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The Adventure of Artificial Intelligence Technology in Education: Comprehensive Scientific Mapping Analysis

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It is known that recent studies on artificial intelligence technologies have been handled by different branches of science. One of the mentioned branches of science is education. The rapid increase in the production of artificial intelligence studies in the field of education in recent years attracts the attention of researchers. In this context, the purpose of the present study was to analyze the bibliometric aspects of journal publications on artificial intelligence technology in educational research. The R-Studio tool was used to examine the data set, which was collected from the Web of Science database. The only index fields allowed for articles are SSCI, SCI-Expanded, and ESCI. According to the results of the study, the journal articles on artificial intelligence technologies have appeared to have significantly increased in recent years. The United States, China, and Spain are the most prolific nations in this regard. Despite being among the ten most productive nations, Türkiye and Russia are among those that do not collaborate internationally. It has been found that journal articles on artificial intelligence give a lot of attention to subjects like dropout, chatbot, language learning, student involvement and performance, e-learning, and collaborative learning. We hope that this research will give academics who desire to study artificial intelligence technologies a general overview.

Introduction

The impulse for creating artificial beings in human dates back to Greek mythology, and it is mentioned that Hephaestus, the son of Hera, Zeus' wife, and queen of the gods, regularly created humanoid creatures in her own iron forge (Khemani, 2013). This can be considered as a sign of the contemporary pursuit of artificial intelligence. In addition, the fact that a famous French economist mentioned in 1828 that "no machine could replace even the worst horses in transportation" (Makridakis, 2017) indicates that the credibility of this issue

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cannot be easily accepted. However, according to Edward Fredkin, who has a routine in his studies in the global natural and artificial intelligence field, this situation is not as the economist of the 19th century thought. According to him; "There are three great mysteries in history. The first is the formation of the universe, the second is the beginning of life, and the third is the emergence of artificial intelligence" (Arslan, 2020).

The emergence of artificial intelligence, which dates back to the fourth century B.C when Aristotle invented the concept of formal logic (Huawei Technologies Co., Ltd., 2021), has overturned previously unimaginable ideas, but there is still no consensus among philosophers since Aristotle on what it actually is (Duan, Edwards, & Dwivedi, 2019; Fahimirad, & Kotamjani, 2018), which can be seen as proof of its complex structure. Artificial intelligence, one of the leading modern applications of information systems as a field of study (Aldosari, 2020), is concerned with the development of intelligent machines that can learn, adapt, synthesize, and self-correct like humans (Alam, 2021; Popenici, & Kerr, 2017; Rapanyane, & Sethole, 2020). It is seen as the process of programming a computer or any device to perform a task that traditionally only human intelligence can achieve, such as perceiving natural language or visual scenes, and designing how it can automatically learn from programmed information (Becker, 2017; Fitria, 2021).

Literature Review

The origin of the term Artificial Intelligence dates back to the "Dartmouth Artificial Intelligence Summer Research Project" in 1956, where three scientists gathered under the leadership of John McCarthy in the state of New Hampshire in the USA to discuss artificial intelligence (Burgard, 2022; Cantú-Ortiz et al., 2020; Holmes, et al., 2022). During this event, artificial intelligence was defined as a separate discipline, and its main goals were identified. These goals include understanding and modeling human thought processes, and designing machines that mimic this behavior (Shukla & Jaiswal, 2013). Looking back on the overall journey of artificial intelligence, since the development of the famous Turing Test in the 1950s to investigate whether machines can think, the field has experienced turbulent periods of growth and stagnation (Kannan & Munday, 2018). However, in the last decade, artificial intelligence has witnessed tremendous developments across a wide range of fields as a result of advancements in computing power and big data technology (Huawei Technologies Co., Ltd., 2021). The increase and diversity of application areas for artificial intelligence have necessitated significant financial investment from various businesses and governments worldwide to finance these applications (Holmes, Bialik, & Fadel, 2019). The support provided by various companies and governments worldwide has brought about the development of artificial intelligence, not only to understand but also to create intelligent entities (Russell & Norvig, 2010). Today, artificial intelligence is being applied in various forms, including computer programs, applications, embedded control systems in equipment, and robots, in areas such as visual and speech recognition, decision-making, natural language processing across different languages, translation, and more (Hwang, Xie, Wah & Gašević, 2020). It is penetrating almost every aspect of our daily lives, including education, healthcare, the economy, government systems, transportation, communication, and many other sectors (Burgsteiner, Kandlhofer & Steinbauer, 2016; Cantú-Ortiz et. al., 2020). This situation has also led to concerns that artificial intelligence seeks to "take control away from humans," and is even seen as a concept that threatens humanity (Kannan & Munday, 2018).

The perception of artificial intelligence as a threat is actually related to its part called "strong artificial intelligence". This section refers to the possibility of creating intelligent machines

that can perform reasoning and problem-solving tasks. It is believed that such machines are conscious and self-aware and can think independently and generate the best solutions to problems. According to the belief, strong artificial intelligence also has its own values and worldview and is equipped with instincts such as survival and security needs, just like all living beings. On the other hand, a part of artificial intelligence is also seen as "weak artificial intelligence", which refers to a situation where machines appear to be intelligent, but do not actually have intelligence or self-awareness (Huawei Technologies Co., Ltd., 2021). Although it is considered dangerous and feared by some groups today, artificial intelligence significantly reduces potential risks for humans and the environment in many applications, and facilitates many of their tasks (Shukla, & Jaiswal, 2013). Along with various industries, it is also becoming increasingly dominant in the education sector with significant development and usage (Fitria, 2021).

The centrality of artificial intelligence (AI) in the field of education was realized with the publication of the International Journal of AI in Education in 1989 and the establishment of the International AI in Education Society in 1993 (Holmes, Persson, et al., 2022). Although the integration of AI into education currently lags behind other fields in terms of desired levels and historical roots, it is believed that AI will significantly impact the main stakeholders that make up education in the near future (Çetin & Aktaş, 2021). The integration of AI in education can not only allow a computer system to act as an intelligent teacher, but it can also facilitate decision-making in educational settings, greatly improve the quality of teaching and learning, assist in assessment and data collection, develop new strategies for learning processes, enable students to benefit from intelligent teachers and real-time learning (Hwang, Xie, Wah, & Gašević, 2020), improve lesson topics, adapt classrooms to students' profiles, and create various content related to students' interests (Fahimirad & Kotamjani, 2018).

When considering the development of artificial intelligence and its contribution to education, it becomes evident that institutions and organizations responsible for implementing education, along with teachers and education stakeholders, must accelerate their efforts towards integrating artificial intelligence into education. This is because the key to not falling behind in a rapidly changing world is known to be adapting to change (Afrianto, 2018). Therefore, examining the existence of educational studies based on artificial intelligence will shed light on the development and integration of artificial intelligence in education.

In this context, it has been identified that artificial intelligence is associated with many areas such as e-learning (Gamage et al., 2022; Martin & Kumar, 2018; Moore et al., 2011; Müller et al., 2021), a chatbot (Hwang & Chang, 2021; Tamayo et al., 2020; Malik et al., 2021), robot-based education (Cao et al., 2021; Huang; 2021; Lasso-Rodríguez, & Herrera, 2019), game-based education (Domínguez et al., 2013; Clyde et al., 2012; Zhan et al., 2022a) in terms of integrating artificial intelligence into education. On the other hand, when the literature in the related field is examined, it can be seen that different studies have addressed artificial intelligence in the context of education (Arslan, 2020; Aldosari, 2020; Becker, 2017; Burgsteiner, Kandlhofer, & Steinbauer, 2016; Cantú-Ortiz, et al., 2020; Chai, et al., 2021; Chiu, 2021; Chiu, et al., 2022; Cope, Kalantzis, & Searsmith, 2021; Çetin, & Aktaş, 2021; Fahimirad, and Kotamjani, 2018; Fitria, 2021; Francesc et al., 2019; Holmes, Bialik, & Fadel, 2019; Holmes, et al., 2022; Hwang, et al., 2020; İşler & Kılıç, 2021; Kannan, & Munday, 2018; Lameras & Arnab, 2022; Oke & Fernandes 2020; Popenici & Kerr, 2017; Shaikh, Kumar, et al., 2022; Yang, Huan & Yang, 2020). Hinojo-Lucena et al., (2019) conducted a bibliometric analysis of scientific articles related to artificial intelligence in higher education

indexed in the Web of Science and Scopus databases between 2007 and 2017. Roll and Wylie (2016) systematically reviewed 47 articles published in different years of the Journal of Artificial Intelligence in Education. Chen, Xie, Zou, & Hwang (2020) examined 45 studies on artificial intelligence in education in terms of leading journals, institutions, countries/regions, most frequently used terms, and adopted theories and technologies. Bhutoria (2022) conducted a systematic review of studies using personalized education in the English language published between 2019 and 2021 in China, India, and the United States. Alam (2021) examined 42 articles with an H-Index greater than 20 in various databases, including EBSCO, ProQuest, and Web of Science (WoS), to determine how artificial intelligence has impacted education.

In this study, unlike previous research mentioned above, a bibliometric analysis was conducted on articles related to artificial intelligence technologies in education. The focus was on research articles that were indexed in Social Sciences Citation Index (SSCI), Science Citation Index Expanded (SCI-Expanded), and Emerging Sources Citation Index (ESCI) in the education category of the WoS database and contained the keyword "artificial intelligence" in the author's keywords. The aim was to reveal the status of the education research dimension in the artificial intelligence literature. In other words, this study aimed to provide a different perspective from previous studies by aiming to access studies that are solely focused on artificial intelligence in education, and to examine the relevant topic area holistically through bibliometric analysis of studies related to artificial intelligence.

In this context, the study aims to answer the following questions:

- How is the distribution of articles published on artificial intelligence technology in education by year?
- Which researchers are the most interested in artificial intelligence technology in education?
- Which countries are the most productive in the field of artificial intelligence technology in education?
- Which articles are the most popular in the field of artificial intelligence technology in education?
- Which journals publish the most articles on artificial intelligence in education?
- What are the most commonly used keywords in articles related to artificial intelligence technology in education?
- What are the trends created by articles related to artificial intelligence technology in education?

Method

In this study, a bibliometric analysis was conducted on articles related to artificial intelligence technologies in education. With the increasing diversity and number of topics studied in a research field, trends in scientific production emerge. These trends are identified through various statistical analyses, one of which is bibliometric analysis. The bibliometric analysis encompasses a comprehensive statistical approach that includes identifying research conducted on a specific topic, a scientific production graph by year, identification of the most influential authors, institutions, and sources, collaboration and citation networks of authors, and current trends in the field (Aria & Cuccurullo, 2017; McBurney & Novak, 2002). In this study, journal articles published in indexed in the WoS databases such as the Social Sciences Citation Index (SSCI), Science Citation Index Expanded (SCI-Expanded), and Emerging

Sources Citation Index (ESCI) in which the keyword "artificial intelligence" appeared were analyzed.

Data Collection

The data set consisting of a certain number of publication types such as books, articles, papers, and theses in a subject area is examined through bibliometric analysis (Ellegaard & Wallin, 2015). In this study, journal articles in the categories of "Education Educational Research" and "Education Scientific Disciplines" were examined in the WoS database. The boundaries for accessing the dataset in the study are shown in the diagram in Figure 1.

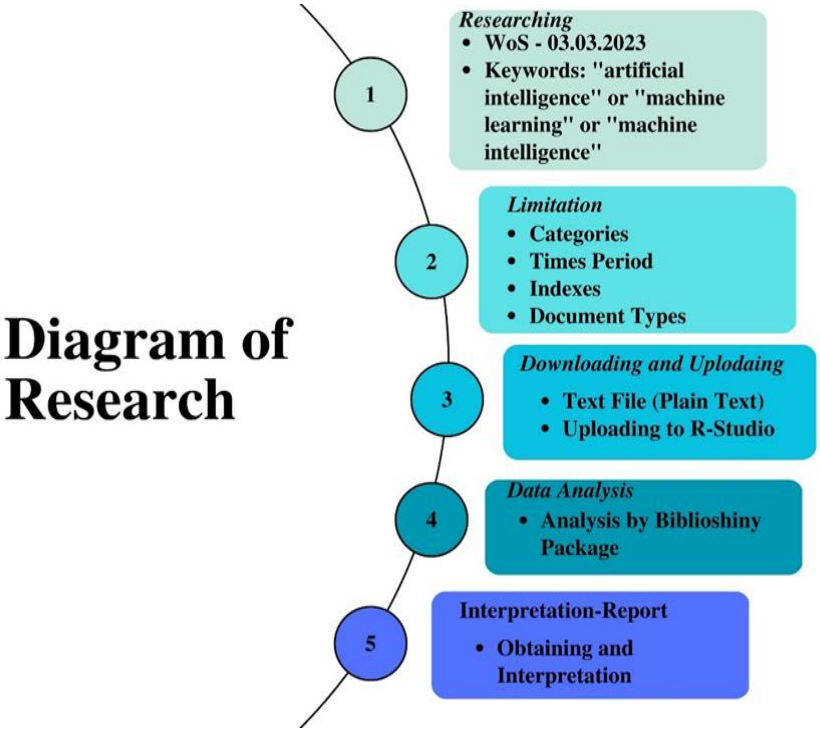

Figure 1. Data Collection Process

In the research, the keywords "artificial intelligence", "machine learning," and "machine intelligence" were searched on the Web of Science (WoS) using the "or" option in line with the aim of the study. To access more reliable studies where authors used these keywords, the "Authors Keywords" option was preferred during the search. In the initial search, where no limitations were made, a total of 167.412 publications related to artificial intelligence technology were reached in all publication types and fields. The publications in the dataset were limited to "Education Educational Research" and "Education Scientific Disciplines" categories, "article" publication type, and SSCI, SCI-Expanded, and ESCI indexes. Later, it was determined that the usage of artificial intelligence technology as a keyword in a study was first observed in 1992 in WoS, and this year was accepted as the starting date for the research. As the year 2023, when the data was downloaded, has not ended yet and it was thought to affect the statistics in the dataset, articles published in 2023 were not included in the dataset. Therefore, the publication period of the articles in the dataset was limited to 1992-2022. After these limitations, it was observed that 775 articles were included in the dataset, and the relevant dataset was saved as a "Plain Text" file in the computer environment by marking the "Full Record and Cited References" tab in WoS.

Data Analysis

The R-Studio program, which is compatible with the infrastructure of the R Statistics program, was used for the analysis of research data. The R programming language is open source and offers users many different options, thus having a constantly updated structure. Users can benefit from the packages offered at https://cran.r-project.org. In this study, the data were analyzed using the "bibliometrics" package developed in collaboration with Massimo Aria and Corrado Cuccurullo from the University of Naples Federico II. The "Plain Text" file downloaded from WoS was added to this interface by activating the "bibliometrics" package added to R-Studio. Productivity graphs, most relevant authors, institutions, countries, collaboration statuses of authors, clarity of responsible authors' international collaborations, trends in artificial intelligence technology in education, and keyword analysis were utilized from various types of analyses provided by the bibliometrics package according to the years it offered. The general framework and trend of articles related to artificial intelligence technology in education were revealed by interpreting the obtained graphics and quantitative data.

Findings

The findings obtained regarding education research studies on artificial intelligence in the analyzed dataset are presented in this section. The following table provides basic information on journal articles focusing on artificial intelligence in education research.

Table 1. Main information

Categories	Results
Timespan	1992-2022
Journals	223
Documents	775
Authors	2257
Authors of Single-Authored Documents	138
Authors of Multi-Authored Documents	2119

According to the information presented in Table 1, the keywords "artificial intelligence," "machine learning," or "machine intelligence" were first used by an author in WoS in 1992, according to the data set accessed on March 3, 2023. In WoS, 775 articles on education research were published in 223 different journals with the keyword "artificial intelligence." Over a 30-year period, a total of 2257 different authors conducted research on artificial intelligence technology in education. When the table above is examined, it can be seen that the majority of authors (f=2119) conducted their research through collaboration. The number of authors who conducted research on artificial intelligence in education as a single author is only 138.

Figure 2 below presents the scientific production graph for journal articles on artificial intelligence technology in education in WoS.

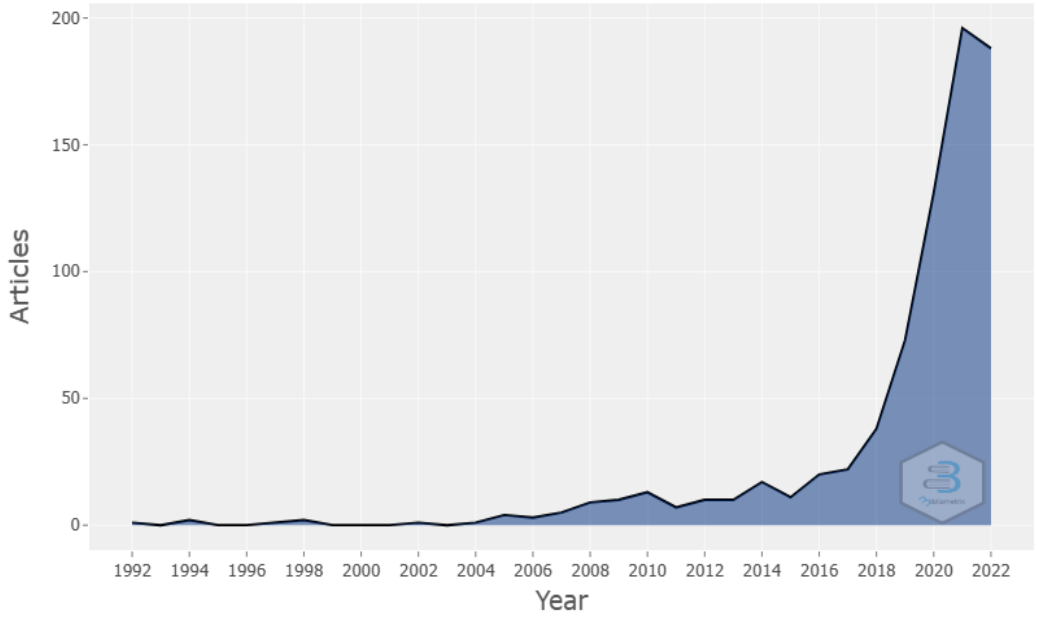

Figure 2. Annual Scientific Article Production

When examining Figure 2 above, it can be seen that the use of artificial intelligence technology in educational research started in 1992. When different periods are examined, a significant increase in the number of articles on artificial intelligence technologies in education is observed after 2018. When the number of articles in the last five years is examined, it can be seen that the number of articles, which was 38 in 2018, reached 73 in 2019, 131 in 2020, 196 in 2021, and 188 in 2022. It can be stated that the increase in the number of scientific articles prepared on artificial intelligence technology has attracted the attention of researchers in this field to respond to the needs of the period in which they are located, which is diversified and accelerated according to technological developments.

Table 2 presents the top 10 researchers who show the most interest in the field of artificial intelligence technology in education research in the WoS database. The table includes the institutions where these researchers work, the year they began writing articles related to the topic, and the number of articles they have produced.

Table 2. Most relevant authors

Authors	Institution	Article (f)
R. Adán Salas-Rueda	Universidad La Salle (México)	13
Xiaoming Zhai	University of Georgia (USA)	8
Kalervo N. Gulson	The University of Sydeny (Australia)	5
Kevin C. Haudek	Michigan State University (USA)	5
Ross H. Nehm	The Ohio State University (USA)	5
Solomon S. Oyelere	Luleå University of Technology (Sweden)	5
Wanli Xing	University of Florida (USA)	5
Cheng-Huan Chen	Asia University (Taiwan)	4
ThomasK. F. Chiu	The Chinese University of Hong Kong	4
Tenzin Doleck	Simon Fraser University (Canada)	4

Upon examination of the table 2, it is observed that Salas-Rueda from Universidad La Salle is the most active author with 13 articles related to artificial intelligence technologies in

education research. Xiaoming Zhai from the University of Georgia follows him. Other researchers have also produced a considerable number of articles on this topic. It is noted that some of the authors come from Far Eastern countries, but they work in universities in the United States. This situation indicates that US universities host researchers from different countries. The starting year of publication and citation explosion values of the researchers interested in the topic are shown in Figure 3.

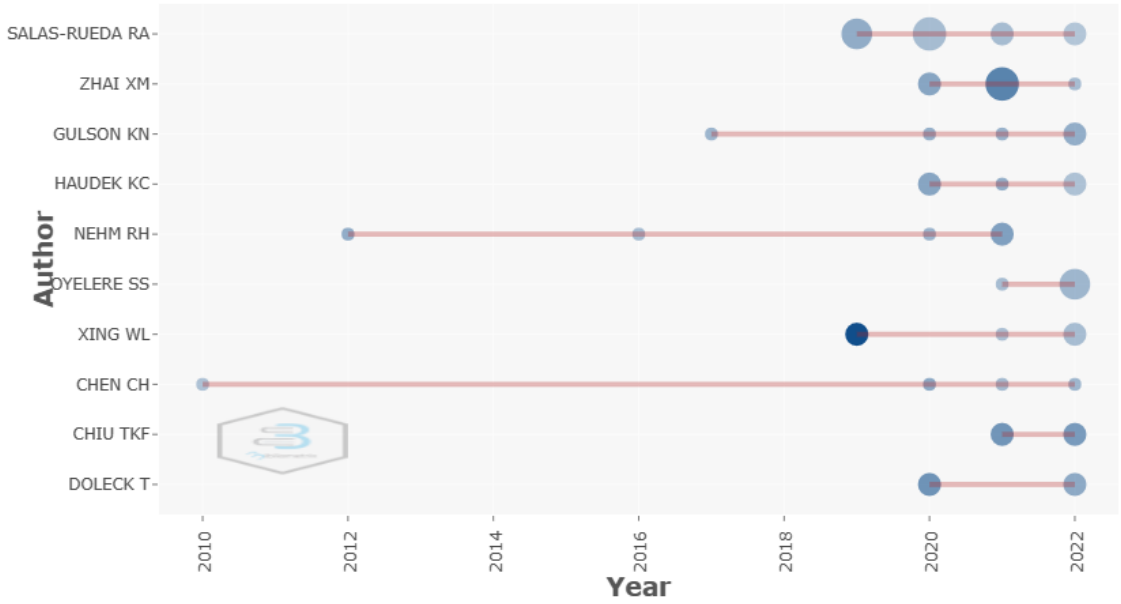

Figure 3. Authors' Production over Time

According to the information presented in Figure 3, it can be seen that Salas-Rueda, who has the highest number of articles, wrote his first article on artificial intelligence technologies in 2019, as limited by WoS. The fact that this author produced 13 articles in a limited period of time indicates an increasing trend in interest in this topic in recent years. Among the top 10 researchers, Cheng-Huan Chen from Asia University is the researcher with the oldest publication on this topic. Chen wrote his first article on this subject in a journal indexed in WoS in 2010 and continued to publish on the subject. When Figure 3 is examined, an increase in the number of articles in the last four years can be observed. This finding can be interpreted as an increasing interest in artificial intelligence technologies by researchers in recent years.

The size of the dots in Figure 3 is related to the number of articles, while the color intensity provides a clue about the citation value of the articles. It can be seen that Salas-Rueda is the researcher who wrote the most articles per year when Figure 3 is examined. Wanli Xing's articles in 2019 can be said to have received more attention from other researchers. As a result of examining one of these articles, it was found that online courses aim to reveal the effects of deep learning on changing traditional education and students dropping out of school (Xing & Du, 2019). Another article from the same year aims to reveal students' feelings of success in online courses (Xing, Tang & Pei, 2019). Figure 4 below presents a scientific production map of artificial intelligence technology-related articles in educational research by country in WoS.

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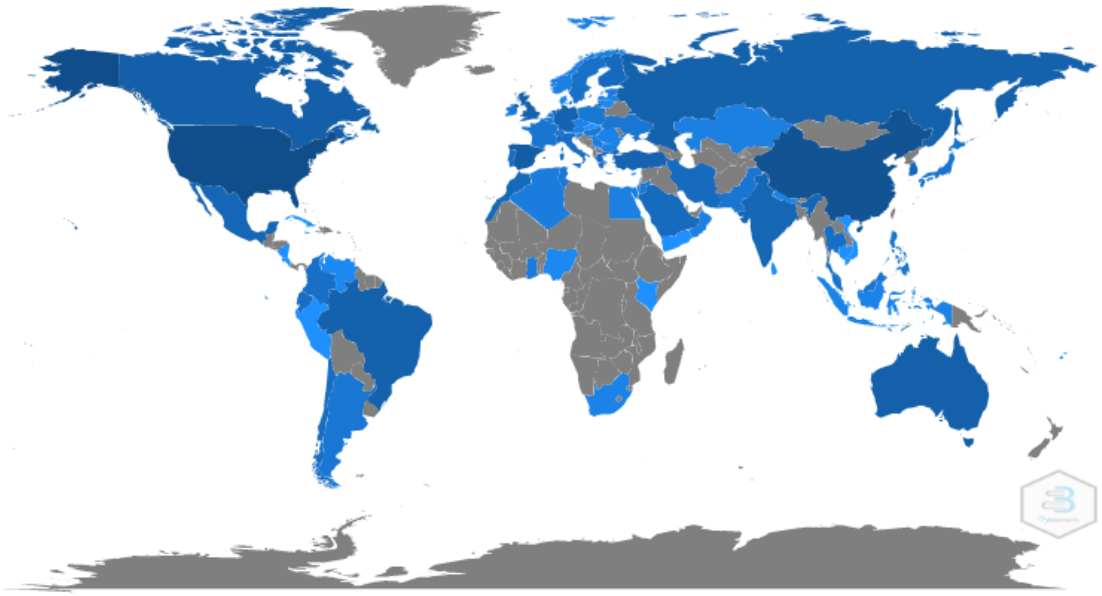

Figure 4. Country Scientific Production

When looking at the scientific production map in Figure 4, it can be seen that the gray colour represents the lack of any article production on the subject in the WoS database. The light blue-colored countries indicate that there is a production of articles related to artificial intelligence technology, while the dark blue-colored countries show that scientific production on this topic is more prominent compared to other countries. As of March 03, 2023, the top 10 countries with the highest production of artificial intelligence technology in educational research are the USA (f=345), China (f=222), Spain (f=85), Canada (f=71), Australia (f=68), United Kingdom (f=67), Brazil (f=62), Russia (f=61), Germany (f=49), and Turkey (f=48). This information suggests that the mentioned countries prioritize artificial intelligence technologies in education compared to other countries.

Table 3 below provides information on which countries have produced the most referenced articles in educational research.

Table 3. Most cited countries

Country	Total Citation	Average Article Citation
USA	1657	10.76
China	1046	9.4
United Kingdom	375	10.4
Greece	305	17.9
Spain	277	6.9
Australia	275	9.1
Turkey	215	9.3
Canada	214	11.2
Netherlands	120	17,1
U. Arab Emirates	111	18,5

According to the information provided in Table 3, the countries where the most referenced articles in education research were conducted are the USA, China, United Kingdom, Greece, Spain, Australia, Turkey, Canada, Netherlands, and the U. Arab Emirates. Upon examination of citation numbers, it can be stated that countries such as the USA, China, United Kingdom,

Spain, Australia, Canada, and Turkey are almost directly proportional to their scientific production data (Figure 4). It can be said that the high number of scientific productions in these countries affects the total citation rate. However, it is observed that countries such as Russia, Brazil, and Germany, which are among the top 10 countries in scientific production, do not appear in the top 10 in terms of citation numbers. In addition, despite not being at the top of the map with less scientific production, it has been found that research conducted in countries such as Greece, Netherlands, and the U. Arab Emirates, which are in the top 10 in terms of total citation rate, despite having fewer publications, are among the top 10 in terms of citation rate. The Average Article Citation data supports this statement. These findings can be interpreted as indicating that the articles produced in these countries receive positive or negative attention in studies on artificial intelligence technology in education.

Figure 5 below shows the collaboration status between the responsible authors' countries and other countries in artificial intelligence technology articles in education research in the WoS database.

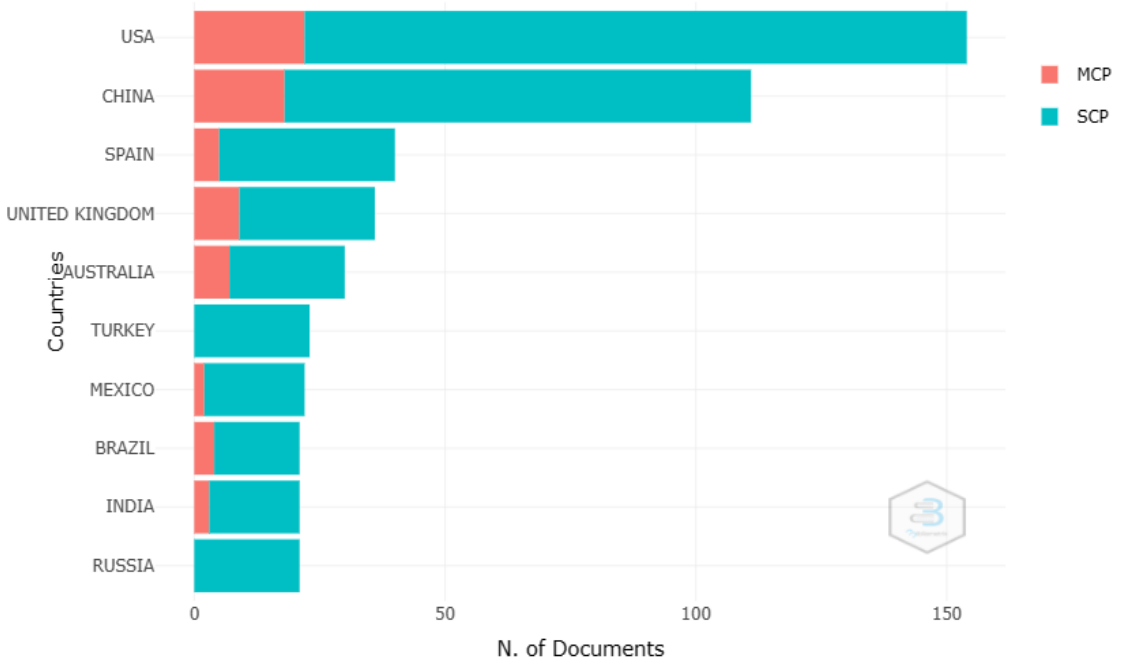

Figure 5. Corresponding Author's Country Collaboration

According to the information in Figure 5, when the MCP (Multi Country Production) and SCP (Single Country Production) ratios are examined, it is seen that responsible researchers in other countries except for Turkey and Russia, among the top 10 countries, conduct research by engaging in international collaboration. On the other hand, research carried out in these two countries is either single-authored or carried out with collaboration within the country. This finding can be interpreted as Turkish and Russian researchers not being open to collaboration.

Figure 6 below shows the diversity of the collaboration network among countries working on artificial intelligence in education.

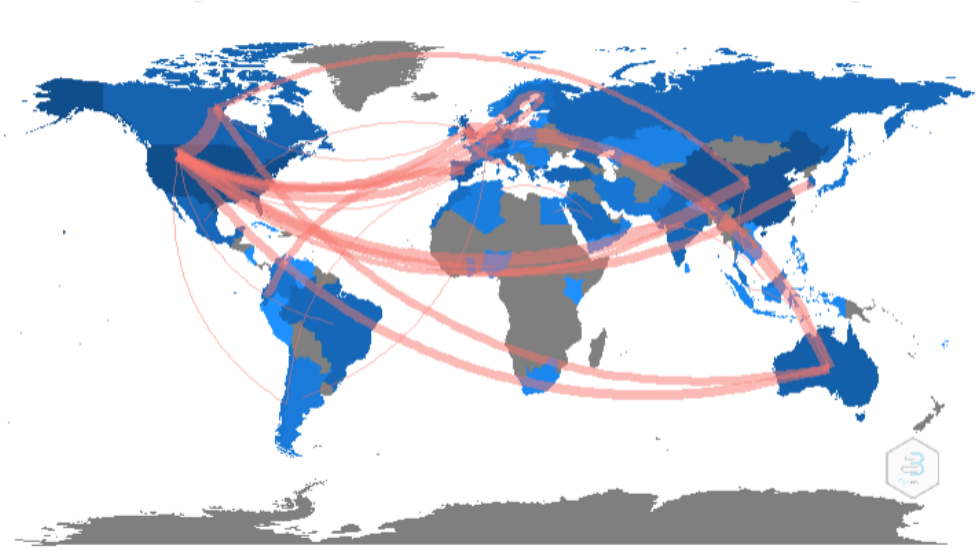

Figure 6. Country Collaboration Network

When the data on the collaboration of responsible authors writing articles on artificial intelligence in education with researchers in their own and other countries were examined, according to Figure 6 above, it was determined that the highest number of researchers from the United States collaborated with researchers in different countries in WoS educational research. American researchers collaborated mostly with researchers from Canada, China, Sweden, South Korea, and Australia. When bilateral countries were examined, a significant network was also detected between Australia and the United Kingdom. These findings can be interpreted as these countries being pioneers in collaboration in artificial intelligence technology studies in education compared to other countries.

Table 4 below presents the global and local citation numbers of scientific articles written on artificial intelligence in the category of educational research according to the WoS data.

Table 4. Most cited articles

Article's Title	Global Citations	Local Citations
"Dropout prediction in e-learning courses through the combination of machine learning techniques"	184	16 (Greece)
"Analyzing collaborative learning processes automatically: "Exploiting the advances of computational linguistics in computer-supported collaborative learning"	153	5 (USA)
"Mining opinions from instructor evaluation reviews: A deep learning approach"	110	0 (Turkey)
"What predicts student satisfaction with MOOCs: A gradient boosting trees supervised machine learning and sentiment analysis approach"	99	5 (Hong Kong)
"Dropout prediction in MOOCs: Using deep learning for personalized intervention"	97	7 (USA)
"The long history of gaming in military training"	92	0 (USA)
"Artificial intelligence and sustainable development"	67	14 (USA)
"Transforming Biology Assessment with Machine Learning: Automated Scoring of Written Evolutionary Explanations"	67	5 (USA)
"Supervised machine learning in multimodal learning analytics for estimating success in project-based learning"	65	1 (Sweden)
"Utilizing early engagement and machine learning to predict student outcomes"	63	4 (United Kingdom)

Based on the information presented in Table 4, the article produced in Greece on predicting school dropout rates (Lykourentzou et al., 2009) received the most attention from researchers who did not work on this topic internationally. This data is confirmed by the data on the increase in citation rates. It can be said that the topic of school dropout rates received less attention in articles on artificial intelligence technology in education. Additionally, the fact that the article was published earlier (in 2009) than other articles may have affected its citation rate. Similarly, the second article, which was published in 2008, focused on language learning (Rosé et al., 2008). It can be said that this topic is also of interest internationally. Despite being written in Turkey, the third article on emotional classification (Onan, 2019) is among the top-cited articles internationally, despite not receiving any local citations. This finding can be interpreted as a result of the topic is a relatively new field in Turkey and not yet widely recognized. Table 5 below shows the journals where scientific articles on artificial intelligence technology in education have been published most frequently.

Table 5. Most relevant sources

Source	Article (f)	Index
“International Journal of Emerging Technologies in Learning”	66	ESCI (Checking)
“Education and Information Technologies”	36	SSCI
“Computer Applications in Engineering Education”	27	SCI-Expanded
“IEEE Transactions on Learning Technologies”	25	SSCI
“Education Sciences”	22	ESCI
“Educational Technology & Society”	19	SSCI
“Frontiers in Education”	19	ESCI
“Computers & Education”	15	SSCI
“Interactive Learning Environments”	14	SSCI
“Journal of Science Education and Technology	13	SSCI

When looking at the journals listed in Table 5 above, it can be seen that these journals are limited to WoS as a database. Upon examining the table, it is observed that the journal with the most articles published on the subject is "The International Journal of Emerging Technologies in Learning" with 66 articles. The data set of this journal was reviewed for ESCI listing on March 3, 2023. Upon examining the other journals, it is seen that the top 10 journals are indexed in SSCI for 6, ESCI for 2, and SCI-EXPANDED for 1. When the publishing scopes of these journals are examined, it can be seen that they publish articles on subjects such as education and information technologies, computer applications, and engineering education. These findings can be interpreted as articles on artificial intelligence technologies in the education category in WoS being carried out for different subject areas in different indexes.

Figure 7 below shows a keyword plus word cloud consisting of the most commonly used keywords from articles related to artificial intelligence technology in education research.

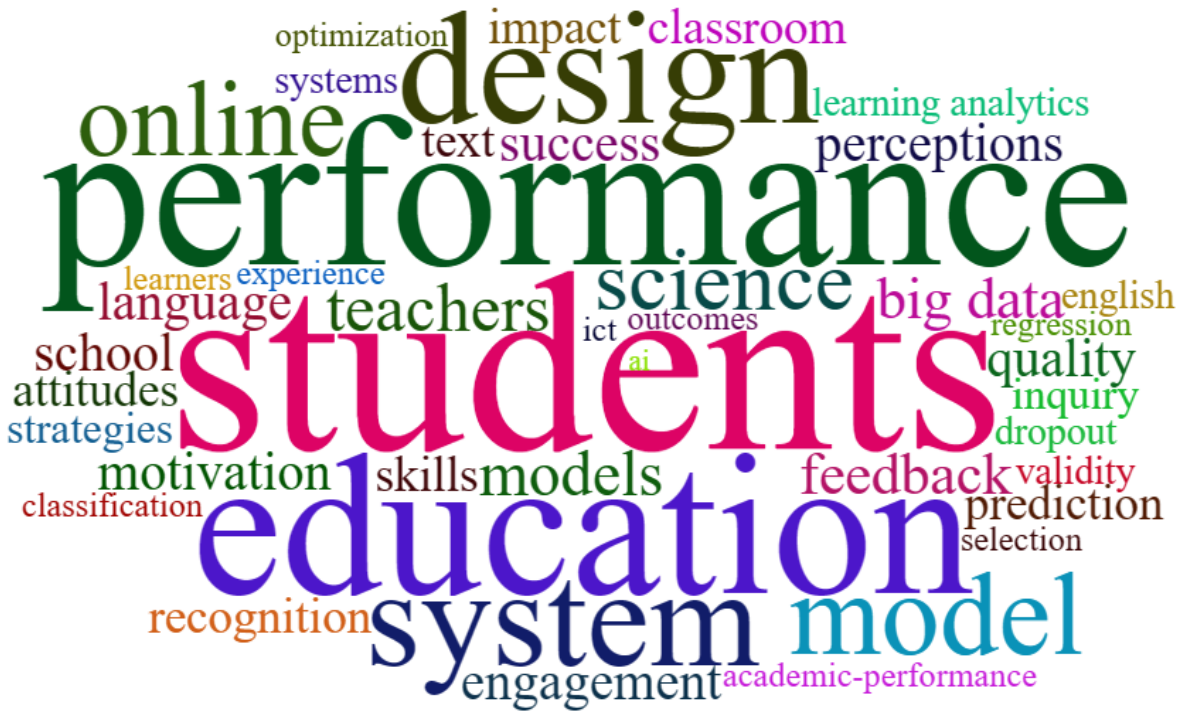

Figure 7. Word Cloud

The word cloud presented above has been limited to a single keyword. Accordingly, the top 50 keywords plus terms that are most commonly used are shown as the limit. In the literature, it is stated that keywords plus, according to Garfield (1990), provides more comprehensive information compared to the keywords used by authors. In this context, researchers aiming to conduct research on a particular topic use 3 to 6 keywords according to the journal guidelines. Web of Science (WoS) generates keyword plus terms to access more comprehensive information in the relevant field through the keywords used by researchers in publications. Therefore, keyword plus reveals the relationship between the main keywords and other related keywords and the trend related to the subject (Tripathi et al., 2018). Based on the Figure above, the most frequently used keywords in articles on artificial intelligence technology in the education research category on WoS are students, performance, education, design, system, online, model, science, and engagement. Co-occurrence word analysis was conducted to determine which keywords are used together more frequently, and the results are presented in Figure 8.

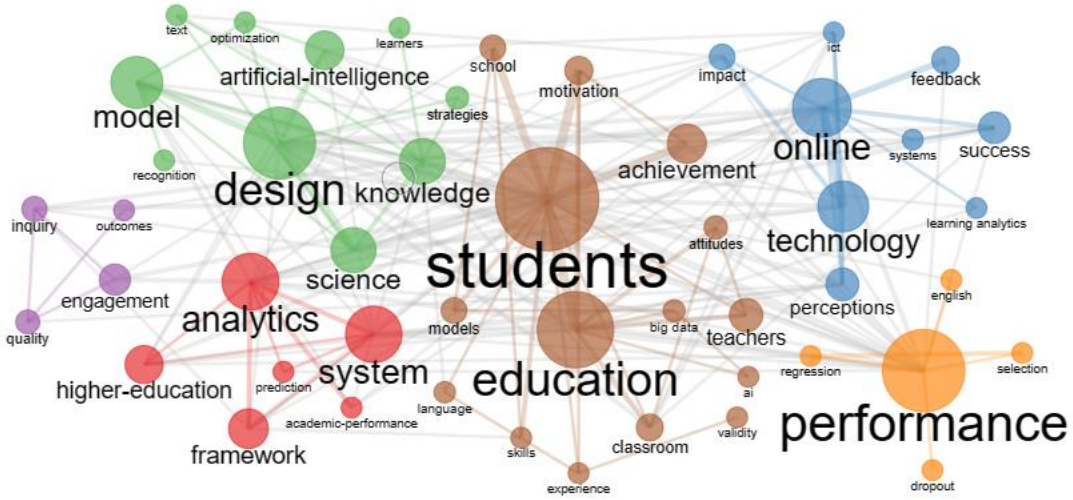

Figure 8. Co-occurrence Word

Figure 8 above shows the groups of keywords that are frequently used together in articles. Keywords such as students, education, achievement, classroom, attitudes, motivation, school, teachers, experience, and big data form a group. It can be stated that some analyses focus on the student in certain studies. In other groups, the presence of keywords such as performance, academic performance, feedback, and success strengthens this interpretation. When other matching keywords are examined, it can be seen that design, artificial intelligence, model, science, and knowledge are in one group, while analytics, system, higher education, and framework are in another group. Based on these findings, it can be stated that articles are written on artificial intelligence technology models and designs.

Figure 9 below shows the trend topics list formed by articles related to artificial intelligence technologies in the education category in WoS.

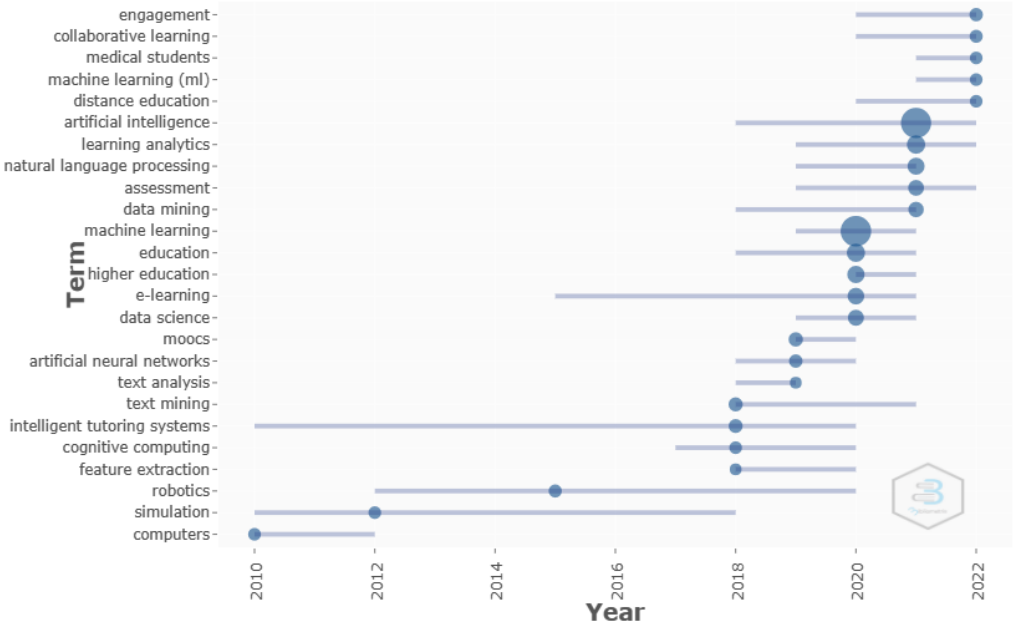

Figure 9. Trend Topics

According to Figure 9 above, the most popular trend topics in education related to artificial intelligence technology in recent years include engagement, collaborative learning, natural language processing, e-learning, artificial neural networks, text analysis, text mining, intelligent tutoring systems, cognitive computing, and simulation. Some of the keywords in Figure 9 may relate to the sample groups used in the research. It can be seen that the topic of intelligent tutoring systems has maintained its popularity for the longest period of time. As technology continues to advance, it can be interpreted that it also affects the increase in types of trend topics over time.

Results and Discussion

A bibliometric analysis was conducted on articles related to artificial intelligence in education. The study found a significant increase and diversity in the number of articles on the subject in recent years, particularly since 2018. Of the total 775 articles examined, approximately 80% were published in 2018 and after. The increase in the number of article production by years is remarkable during the COVID 19 period. In some fields of study, the number of publications on values education (Sökmen & Nalçacı, 2020), social studies education (Palaz, 2022), history education (Bozdoğan & Sönmez, 2023) and skills education (Akcan, Doğan & Ablak, 2023) decreased especially after 2019. During the COVID 19 period, an increase in the number of publications on artificial intelligence in education has been detected. This result shows that research on artificial intelligence can be done beyond socialization. In addition, researchers may have worked to find solutions to increasing problems as the importance of distance education and information technologies increased during the COVID 19 period. According to the results this research, the first education article containing any of the keywords "artificial intelligence," "machine learning," and "machine intelligence" was published in 1992. This article, "Shifting Paradigms, Shifting Sands: Interactive Multimedia for Language Learning" by Morgenstern (1992), explored the possibilities of interactive language learning software with video materials. Subsequently, several articles on language teaching using AI technology were written at different times (Golonka et al., 2014; Kannan & Munday, 2018; Pokrivčáková, 2019; Schulze, 2008; van den Berghe et al., 2019; Viktorivna et al., 2022). A different study analyzing robot-based research with SSCI restrictions found that robot-based AI technology is frequently used in language learning processes (Chu et al., 2022). One of the results obtained in this study is the cumulative increase in the number of articles on AI technology in the education category. Therefore, the topics studied are becoming increasingly diverse. It is clear that there is a rising trend in the use of AI technology in education research, which is likely to continue to increase over time. Wang and Zhan (2021) also found similar results indicating an increasing interest in AI technology in higher education research between 2009 and 2019. The results of this research could provide more comprehensive information. The general trend of educational research on artificial intelligence (AI) technology in education, rather than the specific subject area of AI, has been revealed through limitations of SSCI, SCI-Expanded and ESCI.

When examining the countries that produce articles on AI technology in education, it was found that the USA and China are more productive than other countries. This result may be related to the level of development and education policies of these countries and their leadership in scientific production. A technology-focused education policy also affects the prevalence of technology-focused production in scientific research. In a study by Hwang et al. (2022), which examined articles that used AI and online learning keywords together in WoS between 1997 and 2019, the USA and China also ranked first. These results support the findings of the research. On the other hand, according to Dyatkin's (2022) research, the

countries that invested the most in AI technology between 2013 and 2020 are the USA and China. It can be said that the policies of the USA and China are influential in this research. Among the top 10 countries most interested in the subject, the USA and China share the top two spots, followed by Spain, Canada, the United Kingdom, Australia, Mexico, Brazil, Germany, Russia, and Turkey. The international collaboration status of the authors in these countries is good except for Turkey and Russia. After examining the journals where articles using artificial intelligence technology in education are published, it was found that six of the top 10 most published journals were indexed in SSCI, three in ESCI (one under review) and one in SCI-Expanded. It is known in the scientific community that not all scientific journals have the same value range (Guerrero-Bote & De Moya Anegón, 2012). Publishing articles on artificial intelligence technology in education in SSCI-indexed journals can be seen as proof that the subject is being followed by prestigious journals.

Regarding the most popular topics in international articles on artificial intelligence technology in education, the possibility of students dropping out of school with the advancement of artificial intelligence technology is one of the most significant (Bañeres et al., 2023; Basnet et al., 2022; Lykourentzou et al., 2009; Melo et al., 2022; Kloft et al., 2014). Another topic that has attracted a lot of attention internationally is "chatbots". This subject has been extensively studied, especially in the language learning process (Hwang & Chang, 2021; Kim et al., 2022; Sandu & Gide, 2019; Tamayo et al., 2020; Malik et al., 2021). The fact that the words "dropout" and "language" are among the top 50 most commonly used words in this study is consistent with these results. According to word cloud analysis, the most prominent keywords include "student", "performance", "system", and "design". Co-occurrence word analysis data of the keywords in articles on artificial intelligence technology in education reveals that research focusing on students is at the forefront, with keywords such as "performance", "engagement", "feedback", "achievement", and "motivation" being prevalent. According to trend data from articles written on artificial intelligence technologies in educational research on WoS, topics such as engagement, collaborative learning, natural language processing, e-learning, artificial neural networks, and intelligent tutoring systems have become popular in recent years. These results are similar to the findings of Hwang et al. (2022) and their research data includes articles up until 2019. In this research, it is observed that natural language processing (Asakura et al., 2020; McKnight, 2021; Norouzi et al., 2020; Wu et al., 2023), collaborative learning (Kasepalu, et al., 2022; Sanusi et al., 2022; Zhan et al., 2022b), and engagement have become trends after 2019.

In light of this information, it can be said that the current research results provide a general framework for the use and development of artificial intelligence technology in education. In this context, it is believed that future research on integrating artificial intelligence into education and using and developing artificial intelligence in education will contribute to the field.

Recommendations

- This study is limited to the dataset from WoS. Research results can be compared by conducting similar studies with data obtained from different databases (Scopus, Dimensions, etc.).
- It is recommended to open the way for innovative initiatives by making AI technology-focused updates in education policies for developing countries.

- In this study, journal articles were examined as the publication type. In the future, studies can be carried out on different publication types such as conference proceedings and books.
- The dataset obtained under author keywords was examined in this research. In the future, different studies can be designed based on the research topic and title.
- Scientific research is influenced by the time frame in which it is conducted. This study examined research conducted until 2022. Studies can be conducted for the post-2022 period to identify current trends.

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