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## Artificial Intelligence in Education: A Bibliometric Study

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### Abstract

The aim of this study is to examine the studies in the literature on the use of artificial intelligence in education in terms of its bibliometric properties. The Web of Science (WoS) database was used to collect the data. Various keywords were used to search the literature, and a total of 2,686 publications on the subject published between 2001-2021 were found. The inquiry revealed that most of the studies were carried out in the USA. According to the results, it was seen that the most frequently published journals were Computers & Education and International Journal of Emerging Technologies in Learning. The study showed that the institutions of the authors were in the first place as Carnegie Mellon University, University of Memphis and Arizona State University as the most productive organizations due to the number of their publications, while Vanlehn, K. and Chen, C. –M. were the most effective and productive researchers. As a result of the analysis, it was determined that the co-authorship network structure was predominantly USA, Taiwan and United Kingdom. In addition, when the keywords mentioned together were mapped, it was seen that the words artificial intelligence, intelligent tutoring systems, machine learning, deep learning and higher education were used more frequently.

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### Introduction

Developments in science and technology in recent years have deeply affected societies. One of these developments is artificial intelligence, which is successfully used in many industries today. Artificial intelligence has become increasingly important and inspired many interdisciplinary studies recently, and it is one of the up-to-date study fields of today (Russel & Norvig, 2016; Yabanova, 2016). Artificial intelligence, which first emerged based on concepts such as the ability of computers or robots to think and feel (Özdemir, 2009), has been a field of study that has made incredible progress in the last 50 years. Today, artificial intelligence studies have become one of the areas that countries attach the most importance in their investments. It attracts more and more attention every day with the contribution of successful projects in recent years. The concept of artificial intelligence, which was first voiced by John McCarthy at the Dortmund conference in 1956 (Rajaman, 2014), has started to be accepted as the technology of the future globally and at country level recently. Artificial intelligence, one of the important research areas in the field of computer engineering, can be considered as the driving force of technology since the first half of this century (Arslan, 2017).

The term artificial intelligence was first defined by John McCarthy as intelligent machines, and particularly the

science and engineering of making intelligent computer programs (Demirhan, & Güler, 2012). In general terms, artificial intelligence is the ability of computers to perform higher cognitive functions peculiar to human intelligence, such as perception, decision-making, problem-solving, generalizing, gaining experience and acting accordingly (Alanoğlu & Karabatak, 2020; Nabiye, 2012). Accordingly, artificial intelligence can be named as systems that imitate the human brain in order to fulfill the specified tasks and that can improve itself recursively thanks to the experience gained as a result of the task (İşler & Kılıç, 2021). With regards to education, artificial intelligence is defined as information processing systems that can be involved in processes carried out by humans such as learning, adaptation, synthesis, self-correction, and the use of data for complex processing tasks (Popenici & Kerr, 2017; Taşçı & Çelebi, 2020). Even if different definitions are made about this concept, the common point is that artificial intelligence represents systems that can make human-like decisions by emulating human thinking processes (Yabanova, 2016). The aim of artificial intelligence is to imitate human intelligence through computers, in this sense, to give computers the ability to learn (Tektaş, Akbaş & Topuz, 2002). However, most of the artificial intelligence studies model the brain and intelligence of the humans, who are accepted as the most intelligent creatures known in the world (Kayabaş, 2010).

With an increasing momentum since the 1960s, artificial intelligence studies have begun focusing more on the realistic and achievable goal of developing algorithms, programs, and systems that can model the problem-solving skill of the human brain rather than producing machines that think like humans (Coppin, 2004; Kayabaş, 2010). This has led to the development of many different artificial intelligence technologies such as artificial neural networks, expert systems, agents, fuzzy logic, natural language processing, Bayesian networks, genetic algorithms, deep learning, machine learning, speech recognition, computer vision. Although most of them are at the level of laboratory studies, it is mentioned that there are more than 60 artificial intelligence technologies today (Öztemel, 2003). However, there has been no consensus so far on establishing the standard approach to find out which technique has the most appropriate artificial intelligence learning theory for a particular learning environment. Moreover, scientists have not yet developed a software tool to make it easier to determine learning style using the students' learning behavior as a model (Fahimirad & Kotamjani, 2018).

With the investments and technological developments made over the years, artificial intelligence applications have started to be used in many areas and have provided great convenience in these areas. Artificial intelligence applications are used in many fields such as industry, energy, health, banking, transportation, engineering, defense, and security. By using artificial intelligence in these areas, time and cost savings become possible, and this contributes significantly to production by minimizing error rates. It can be said that artificial intelligence has started to show itself in the education and can provide important developments in this field. Artificial intelligence applications in education are widely used by students and educators today, and include various tools and applications such as smart lesson systems, teaching robots and adaptive learning systems (Chen, Xie, & Hwang, 2020). According to the 2018 Horizon report, artificial intelligence is one of the important developments in the field of educational technologies (Becker et al., 2018). In particular, over the past two decades, the increasing trend of big data and machine learning has significantly contributed to the educational development of artificial intelligence (Song & Wang, 2020). The incorporation of artificial intelligence technology in education has broadened the scope of education, which was previously a human-oriented system

(Roll & Wylie 2016; Liu, Hu, & Wang, 2018). It is worth mentioning that studies on the use of artificial intelligence in education have increased in numbers. However, more research is necessary to ensure successful practice of artificial intelligence applications in the field of education.

It is believed in the literature that artificial intelligence applications add a different dimension to education and have many benefits. First, it can be said that artificial intelligence enables individualization of the learning process (Chatterjee & Bhattacharjee, 2020; Taşçı & Çelebi, 2020). Moreover, with artificial intelligence, students with learning difficulties can be identified at an early stage, and special solutions can be produced for them (Drigas & Ioannidou, 2012). Thus, effective teaching practices can be realized for students with special needs (Alanoğlu & Karabatak, 2020). Among the prominent benefits of artificial intelligence applications is the fact that they offer excellent observations and inferences very quickly and at minimum cost (Taşçı & Çelebi, 2020; Zeide, 2019). Besides, artificial intelligence is also used in the evaluation of student participation and academic integrity. Furthermore, it prevents loss of time for teachers, and provides the opportunity to easily collect and store student data (İşler & Kılıç, 2021; Karsenti, 2019; Karsenti, Bugmann, & Gros, 2017). On the other hand, artificial intelligence is used in the process of monitoring students' performance. Additionally, artificial intelligence is also used to provide useful feedback to students and teachers and to assist students in improving their academic writing skills (Fahimirad & Kotamjani, 2018; Taşçı & Çelebi, 2020; Zawacki-Richter, Marín, Bond, & Gouverneur, 2019). Artificial intelligence can raise awareness among school administration and teachers by giving early warning about unwanted student behavior and performance (Murphy, 2019). Using artificial intelligence, teachers can analyze students in a classroom and understand who a slow learner is. In some areas where the student is weak or unsuccessful, appropriate steps can be taken to support learning with artificial intelligence analysis (Fahimirad & Kotamjani, 2018). Therefore, these potentials of artificial intelligence in the field of education have led to investments in many countries to further develop artificial intelligence and to increase the number of studies in recent years.

### **Objectives of the Study**

Various scientific studies have been carried out on artificial intelligence in education for many years. The increasing number of scientific studies makes it necessary to interpret and summarize the accumulated knowledge. However, although the presentation of bibliometric analyses through visual maps has become widespread, especially in recent years, it is observed that the studies on the subject have remained limited. For this reason, it can be said that there is a need for studies in which studies conducted on the subject are analyzed under various dimensions. The purpose of this research is to examine the studies on artificial intelligence in education in terms of bibliometric properties and to make evaluations on the subject based on those findings. In this context, the link between a publication and other publications can be analyzed, or data such as showing the most important publications and authors can be analyzed in depth. We believe that the research can provide information about the appearance of the studies conducted on the subject, guide the field experts in determining different study topics and prevent the studies from being repetitive of each other. In line with the hypothesis of the research, answers were sought for the following questions:

1. What is the distribution of the relevant studies by years and country?

2. What are the citation rankings of relevant studies, authors, journals, and institutions?
3. What kind of a structure emerges regarding co-author analysis (countries, institution)?
4. What kind of a structure emerges regarding co-citation analysis (author)?
5. What kind of a structure emerges regarding co-occurrences?

## **Method**

The bibliometric analysis method was used in the study. This method is a content analysis method that reveals the connection of any publication, author or cited author with other publications and authors through visual maps (Zupic & Cater, 2015). Although bibliometric studies cannot completely replace the literature reviews, they are of significance as a supplementary tool.

## **Data Collection**

In this study, WoS (Web of Science) database was used to obtain data. We tried to reach relevant studies by using WoS's advanced search query and filtering options. Table 1 shows the codes written in the database. The search query was determined with reference to previous studies (Chen, Xie, & Hwang, 2020; Song & Wang, 2020).

Table 1. Search Query in Web of Science

Topic	"artificial intelligence" OR "machine intelligence" OR "neural network*" OR "machine learn*" OR "deep learn*" OR "natural language process*" OR "thinking computer system" OR "expert system" OR "evolutionary computation" OR "hybrid intelligent system*" OR "fuzzy logic" OR "computer vision" OR "genetic algorithm*" OR "agent-based systems" OR "intelligent agents" OR "intelligent tutoring" OR "autonomous robots"
Categories	Education Educational Research OR Psychology Educational OR Education Scientific Disciplines OR Education Special
Document types	Article
Time span	2001-2021
Indexes	SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI.

The last screening took place in March 2021. No filtering was made for the language of the publications. A total of 2,686 studies were reached. Bibliographic data of these publications were also reached.

## **Data Analysis**

The data obtained from the study were analyzed through the descriptive analysis technique. In addition, density maps for various variables were created by using VOSviewer visual mapping program. Before the maps were created, terms that meant the same were combined. The images obtained are presented in the Findings section.

## Results

### Distribution of Publications by Years and Country

In the study, the distribution of the studies published in the WoS database by year was examined first. The findings obtained are presented in Figure 1.

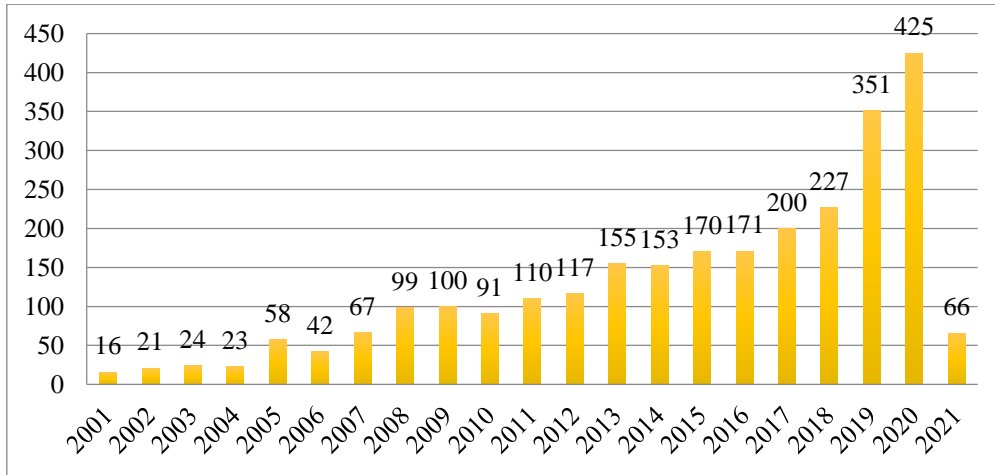


Figure 1. Distribution of Publications by Years

When Figure 1 is analyzed, it is seen that the number of publications between 2001-2004 was low, but there was an increase in the number of publications towards the later years. Moreover, studies published after 2015 constitute 60% of the total publications. The years with the greatest number of publications were 2019 ( $f=351$ ) and 2020 ( $f=425$ ).

The distribution of the publications in the field by country was also examined. The top 10 countries with the most publications are listed in Figure 2.

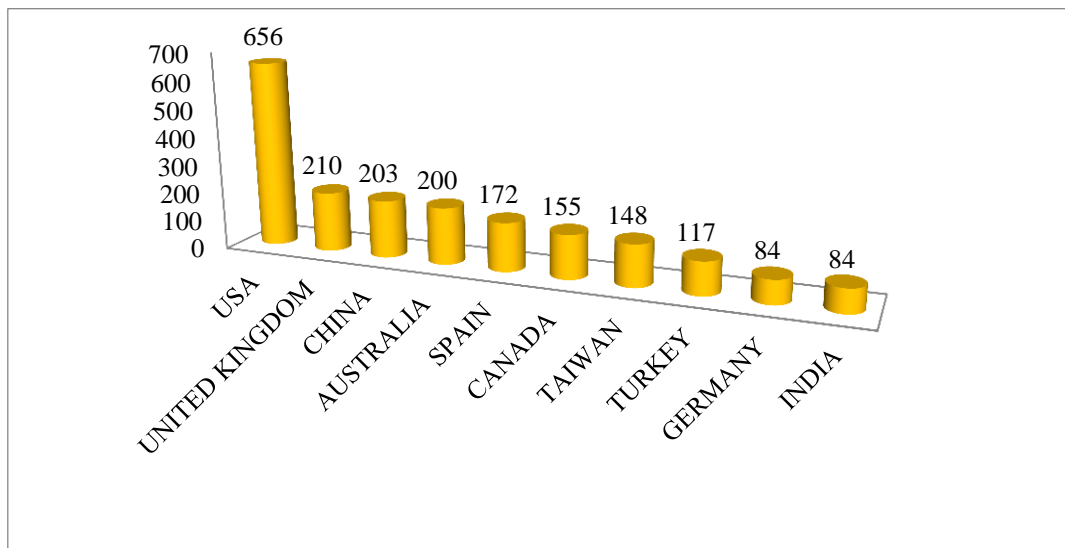


Figure 2. Distribution of Publications by Country

When Figure 2 is examined, it is seen that most of the studies were carried out in USA (f=656). United Kingdom (f=210) followed the list, China (f=203), Australia (f=200), Spain (f=172) and others.

**Citation Analysis (Journal, Author, Institution and Document)**

Citation analysis of the journals with the highest number of publications on the subject in WoS was examined first. The relevant data is presented in Table 2.

Table 2. Journal Distribution of Publications and Number of Citations

<b>Journal</b>	<b>Number of articles</b>	<b>Number of citations</b>	<b>Link strength</b>	<b>Number of citations per research</b>
Computers & Education	135	4318	204	32.0
International Journal of Emerging Technologies in Learning	90	244	17	2.7
Computer Applications in Engineering Education	75	360	45	4.8
IEEE Transactions on Learning Technologies	62	552	79	8.9
Educational Technology Society	61	916	78	15.0
International Journal of Engineering Education	56	176	54	3.1
Education and Information Technologies	53	199	21	3.8
IEEE Transactions on Education	38	1056	64	27.8
Interactive Learning Environments	38	213	34	5.6
International Journal of Electrical Engineering Education	34	66	5	1.9

When the journal-based distribution of the publications is examined, the most published journals are found to be Computers & Education (f=135) and International Journal of Emerging Technologies in Learning (f=90). When the number of citations per publication is examined, it is seen that Computers & Education, IEEE Transactions on Education and Educational Technology Society stand out.

The study also examined the authors of the articles on the subject based on WoS citation data. Table 3 contains the number of articles and citations of the most productive and influential authors on the subject. The top 10 authors with at least two articles in the relevant references are listed according to their citation count. When the table is examined, it is seen that Vanlehn, K. and Chen, C. –M. stand out in terms of productivity and impact.

Table 3. Author Rankings

<b>Author</b>	<b>Institution</b>	<b>Country</b>	<b>Number of articles</b>	<b>Number of citations</b>
Vanlehn, Kurt	Arizona State University	USA	10	519
Chen, Chih-Ming	National Chengchi University	Taiwan	10	437
Virvou, Maria	University of Piraeus	Greece	6	408
Amandi, Analia	UNICEN Natl University	Argentina	5	375
Schiaffino, Silvia	UNICEN Natl University	Argentina	3	348
Garcia, Patricio	Universidad de La Frontera	Chile	2	339
Ke, Fengfeng	Florida State University	USA	4	317
Mclaren, Bruce M.	Carnegie Mellon University	USA	7	309
Aleven, Vincent	Carnegie Mellon University	USA	10	307
Koedinger, Kenneth R.	Carnegie Mellon University	USA	6	266

In the study, the article and citation rankings of the institutions where the authors work were examined. The related data are given in Table 4.

Table 4. Citation Ranking of Institutions

<b>Institution</b>	<b>Country</b>	<b>Number of articles</b>	<b>Number of citations</b>	<b>Link strength</b>
Carnegie Mellon University	USA	26	654	57
University of Memphis	USA	24	251	54
Arizona State University	USA	22	600	111
Michigan State University	USA	17	126	47
Georgia State University	USA	17	51	13
National Taiwan University of Science Technology	Taiwan	16	542	38
University of Sydney	Australia	15	229	21
National Chengchi University	Taiwan	14	513	36
National Taiwan Normal University	Taiwan	14	245	32
Nanyang Technological University	Singapore	14	192	7

When Table 4 is examined, Carnegie Mellon University stands out as the most productive institution in terms of number of publications and citations. This institution is followed by University of Memphis in terms of the number of publications. Arizona State University is the third most productive institution in terms of number of publications, but ranks second in terms of number of citations.

Within the scope of the research, the data obtained by examining the most cited publications on the subject are shown in Table 5.



Table 5. Most Cited Articles

NO	Article	Authors	Year	Source	Number of citations
1	Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting Learning by Design (TM) into practice	Kolodner, J. L. et al.	2003	Journal of the Learning Sciences	439
2	The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems	VanLehn, K.	2011	Educational Psychologist	389
3	The conscientious consumer: Reconsidering the role of assessment feedback in student learning	Higgins, R. et al.	2002	Studies in Higher Education	322
4	Personalized e-learning system using item response theory	Chen, C.M. et al.	2005	Computers & Education	264
5	Engaging online learners: The impact of web-based learning technology on college student engagement	Chen, P. S. D.	2010	Computers & Education	244
6	AutoTutor: An intelligent tutoring system with mixed-initiative dialogue	Graesser, A.C. et al.	2005	IEEE Transactions On Education	238
7	Dynamics of affective states during complex learning	D'Mello, S. & Graesser, A.	2012	Learning and Instruction	224
8	Evaluating Bayesian networks' precision for detecting students' learning styles	Garcia, P. et al.	2007	Computers & Education	213
9	A reference model for learning analytics	Chatti, M. et al.	2012	International Journal of Technology Enhanced Learning	212
10	Combining software games with education: Evaluation of its educational effectiveness	Virvou, M. et al.	2005	Educational Technology & Society	212

The table above gives information about the authors and citation numbers of the most frequently cited publications in WoS. According to these data, the most frequently cited publication belongs to Kolodner et al. (2003) with 439 citations. The author is followed by the publications of VanLehn (2011) and Higgins et al. (2002), respectively.

**Co-author Analysis (Countries, Institution)**

The co-author analysis for the international cooperation of the publications published in WoS is presented in Figure 3. Here, each round figure represents a country. Large circles show the dominance of the countries. If there is a line between two country names, it indicates that these two countries work together. It also shows that the closer the two countries are, the stronger and wider the connections of these countries are.

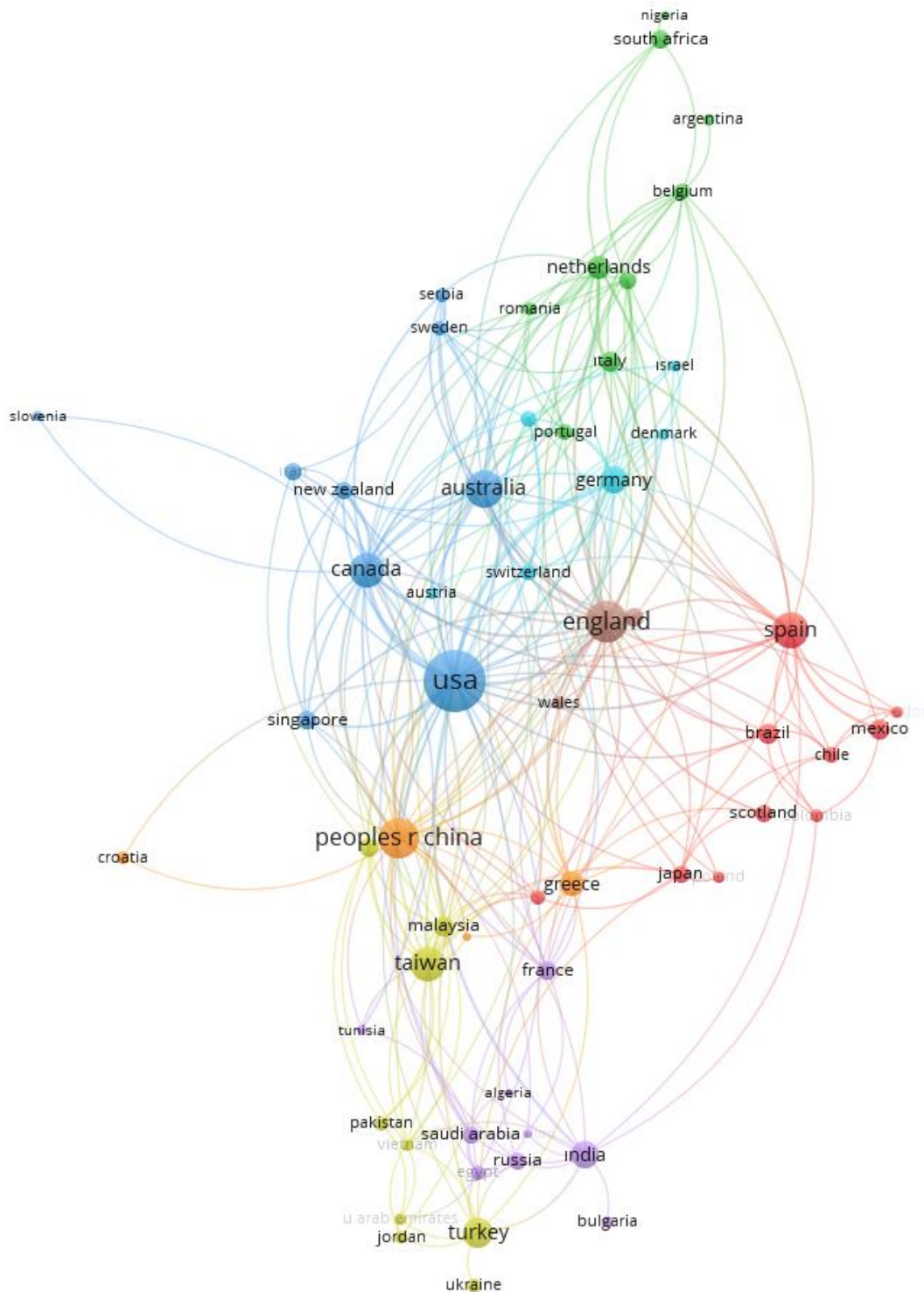


Figure 3. Network of Cooperation between Countries

When the countries of the co-authors were analyzed, it was determined that the USA worked with 38 countries, Taiwan with 34 countries and the UK with 32 countries. China followed the list (29 links), Canada (25 links), Germany (21 links) and others.

The co-author analysis for inter-institutional cooperation is presented in Figure 4. As can be seen from Figure 4, it is seen that Carnegie Mellon University, Arizona State University, National Taiwan University of Science Technology and Georgia State University are dominant.

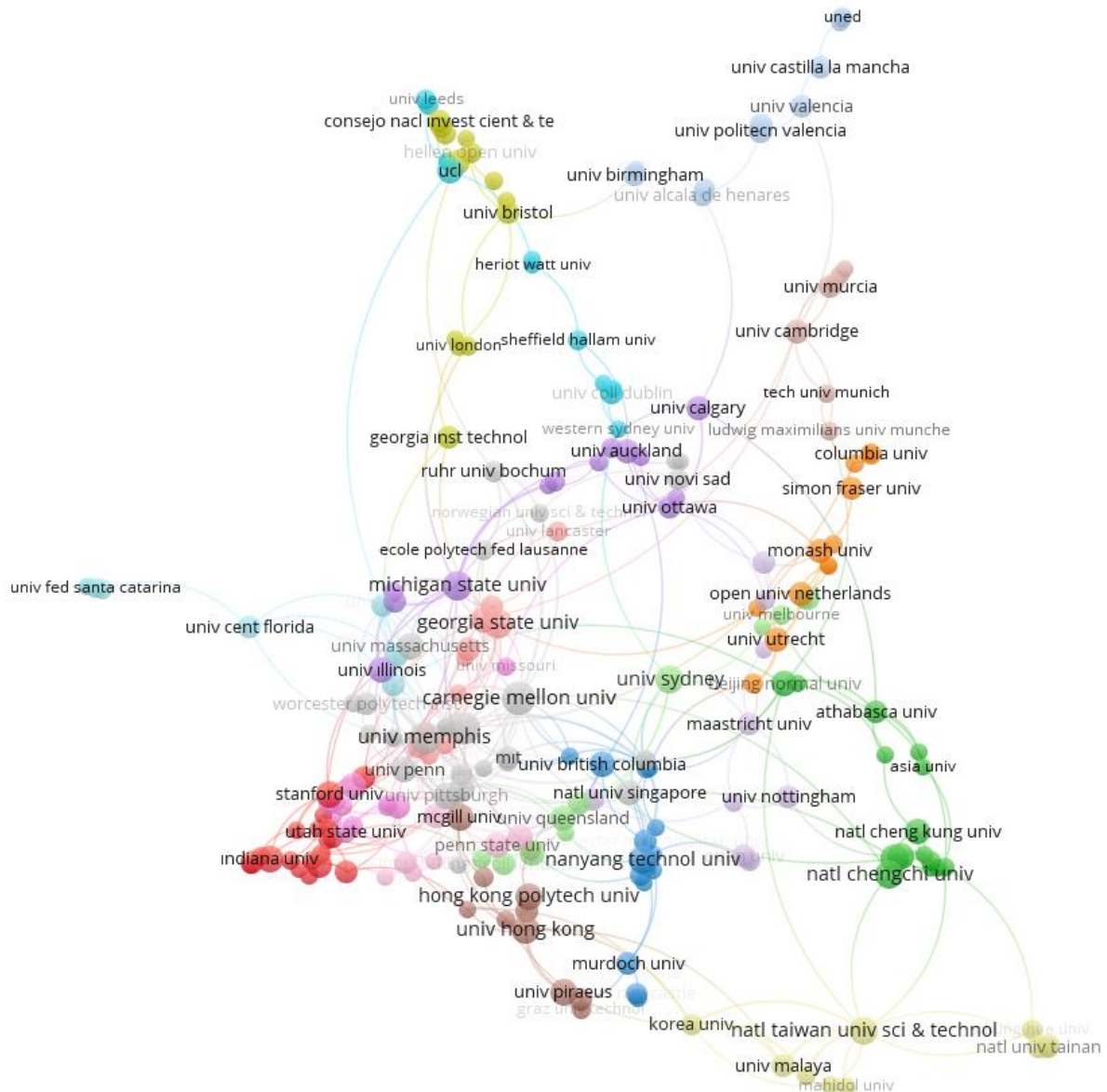


Figure 4. Institutional Cooperation Network

### Co-citation Analysis (Author)

The network structure of the co-citation analysis of the publications on the subject is given in Figure 5.

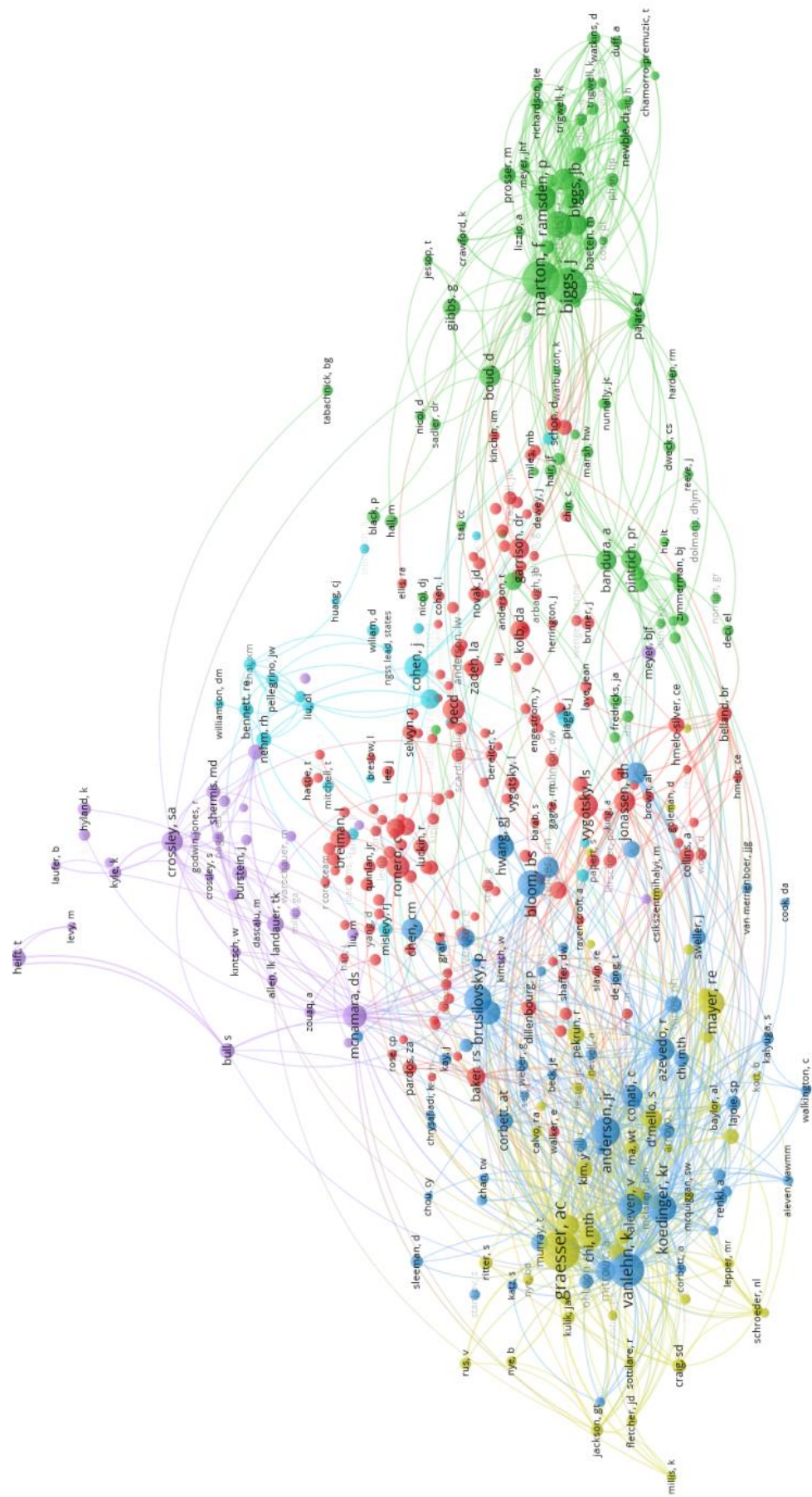
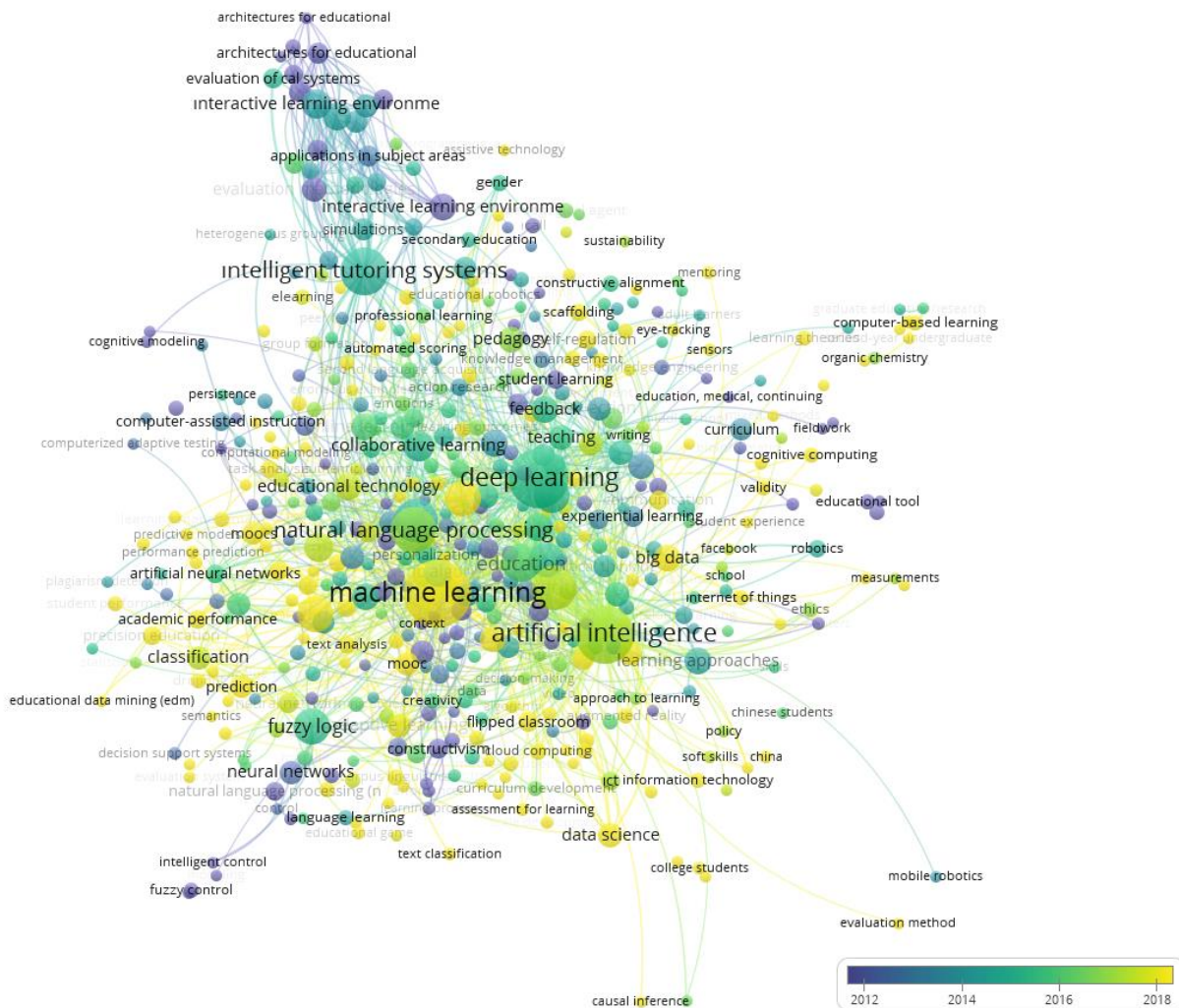


Figure 5. Co-citation (Author) Network

When the common citation network is examined, five different colored clusters are seen. Authors who receive many citations together are gathered in the same cluster. Publications in the center show that they are often cited from different fields and have more detailed connections with many clusters. When Figure 5 is examined in its entirety, the red, green, yellow, and blue clusters are large and more prominent than the others. Besides, authors such as Graesser, A. C., Biggs, J., Marton, F., Vanlehn, K., Anderson, J. R., Crossley, S. A. and Koedinger, K. R. appear to be nearly at the center and associated with many different clusters.

### **Co-occurrences Analysis**

The network structure of the relationships between keywords is given in Figure 6. A bigger circle size indicates a more frequently discussed subject, while the yellow ones show the most popular subjects.



**Figure 6. Keywords Network Based on Co-occurrence**

As can be seen from Figure 6, artificial intelligence, intelligent tutoring systems, machine learning, deep learning and higher education are located in the center of the map. These words are concepts that have been studied together with other clusters and have been identified as the most frequently used keywords. It is

noteworthy that popular topics are topics such as data science, learning analytics, computer-based learning, educational data mining and machine learning.

## **Discussion and Conclusion**

In this study, published scientific studies on artificial intelligence in education indexed in the WoS database were examined through descriptive and bibliometric analysis. VOSviewer software was used to analyze and visualize all this information. As a result of the research, it can be said that there were fluctuations in the number of publications from 2003 to 2014. However, it can be stated that there has been an increase in the number of publications in recent years; so, interest in artificial intelligence studies in education has increased. In the study conducted by Moreno-Guerrero et al. (2020), it was stated that the number of scientific studies on educational artificial intelligence has been irregular until today, but this study topic aroused the interest of the scientific community in 2018 and 2019. In the studies conducted by Song and Wang (2020) and Chen, Xie, and Hwang (2020), it was determined that the number of publications on educational artificial intelligence generally increased every year. When the distribution of the studies by country is examined, it is seen that USA and United Kingdom, China and Australia stand out. It was determined that similar results have been reached on the subject in the literature, and the country with the most publication on educational artificial intelligence was USA (Chen, Xie, & Hwang, 2020; Moreno-Guerrero et al., 2020; Song & Wang, 2020).

When the distribution of the journals with the highest number of publications on the subject was examined, it was determined that important journals related to the use of technology in education stood out. The most published journals were *Computers & Education* and *International Journal of Emerging Technologies in Learning*. When the number of citations per article was examined, the journals *Computers & Education*, *IEEE Transactions on Education* and *Educational Technology Society* were found to be the most popular ones. Again, in the study conducted by Moreno-Guerrero et al. (2020), *Computers & Education* was found to be among the most published journals. In the study conducted by Chen, Xie, and Hwang (2020), most of the published scientific research on artificial intelligence in education were proceedings papers and in terms of scientific journals, *Computers & Education*, *International Journal of Engineering Education*, *IEEE Transactions on Education* and *Computer Applications in Engineering Education* stood out.

When the number of articles and citations of the most productive and influential authors were examined, it was found that VanLehn, K. and Chen, C. –M. were in the leading position. Since these authors are among the leading authors on artificial intelligence in the literature, it can be stated that this result is not surprising. Five of the 10 most prolific authors in publishing articles on this subject are located in USA, which demonstrates the country's superiority in this field. Moreno-Guerrero et al. (2020) reached the conclusion that Blandford, A. E., Bondarovskaya, V. M. and Cumming, G. were the most published authors in this field. In the study by Chen, Xie, and Hwang (2020), it was concluded that 15 of the 44 most productive authors were in the USA. According to the research results, the most frequently cited study belongs to Kolodner et al. (2003). The author is followed by the publications of VanLehn, K. (2011) and Higgins et al. (2002), respectively. According to Moreno-Guerrero et al. (2020), the most cited publications about artificial intelligence in education belong to Devedzik

(2004), Parton (2006), and Nagy and Burch (2009). In the study by Chen and Hwang (2020), it was determined that the most frequently cited publication belongs to Dautenhahn (2007).

When institutions are considered in terms of productivity, Carnegie Mellon University stands out as the most productive institution in terms of number of citations. This institution is followed by University of Memphis and Arizona State University in terms of the number of publications. The top five institutions are located in the USA. In addition, three institutions are located in Taiwan, one institution in Australia and one institution in Singapore. In the study of Moreno-Guerrero et al. (2020), the reference institution for the publications on educational artificial intelligence was indicated as Open University UK. In the study conducted by Chen, Xie, and Hwang (2020), the most productive institutions were indicated as the University of California System, University System of Georgia, and Pennsylvania Commonwealth System of Higher Education.

When the countries of the co-authors were examined, it was determined that USA worked with 38 countries, Taiwan with 34 countries and UK with 32 countries. When the institutions of co-authors were examined, it was found that Carnegie Mellon University, Arizona State University, National Taiwan University of Science Technology and Georgia State University were dominant. Co-occurrences analysis reflects the content analysis of the examined studies and reveals commonly used concepts. The analysis showed that artificial intelligence, intelligent tutoring systems, machine learning, deep learning and higher education were standing out in the clusters. In the study conducted by Chen, Xie, and Hwang (2020), the most frequently used keywords related to artificial intelligence in education were revealed as education, machine learning, robotics, artificial intelligence, deep learning, system, and educational robotics.

Artificial intelligence, whose main theme is to develop intelligent systems by understanding intelligence, is an important and popular computer sciences discipline. This concept, which is growing and changing day by day, has become widespread especially in the field of education, and the investments made in this technology have increased. This research has presented an overview of the developments in the studies on artificial intelligence in education indexed in the WoS database. In this context, the fact that the publications in other databases could not be included in the analysis can be interpreted as a limitation. Additionally, the research was limited to the years 2001-2021. Again, papers, books and book chapters published on the subject were not included in the analysis. In this context, it is thought that in future research, the chance of researchers to reach new findings will increase by including papers, theses, books and book chapters in addition to the articles in WoS. In order to understand the role of artificial intelligence in higher education policy, there is a need to include more research on artificial intelligence.

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