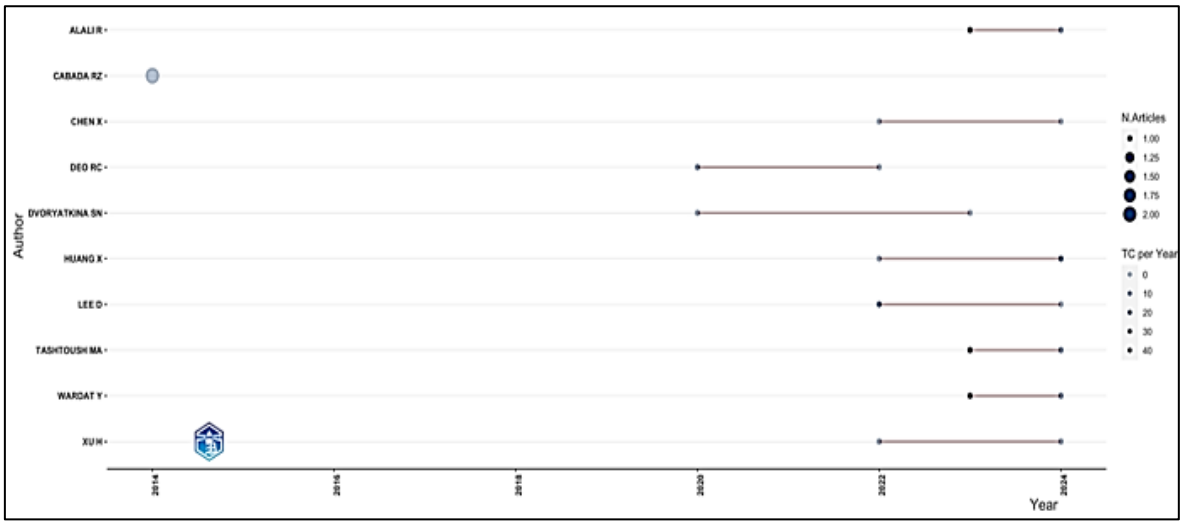

Figure 4. Authors Overtime Productions

Based on Figure 4, the number of publications for every top ten authors doesn't exceed two documents during time period. This top 10 is ranked Alphabetically. Cabada Published two documents in 2014 and no publication after 2014. Some authors published in two consecutive years for example Alali published an article in 2023 and the other one in 2024. However, there are authors that published two documents in inconsecutive years, namely Chen. Despite of Cabada two publication in a year, Cabada's Total Citations is less than 20 citation. This number is less than Wardat's Total Citation that greater than 20 citation, even though Wardat has less documents during time period.

In the other hand, the number of citations based on the document can be seen in Figure 5.

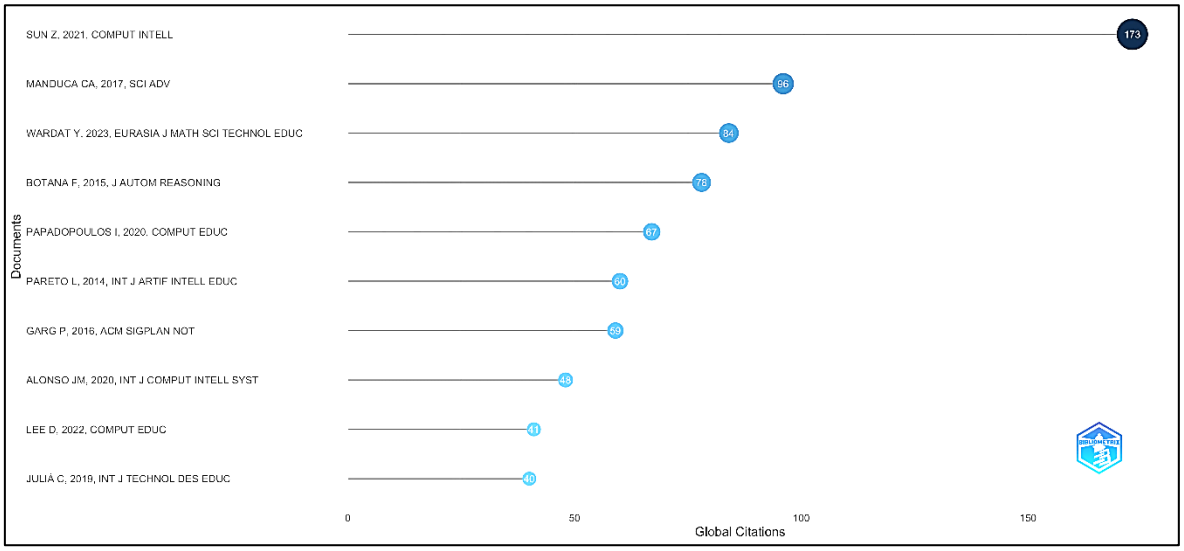

Figure 5. Top 10 Documents Citations

Sun (2021) publication had the most cited documents and followed by Manduca (2017) and Wardat's publications during time period. The highest number of citations is 174 and the lower number of citations is 20 during time period.

Cabada has 2 publication in 2014. Cabada start publication of artificial

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intelligence in mathematics teaching by using intelligence tutoring system terminology that refers to Artificial Intelligence (Cabada et al., 2014). Cabada developed this research by join to other researcher. The research use Artificial Intelligence in natural number teaching (Barrón Estrada et al., 2014). Several researchers also have two publications, even though in inconsecutive years. Wardat's document in 2023 showed that artificial intelligence was golden tool to teach mathematics in this case Wardat uses ChatGPT application (Wardat et al., 2023). In the other hand, this technology was new invention and, in its implementation, faced several challenges. Wardat's descriptive research in 2024 tried to describe the challenges due to teacher perspective (Wardat et al., 2024). Wardat's documents has less number of citations than Sun's documents. In this Case, Wardat's documents tend to mathematics education so their relatively exclusive. In the other hand, Sun's document tend to general work of artificial intelligence.

C. Country Production In Artificial Intelligence In Mathematics Teaching

Figure 6 Show country production over time in 2014 until 2024. Australia was dominating publication in Artificial Intelligence in mathematics teaching until 2021. The number of China publication increment was started in 2020 and it overtook the number of Australia publication in 2021. In the end of the day, China is dominating in publication.

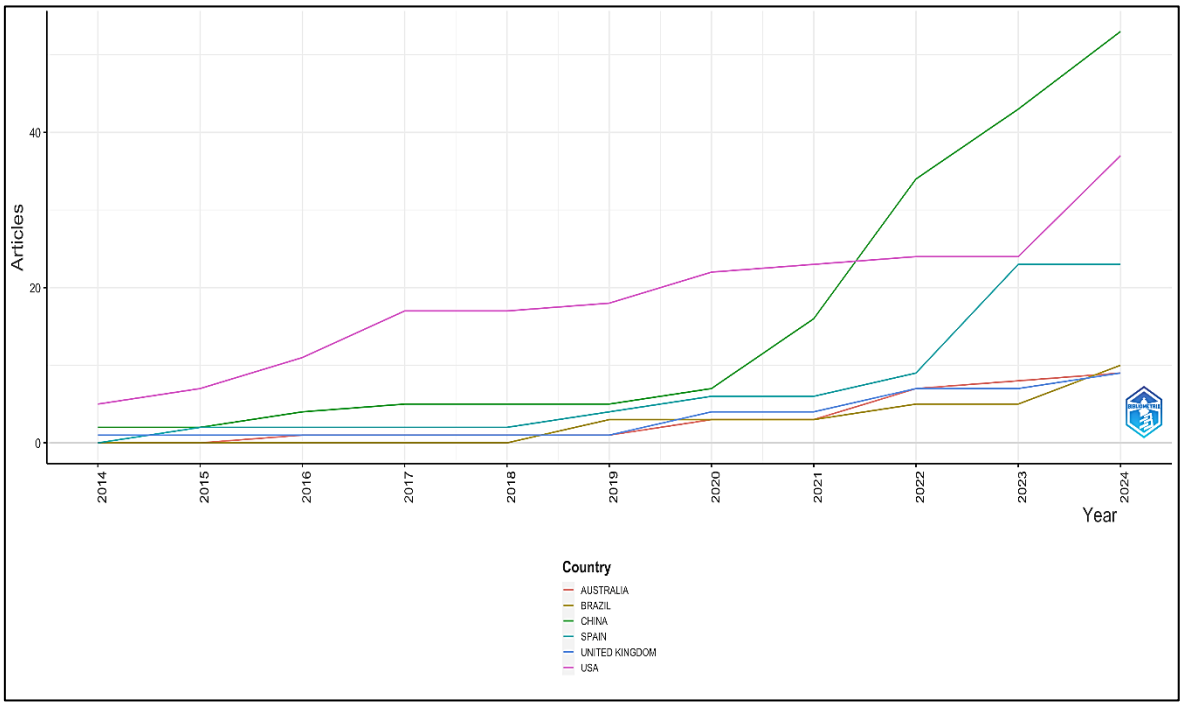

Figure 6. Country Production Overtime

Figure 7 describes accumulation of every country publication numbers during time period. The number of China publication is dominating the others. Spain, USA, and Australia are following China. There is no country that have number of

author collaboration across country greater than ten publication. There is some country that don't have author collaboration across country, which are USA, Brazil, India, Saudi Arabia, Italy, Norway, Slovenia, Sweden, and Armenia.

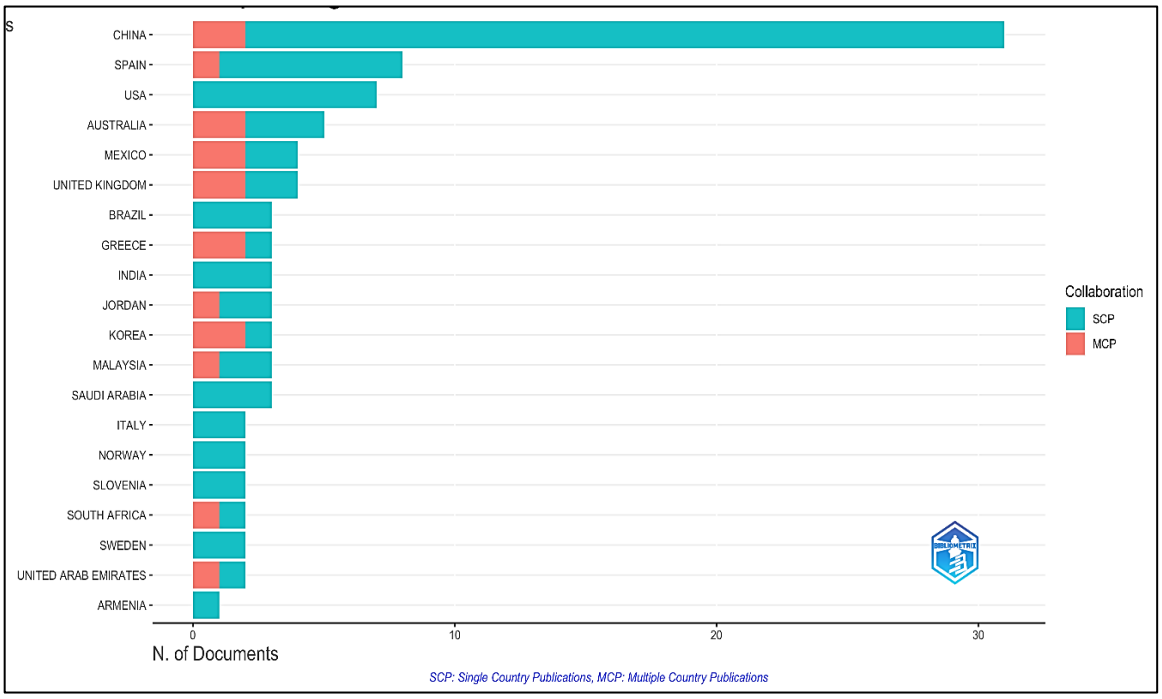

Figure 7. The Author Publication For Every Country

However, Figure 7 describes the number of author's countries that is dominated by China and it's followed by Spain, USA, and Australia. Australia was in fourth rank even though it was dominating during 2014 until 2024. Thus, we can conclude that china has been dominating the number of research documents production in Artificial Intelligence in mathematics Teaching.

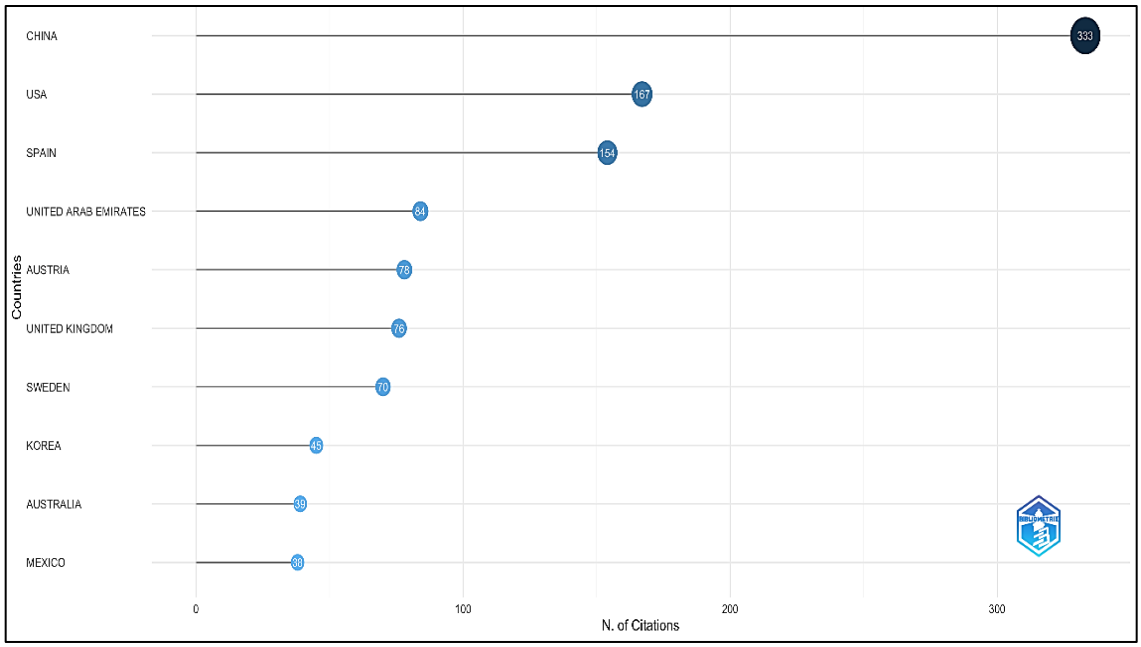

Figure 8. Citation for Every Country

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However, Figure 8 describes the number of author's countries that is dominated by China and it's followed by Spain, USA, and Australia. Australia was in fourth rank even though it was dominating during 2014 until 2024. Thus, we can conclude that china has been dominating the number of research documents production in Artificial Intelligence in mathematics Teaching.

Due to the phases of artificial intelligence in mathematics teaching, There are two main phase which are 2014 to 2020 and 2021 to 2024. During 2014 to 2020, Australia leads in number of publication and it's followed by China. During 2021 to 2024, China overtakes Australia position. China overtaking was supported by Covid-19 pandemic. As well known, the disease began to occur in China 2019. In 2020, China fight back by applying lockdown (Xu et al., 2020). This condition forces China to invent innovation especially in mathematics education (Tarkar, 2020). Artificial intelligence was one of the inventions. This imply the number of researches in artificial intelligence in mathematics education significantly increase.

D. The Trend of Publishing Articles in AI Integration in Mathematics Teaching

Trend of publishing will be described by two interpretation which are documents by subject area and research topics. Figure 9 describes the percentage of documents subject area during time period and Figure 10 describes frequency overtime of topics during time period.

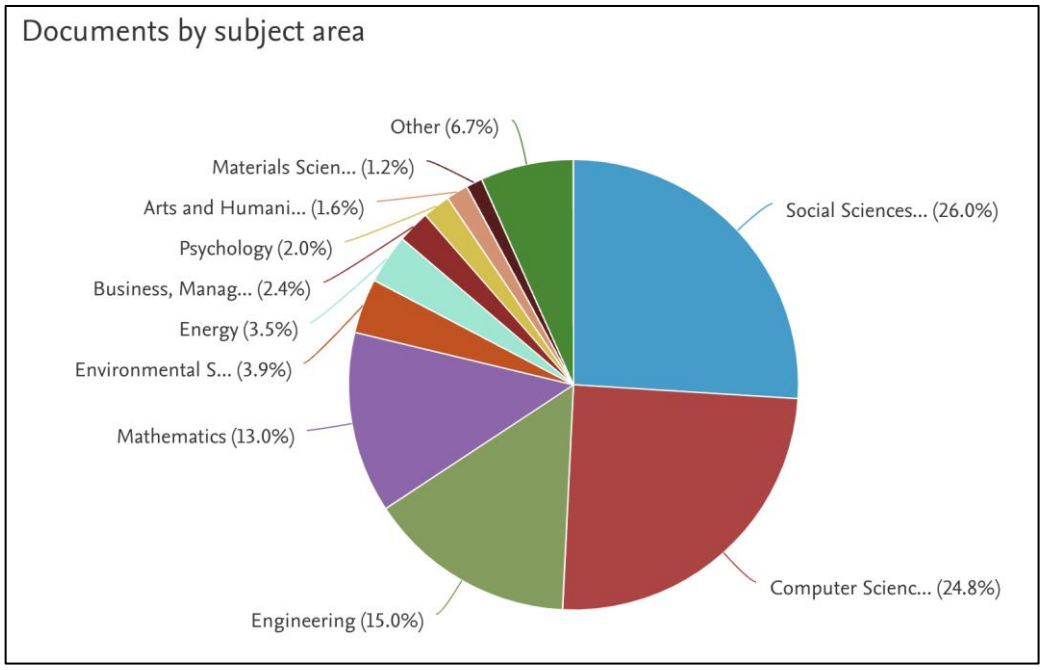

Figure 9. Subject Area Percentage

Figure 9 shows that artificial intelligence in mathematics teaching was popular in social science and computer science. Mathematics and engineering follow them by collect 13 percent and 15 percent documents from the whole. The other subjects are following by collecting

percentage under 4 percent during time period.

Figure 10 shows that there are top 16 trends topics in artificial intelligence in mathematics teaching. Neural networks topic exists consistently during 2014 until 2022. Even though the topic was consistently existing but the topic doesn't exist during 2023 until 2024 and the number of documents in this topic is less than 20 documents. Students, Teaching, and Artificial intelligence are topics with the number of documents greater than 30 documents.

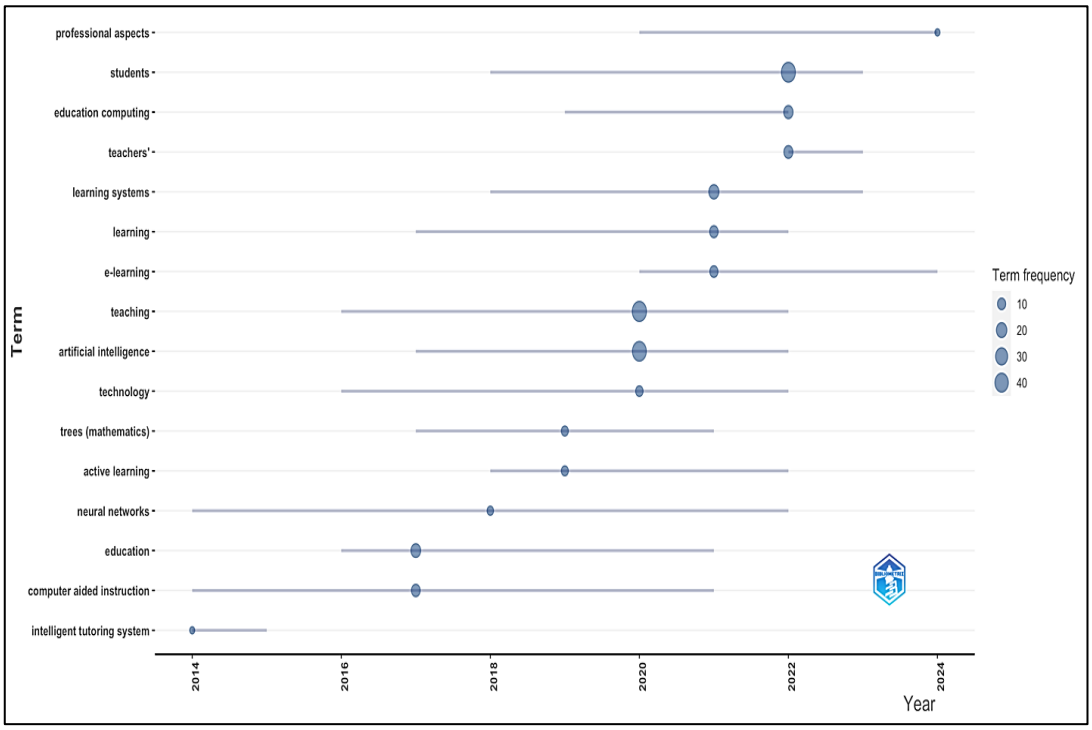

Figure 10. Trend Topic During Time Period

Subject area of artificial intelligence in mathematics educations is dominated by computer science and social science. Some of computer science area documents are discussing about how AI become effective to interact with human. In other hand, social science subject area discussing about application of AI in learning (Zhai et al., 2021). Publication trend depends on research topic are dominated by "Students", "Teaching", and "Artificial Intelligence". Wardat, et al (2024) described how artificial intelligence work in mathematics teaching. This also confirmed that in latest year artificial intelligence and teaching still in trend. Study about "Students", "Teaching", and "Artificial Intelligence" can be seen in development of artificial intelligence to teach students undergraduate (Deo et al., 2020).

IV. CONCLUSION

Several documents were collected from Scopus database and analysed by Bibliometrix software. Based on Result and discussion, there are several conclusions due to research objectives. First, the number of documents in the last decade is increasing from 6 documents during 2014 into 26 documents during 2024. Second, the most cited author is Zhongda Sun that

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concern in computer intelligence. Third, the most productive country was China that overtake Australia's number of publications in 2021. Last, artificial intelligence in mathematics teaching was popular in social science and computer science and the most popular topics are students, artificial intelligence, and teacher. According to results, research might be developed into systematic literature review about AI integration in mathematics teaching articles. This study explains the identification of research in AI integration in mathematics teaching domain.

This study excludes to article documents only. Different possible interpretation might be occurred if the study includes the other documents types. In other hand, researcher may develop AI integration in mathematics teaching by results of this research.

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