www.ijemst.net

Artificial Intelligence in Education: A Science Mapping Approach

Abdullatif Kaban
Ataturk University, Turkiye

To cite this article:

Kaban, A. (2023). Artificial intelligence in education: A science mapping approach. *International Journal of Education in Mathematics, Science, and Technology (IJEMST), 11*(4), 844-861. https://doi.org/10.46328/ijemst.3368

International Journal of Education in Mathematics, Science and Technology

2023, Vol. 11, No. 4, 844-861 https://doi.org/10.46328/ijemst.3368

Artificial Intelligence in Education: A Science Mapping Approach

Abdullatif Kaban

Article Info

Article History

Received:
03 December 2022
Accepted:
24 April 2023

Keywords

Education
Artificial intelligence
Machine learning
Deep learning
Bibliometric analysis

Abstract

While using artificial intelligence in education is a popular field of study for researchers, it has become a joint application for educational institutions. Educational institutions are trying to establish artificial intelligence-based systems to improve the existing education systems. On the other hand, education researchers want to determine which artificial intelligence models are the most effective. To provide an in-depth resource for both researchers and educators on the use of artificial intelligence in education, this study aims to make a bibliometric analysis of articles related to artificial intelligence in education. After the query was made in the Web of Science database, 1153 articles related to the subject were obtained. As a result of the bibliometric analysis of the articles obtained, the most influential journals are Education and Information Technologies and Computers & Education, and the most influential authors are Scouller, Biggs, and Hwang. After 2019, it has been observed that there has been a significant increase in the number of studies, the first examples of which were found in 1985. It is thought that this study, which provides results on the most cited publications, trending topics, thematic map of keywords, and co-occurrence network, will serve as a bedside resource for both educators and researchers. Implications of the findings for theory and practice are discussed.

Introduction

The first examples of the use of artificial intelligence in education can be found in the studies presented at the Computer Assisted Learning (CAL-83) and Artificial Intelligence and Education conferences held in 1983. Good (1987) defined artificial intelligence-based computers in education as intelligent computer-assisted instruction in those years. There were two different approaches to using artificial intelligence in education: Intelligent Tutoring Systems (O'Shea & Self, 1983; Sleeman & Brown, 1982) and Computer Assisted Learning Environments (Lawler, 1984; Papert, 1980). The application of expert systems has resulted in tutoring systems that understand what they are teaching and have a variety of teaching tactics that may be deployed selectively based on the many components of the "user model" generated by the system through past interactions (Yazdani & Lawler, 1986). When computer-assisted learning environments are mentioned, the use of computers in various classroom teaching applications comes to mind. Intelligent teaching systems, on the other hand, focus on the expertise obtained from the interpretation of students' contacts with the subject (Sharma & Harkishan, 2022).

Today, we see studies on the use of artificial intelligence in education in different ways as early warning systems (Jokhan et al., 2018), educational data mining (Nahar et al., 2021), predicting student performance (Shen et al., 2022), and predicting school dropouts (Lykourentzou et al., 2009). Deep learning is one of the most frequently used methods, especially in predicting student performance. Such studies focus on data from learning management systems. On the other hand, early warning systems are based on the logic of analyzing student data with artificial intelligence methods and predetermining at-risk students (Bañeres et al., 2020). While doing this, the movements made by the students on the teaching management system are analyzed with artificial intelligence methods and a profile structure is created for risky students. Students approaching this profile are informed about the situation with certain warnings and they are tried to be removed from the risk group. Early warning systems focus on early detection of students with low academic achievement and a tendency to drop out.

Educational data mining primarily aims to analyze such data by utilizing statistical, machine learning, and data mining algorithms on different training data to solve educational research problems (Romero & Ventura, 2010). The data accumulated every year in instructional management systems, where every movement of the student is recorded, constitute a very important resource for educational data mining. These data are analyzed by basic statistical methods as well as by artificial intelligence methods. As a result of the analyzes made, it tried to predict the progress of the students during the term or their possible success at the end of the term. For example, in his study Aydoğdu (2020) claimed that he developed an artificial intelligence model that predicts student performance with 80% success by using variables of gender, content score, time spent on content, number of accesses to content, assignment score, number of participations in live sessions, total time spent in live sessions, number of participants in archived lectures, and total time spent in archived lectures. Basnet et al. (2022) developed models that could predict school dropouts with machine learning and deep learning methods with a success rate of over 85%, using the data obtained from a MOOC system. Al-Sudani and Palaniappan (2019) found that artificial neural networks were the most successful among the artificial intelligence models used by students to classify their final grades.

In the literature, it is possible to come across studies that make a bibliometric analysis of studies related to different forms of artificial intelligence use in education. Agbo et al. (2021) conducted a study that conducted a bibliometric analysis of studies on intelligent learning environments. In the study, the articles published in the Scopus database were examined and focused on intelligent learning environments, a branch of educational artificial intelligence. Hinojo-Lucena et al. (2019) focused on artificial intelligence in higher education in their bibliometric analysis study. Song and Wang (2020) scanned the Scopus database and made a bibliometric analysis of educational artificial intelligence studies between 2000-2019. The study focused on the distribution of educational artificial intelligence studies by country and how it developed from 2000 to 2019. Taş (2021), on the other hand, made a literature review on artificial intelligence studies in education. Baek and Doleck (2020) conducted a bibliometric analysis of articles published in the Journal of Artificial Intelligence in Education. Talan (2021), on the other hand, examined the articles between the years 2001-2022 in the bibliometric analysis of studies on artificial intelligence in education, while Azza Abdullah (2022) examined the articles between the years 2010-2020. All these studies provide valuable information regarding the subject and year they cover. However, a more comprehensive, detailed, and in-depth study covering all years is needed. Based on this need, this study decided

to examine all studies related to artificial intelligence in education scanned in the Web of Science database. Therefore, this study is aimed to examine the papers on artificial intelligence in education from an international perspective and to reveal the trends in artificial intelligence in education in terms of various variables by using the bibliometric mapping method. For this purpose, answers to the following questions were sought:

1. Which are the most relevant journals on artificial intelligence in education?
2. Which are the most relevant authors on artificial intelligence in education?
3. Which are the most relevant articles on artificial intelligence in education?
4. What are the keywords and trending topics of studies on artificial intelligence in education?
5. What are the thematic clusters according to co-occurrence analysis on author keywords of studies on artificial intelligence in education?

Method

Research Design

In this study, the bibliometric mapping method was used to examine the articles written on artificial intelligence in education regarding various variables. Bibliometric mapping is a spatial representation of relationships between disciplines, fields, individual publications, or authors (Small, 1999). Bibliometric studies allow the identification of trends in the field by quantifying some features of research in a particular field and evaluating the results (Kasemodel et al., 2016). Bibliometric analysis ensures that the studies, researchers, institutions, and scientific flow related to the determined scientific subject are followed (Martí-Parreño et al., 2016). Quantitative analysis and statistics are used to identify publication patterns within a particular field of literature. Researchers use bibliometric evaluation methods to determine the influence of a single author or to identify the relationship between two or more authors or works (Thanuskodi, 2010). The accepted analysis procedure consists of three main steps; research mapping, quantitative analysis, and analysis of trends and patterns.

Obtaining the Meta-Data Set

A search result of the query expression shown in Figure 1 on Web of Science in October 15, 2022 yielded 9387 publications. Then, 1153 articles were obtained as a result of document types (document types = articles), Web of Science category (WOS Categories = education educational research), and language (languages = English) filters. Descriptive data of the studies obtained are given in Table 1.

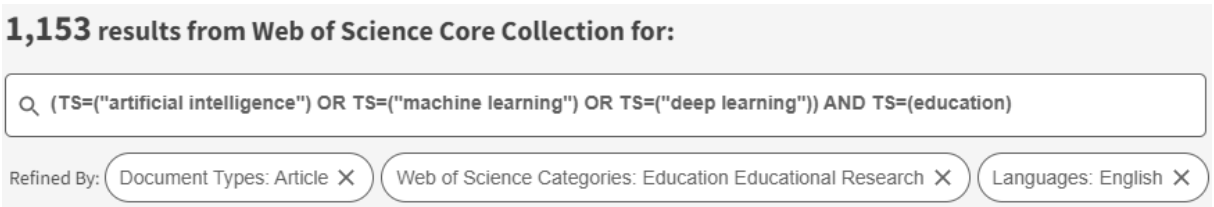

Figure 1. Web of Science Search and Filter Query

Table 1. Descriptive Data of Obtained Studies

Description	Results
Timespan	1985:2022
Sources (Journals)	340
Documents	1153
Average citations per doc	11.08
References	45532
Authors	2853
Single-authored docs	252
Co-Authors per Doc	2.81

When Table 1 is examined, it is seen that 1153 articles obtained from 340 different sources started in 1985 and continue until today. It is seen that the average citation rate per document is 11.08. In total, 45532 references are cited. In these studies, in which 2853 authors took part, the number of single-author documents is 252. The number of co-authors per document is 2.81. The distribution of the number of studies by year is given in Figure 2. It is seen that the number of publications started to climb after 2004, and there was a severe increase in 2019.

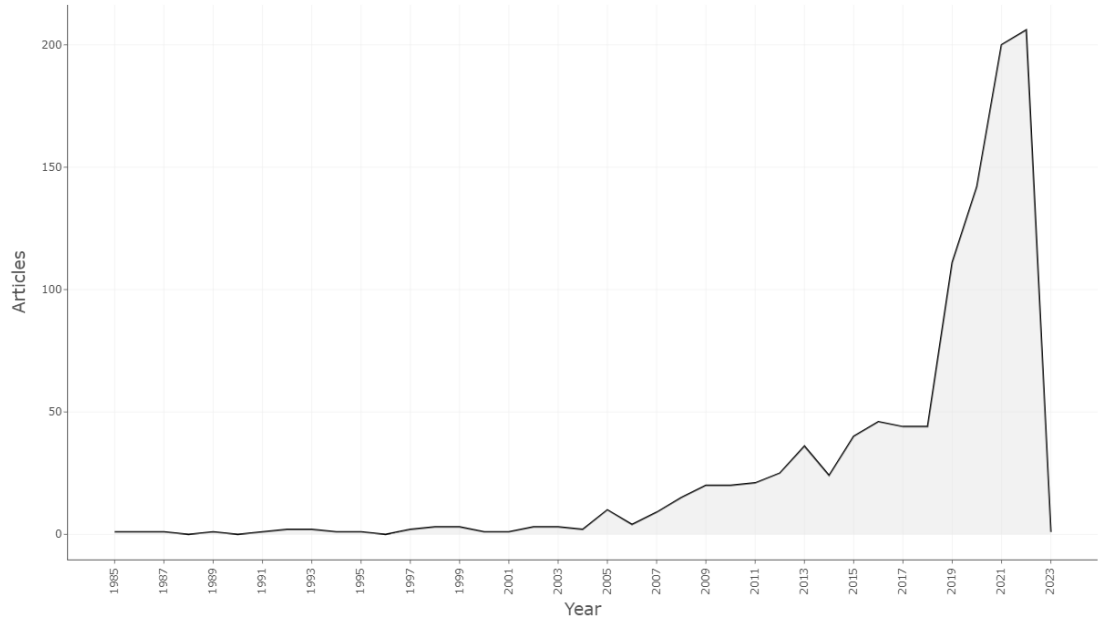

Figure 2. Annual Scientific Production

Data Analysis

The metadata data of the articles published in the Web of Science related to the subject were downloaded in BibTeX file format and analyzed using the "bibliometrix" library developed for the R programming language. The Bibliometrix is a reliable, open-source tool developed to perform a comprehensive scientific literature science mapping analysis (Aria & Cuccurullo, 2017). In the study, the VOSviewer program was also used to analyze the data. When creating visualization maps using bibliographic data, RIS files were exported from Web of Science

and then imported into VOSviewer. VOSviewer software uses natural language processing techniques to find and extract keywords from recording titles and abstracts.

Results

Most Relevant Journals

The compilation of bibliographic matching, citation analysis, and co-citation analysis highlights the journals that have made the largest contribution to the growth of AI studies in education since 1985. 275 of the 340 journals in the data set made 12776 citations to each other in total, reaching an average of 46.46 citations per journal. Table 2 lists the 10 journals with the most publications, the most co-citations, and the most bibliometric couples.

Table 2. Comparison of Journals in Citation, Co-citation and Bibliographic Coupling

Citation Analysis				**Co-Citation**			**Bibliographic Coupling**		
No	**Sources**	**P**	**TC**	**No**	**Sources**	**TC**	**No**	**Sources**	**LS**
1	Education and Information Technologies	62	428	1	Computers & Education	1074	1	Education and Information Technologies	3365
2	International Journal of Emerging Technologies in Learning	58	336	2	British Journal of Educational Psychology	446	2	Computers & Education	3208
3	Computers & Education	42	2423	3	Computers in Human Behavior	445	3	Education Sciences	2126
4	Education Sciences	35	210	4	British Journal of Educational Technology	378	4	Educational Technology & Society	1699
5	Interactive Learning Environments	32	349	5	Higher Education	368	5	Interactive Learning Environments	1555
6	Educational Technology & Society	29	277	6	Studies in Higher Education	303	6	British Journal of Educational Technology	1197
7	British Journal of Educational Technology	24	451	7	Assessment & Evaluation in Higher Education	275	7	Assessment & Evaluation in Higher Education	1176
8	IEEE Transactions on Learning Technologies	24	199	8	Educational Technology & Society	262	8	International Journal of Educational Technology in Higher Education	1170
9	Frontiers In Education	18	18	9	Journal of Educational Psychology	242	9	Frontiers in Education	1121
10	BMC Medical Education	16	116	10	Lecture Notes in Computer Science	231	10	Higher Education Research & Development	1109

Note: P=Papers, TC= Total Citations, LS= Link Strength

The top three journals with the most publications are Education and Information Technologies (Papers:62, citations: 428), International Journal of Emerging Technologies in Learning (papers:58, citations: 336) Computers & Education (papers: 42, citations: 2423). In addition, the analysis of common citations reveals that 311 out of 20098 cited journals received at least 20 citations. Computers & Education (1074), British Journal of Educational Psychology (446), and Computers in Human Behavior (445) are the journals with the most cited articles. Finally, a minimum requirement for bibliographic coupling analysis was determined to be at least two articles per journal (Ferreira, 2018). 172 out of 340 journals met this criterion. Among these, the three journals with the highest connectivity were Education and Information Technologies (3365), Computers & Education (3208) and Education Sciences (2126).

Most Relevant Authors

Although artificial intelligence studies in education are not very new, the interest of education researchers in this field has increased significantly in recent years. There are 1153 articles produced by 2853 authors alone or together in the data set. 3027 authors were cited in these articles. Web of Science data contains only the information of the first authors of the cited articles. Other authors are not considered in the co-cited analysis. The fact that an author has produced the most publications does not mean that he has the highest citations and total link strength. For this reason, the focus is on the number of citations and the strength of connection in joint studies rather than the number of publications produced by the authors. According to the results of the author analysis, the findings about the total number of citations of the authors, the number of citations in terms of working together, and their connection strength are given in Table 3.

Table 3. Comparison of Authors in Citation, co-citation and Bibliographic Coupling

Citation Analysis			**Co-Citation**			**Bibliographic Coupling**		
No	**Author**	**TC**	**No**	**Author**	**TC**	**No**	**Author**	**LS**
1	Scouller K.	399	1	Biggs, J.	216	1	Hwang, G. J.	3851
2	Higgins R.	351	2	Marton, F.	158	2	Neimann, T.	3811
3	Hartley P.	351	3	Ramsden, P.	102	3	Wang, V. C. X.	3811
4	Skelton A.	351	4	Entwistle, N.	101	4	Filius, R. M.	3049
5	Chen P. S. D.	315	5	Williamson, B.	95	5	Chiu, T. K. F.	2934
6	Lambert A. D.	315	6	Biggs, J. B.	86	6	Jacobs, G.	2821
7	Guidry K. R.	315	7	OECD	86	7	Murray, M.	2821
8	Jamet E.	289	8	Kember, D.	82	8	De Kleijn, R. A. M.	2780
9	Amandi A.	274	9	Hwang, G. J.	72	9	Grobbee, D. E.	2780
10	Garcia P.	274	10	Romero, C.	72	10	Prins, F. J.	2780

Note: TC= Total Citations, LS=Link Strength

When Table 3 is examined, it is seen that the most cited authors among 2853 authors with articles in the data set used in this study are Scouller (399), Higgins (351), Hartley (351), Skelton (351), Chen (315), Guidry (315), Lambert (315), Jamet (289), Amandi (274), Garcia (274). Of the 32187 cited authors, only 106 were cited more

than 20 times for co-citation results. These top five are Biggs (216), Marton (158), Ramsden (102), Entwistle (101) and Williamson (95). Finally, a bibliographic link reveals that the most relevant authors are Hwang (3851), Neimann (3811), Wang (3811), Filius (3049) and Chiu (2934), indicating that the citation network is more centralized and closely intertwined with discussion.

Most Relevant Articles

Considering the volume of empirical output given in Figure 2, it is understood that there has been an unprecedented increase in the number of articles examining artificial intelligence in education after 2018 when the discipline started to mobilize after 2005. The bibliographies of the dataset were analyzed using co-citation analysis, which provides insight into the contributions made by the primary references. When the minimum number of citations is 20, 173 articles remain out of 1153 articles in the data set. The first three of these are articles by Scouller (1998), Higgins et al. (2002), and Chen et al. (2010). 1153 articles within the scope of the study were examined in terms of citation, co-citation, and bibliometric matching and the results are presented in Table 4.

Table 4. Comparison of Documents in Citation, Co-citation and Bibliographic Coupling

Citation Analysis			**Co-Citation**			**Bibliographic Coupling**		
No	**Author**	**TC**	**No**	**Author**	**TC**	**No**	**Author**	**LS**
1	K Scouller (1998)	399	1	F Marton (1976)	74	1	Neimann (2017)	1624
2	R Higgins (2002)	351	2	J Biggs (2001)	59	2	Jacobs (2010)	1246
3	PSD Chen (2010)	315	3	J Biggs (1987)	41	3	Chen (2010)	998
4	S Erhel (2013)	273	4	O Zawacki-Richter (2019)	33	4	Lee (2017)	813
5	P Garcia (2007)	238	5	V Braun (2006)	32	5	Gilbert (2012)	753
6	N Vos (2011)	200	6	FD Davis (1989)	30	6	Leiva-Brondo (2020)	512
7	I Lykourentzou (2009)	181	7	R. Luckin (2016)	30	7	Buyukozturk (2010)	496
8	TFN Laird (2008)	170	8	F Marton (1976)	29	8	Maciejewski (2016)	433
9	F Ke (2010)	134	9	L Vygotsky (1978)	26	9	How (2019a)	402
10	E Enright (2010)	132	10	NJ Entwistle (1983)	23	10	Faranda (2021)	382

Note: TC= Total Citations, LS=Link Strength

This study demonstrates the usefulness of a comparative approach to evaluating effective articles, showing how the three criteria yield significantly different results. According to citation analysis, Scouller (1998) wrote the most cited article. The aggregated citations are more likely to be discovered in older journals and accumulate over time. Co-citation analysis is expressed as the frequency at which two articles are cited together by other articles. According to the analysis, the study by Marton (1976) had the highest citation amount. Bibliometric matching occurs when two articles refer to a common third work in the bibliography list. As the number of citations

increases, the link strength of both studies increases. According to the bibliometric match analysis performed in this study, the study with the highest link strength was the book chapter of Neimann and Wang (2017).

Keywords and Trending Topics

Analyzing the keywords used by the authors in the publications is a crucial tool in determining the trending topics and presenting ideas to the researchers who will work on the topic (Y. Song et al., 2019). Keyword analysis helps to determine the topic and focus of that post quickly. Articles scanned in Web of Science have KeyWords Plus data besides their keywords. Although these data are not included in the article's title, they are automatically derived from frequently repeated words in the titles of the references in the bibliography list. Based on a proprietary algorithm specific to Clarivate databases, KeyWords Plus increases the power of citation-reference search by searching across disciplines for all articles with standard references (Clarivate, 2022). The 10 most repeated KeyWords Plus words are education (*f*=139), students (*f*=94), performance (*f*=82), higher-education (*f*=68), design (*f*=49), technology (*f*=45), knowledge (*f*=42), science (*f*=42), achievement (*f*=37), model (*f*=35). On the other hand, the 10 most repeated words in authors keywords are artificial intelligence (*f*=170), machine learning (*f*=153), deep learning (*f*=122), education (*f*=109), learning (*f*=108), higher education (*f*=89), learning analytics (*f*=40), e-learning (*f*=37), assessment (*f*=34), educational data mining (*f*=29). The graph that gives the distribution of the frequency of use of the authors' keywords by years is given in Figure 3.

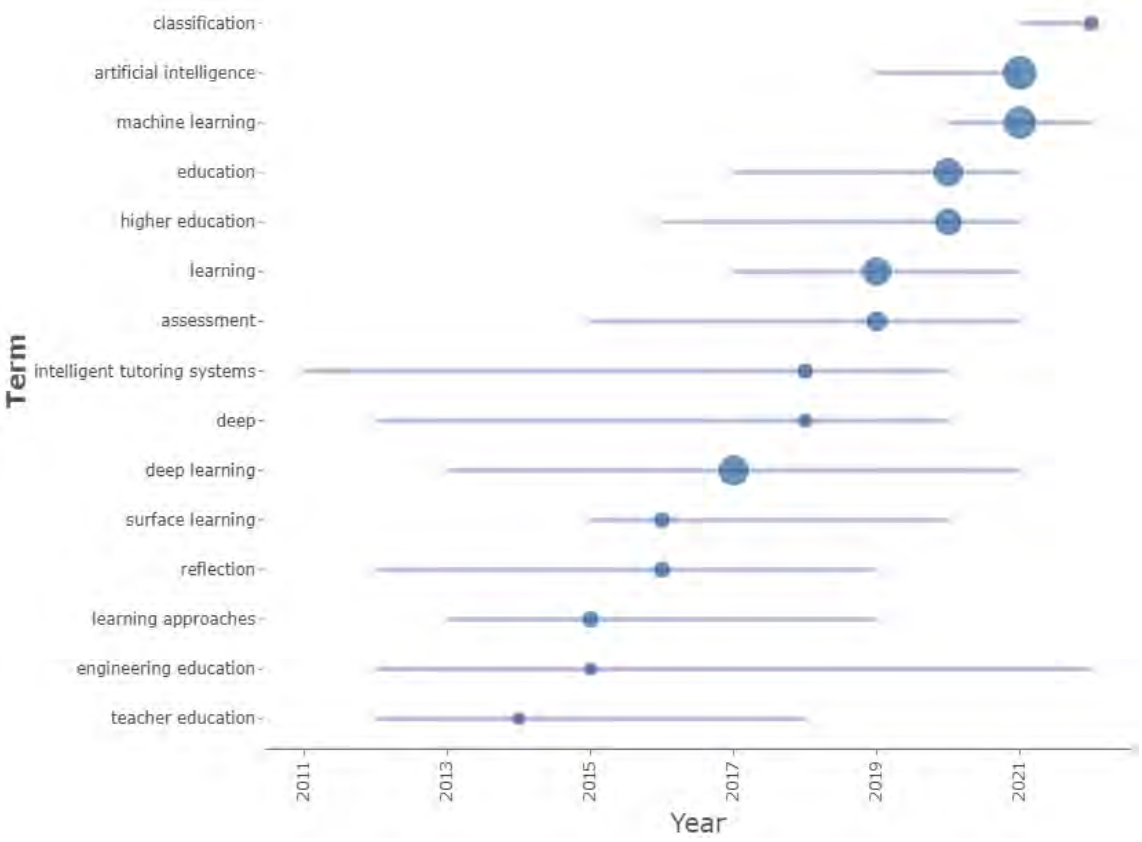

Figure 3. Trending Topics

The lines appearing in the trending topics graph, created with the criteria of at least 10 frequency frequencies and

top 2 keywords for each year, represent the years in which the relevant keyword was used. The size of the circles indicates the frequency of use, while the position of the circles indicates which year that keyword is the most popular in. For example, the keywords with the highest frequency, “artificial intelligence” (*f*=170) and “machine learning” (*f*=153) are the 2 most used keywords in 2011. The following keyword “deep learning” (*f*=122) became the most used keyword in 2017, although it was used between 2013-2021. Although it is not used much yet, the keyword “classification” (*f*=13) is on its way to becoming the most-used keyword in 2022.

Thematic Clusters

Co-occurrence analysis on author keywords examines the content of the publications in order to define the relevant research area expertise and determines the relationships between terms (López-Fernández et al., 2016). This study focused on identifying subject areas (clusters) that can be used as basic building blocks or research concepts (Manesh et al., 2021). The results of the cluster analysis are given in Table 5.

Table 5. Cluster Analysis

Cluster	Keyword	OC	LS	Cluster	Keyword	OC	LS
1 (Red)	deep learning	130	109	3 (Blue)	education	57	74
	assessment	32	35		learning	23	37
	learning approaches	19	22		data science	22	47
	surface learning	17	32		technology	19	30
	reflection	16	21		educational technology	18	35
	active learning	14	23		teaching	14	29
	experiential learning	13	11		AI	13	21
	learning approach	12	7	4 (Yellow)	artificial intelligence	154	139
	learning strategies	12	12		e-learning	35	35
	science education	12	14		online learning	26	31
	engineering education	11	8		artificial ıntelligence	25	25
	teacher education	11	7		distance education	16	19
	approaches to learning	10	12		online education	15	22
2 (Green)	machine learning	164	177		big data	13	27
	learning analytics	44	68	5 (Purple)	higher education	99	119
	educational data mining	32	45		blended learning	15	26
	pedagogy	24	19		artificial intelligence (AI)	11	2
	natural language processing	22	28		self-efficacy	11	11
	classification	13	22		student engagement	10	6
	data mining	12	19				
	artificial intelligence in education	10	10				
	collaboration	10	13				
	precision education	10	15				

OC: Occurrences; LS: Total Link Strength

Since author keywords are thought to describe the content of an article more comprehensively, author keywords were chosen for co-occurrence analysis instead of Keywords Plus, which is the analysis unit in Web of Science. Considering that this study aims to identify clusters of themes on the use of artificial intelligence in education, it is vital to examine the content of each article in detail. The clusters obtained as a result of the co-occurrence analysis and the keywords of these clusters are given in Table 5.

When Table 5 is examined, it is seen that the author keywords are divided into 5 clusters as a result of the co-occurrence analysis. As seen in Figures 4, 5 and 6, other keywords are gathered around these five clusters. The most visible keywords of each cluster are respectively cluster 1 – deep learning (130), cluster 2 - machine learning (164), cluster 3 – education (57), cluster 4 - artificial intelligence (154) and cluster 5 - higher education (99). This study tries to explain each cluster as comprehensively as possible, recognizing that no description can fully represent the richness of each cluster. Each of the five thematic clusters outlined below provides an overview of the essential subject areas that influence the perspective on the use of AI in education.

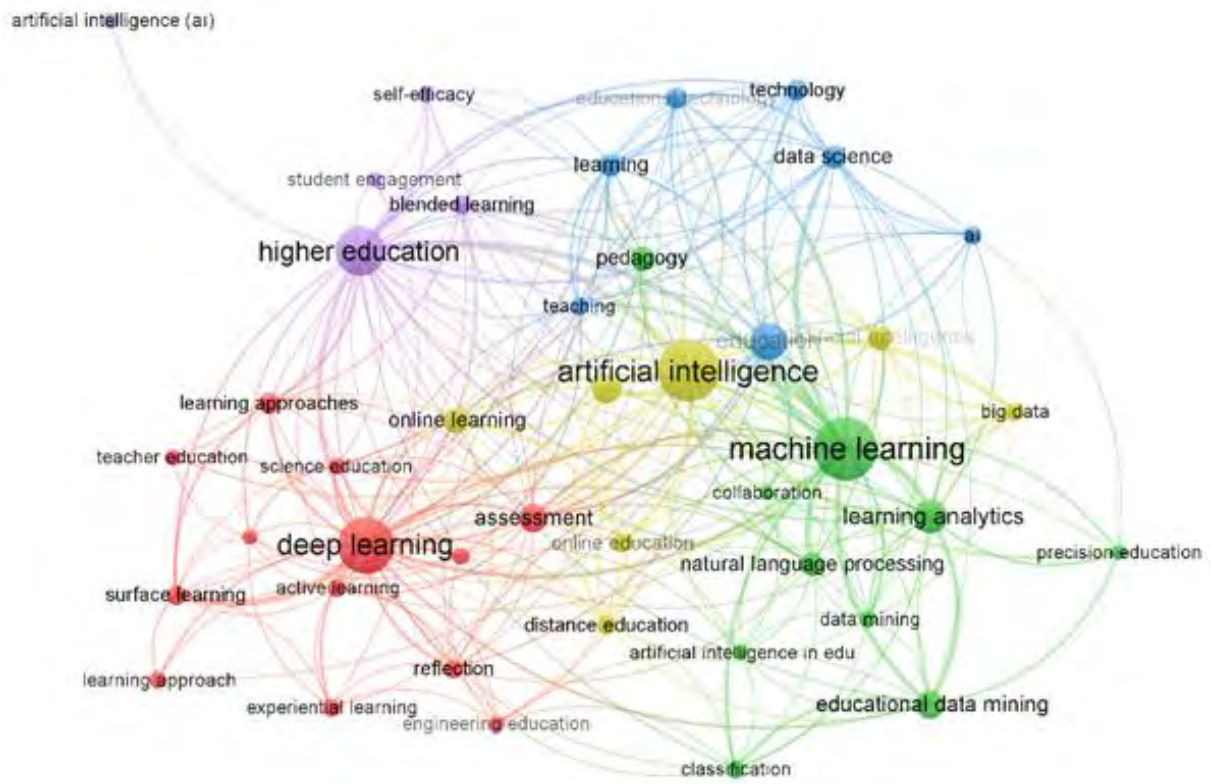

Figure 4. Network Diagram of Authors' Keywords Co-occurrences

The keyword co-occurrence network of the authors, in which each cluster is expressed with different colors, is given in detail in Figure 4. The size of the circles shown in the graph represents the frequency of occurrence of the relevant keyword. Figure 5 shows the usage density of each cluster as a result of the co-occurrence network analysis. The yellow colors in the graph show that the relevant theme is used extensively. Finally, as a result of the co-occurrence analysis of author keywords, the usage density of related keywords over time is shown in Figure 6.

Cluster 1 (red) focuses on various learning styles. Studies in this cluster generally examine the relationship between various learning approaches with deep learning and surface learning. When the publications using the keyword deep learning are examined, it is understood that deep learning here is not about machine learning, which is a sub-topic of artificial intelligence, but about the depth of learning that occurs in students. In these publications, it is seen that the keywords of surface learning are used together with deep learning. When **Hata! Başvuru kaynağı bulunamadı.** is examined, it is understood that the topics in this cluster are popular. However, looking at Figure 6, it is concluded that this density was in the years 2016-2017.

Cluster 2 (green) is more relevant to the keywords of the use of artificial intelligence in education, which is the main idea of this study. It is quite remarkable that the keywords such as learning analytics and educational data mining are included in the same cluster in relation to concepts such as pedagogy, collaborative learning and precision education. When Figure 5 is examined, it is seen that the keywords in this cluster are again used intensively. The yellow color of this set in Figure 6 is an indication that it is still used extensively today.

Cluster 3 (blue) covers studies in which education and technology are related in general. In this cluster, the concepts of education, learning, teaching, technology and technological education are given together. The green color of this cluster in Figure 5 indicates that it is less popular than other clusters. Looking at Figure 6, it is understood that this set was widely used in 2019.

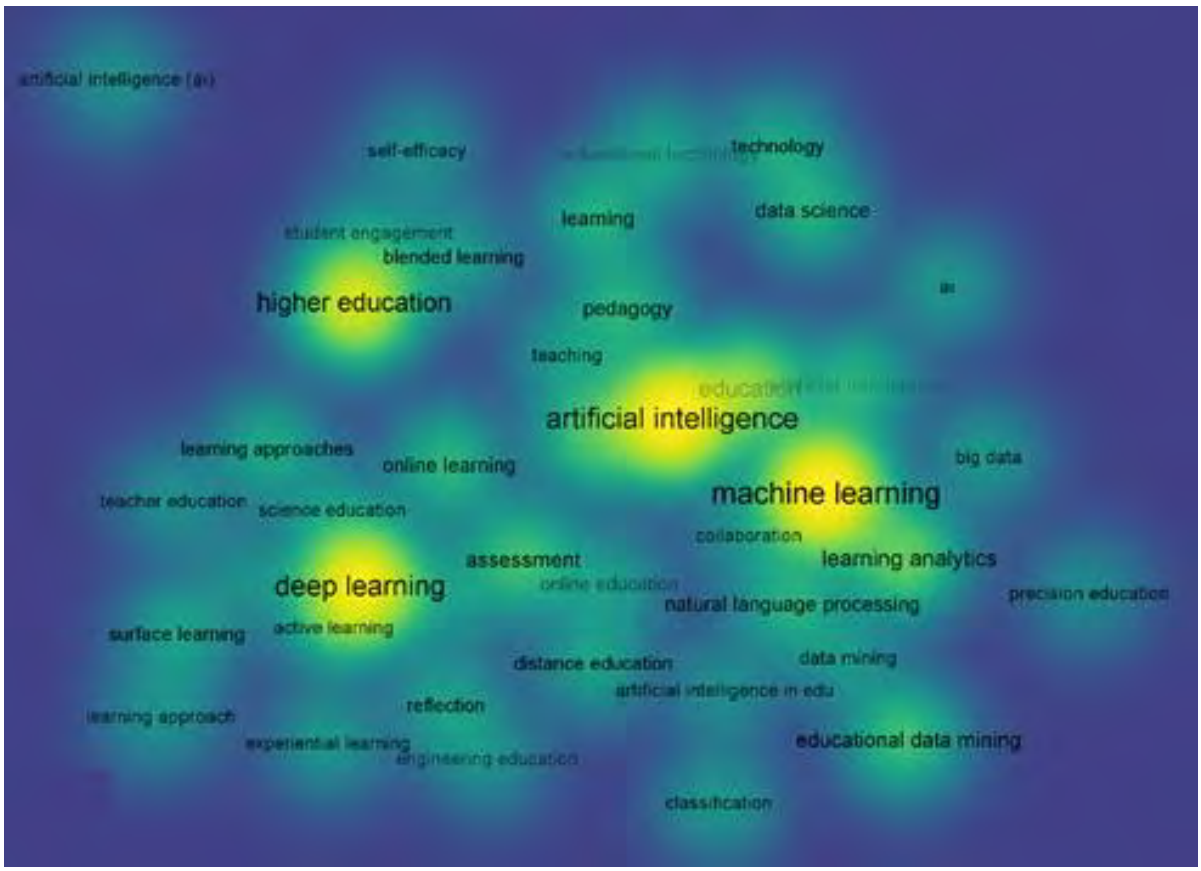

Figure 5. Density Visualization of Authors' Keywords Co-occurrences

Cluster 4 (yellow) refers to studies in which internet-based education-related keywords are used extensively. These studies focus on e-learning, distance education, online learning and online education. In particular, machine learning data to be used in artificial intelligence models can best be made with records kept in online education environments. When Figure 5 is examined, it is seen that the keywords in this cluster are used frequently. However, Figure 6 shows that the popularity of these studies belongs to 2019.

Cluster 5 (purple) brought together studies focusing on higher education, blended learning and self-efficacy. Although Figure 5 shows the intensity of these studies, Figure 6 shows that these topics are among the popular topics of 2018-2019.

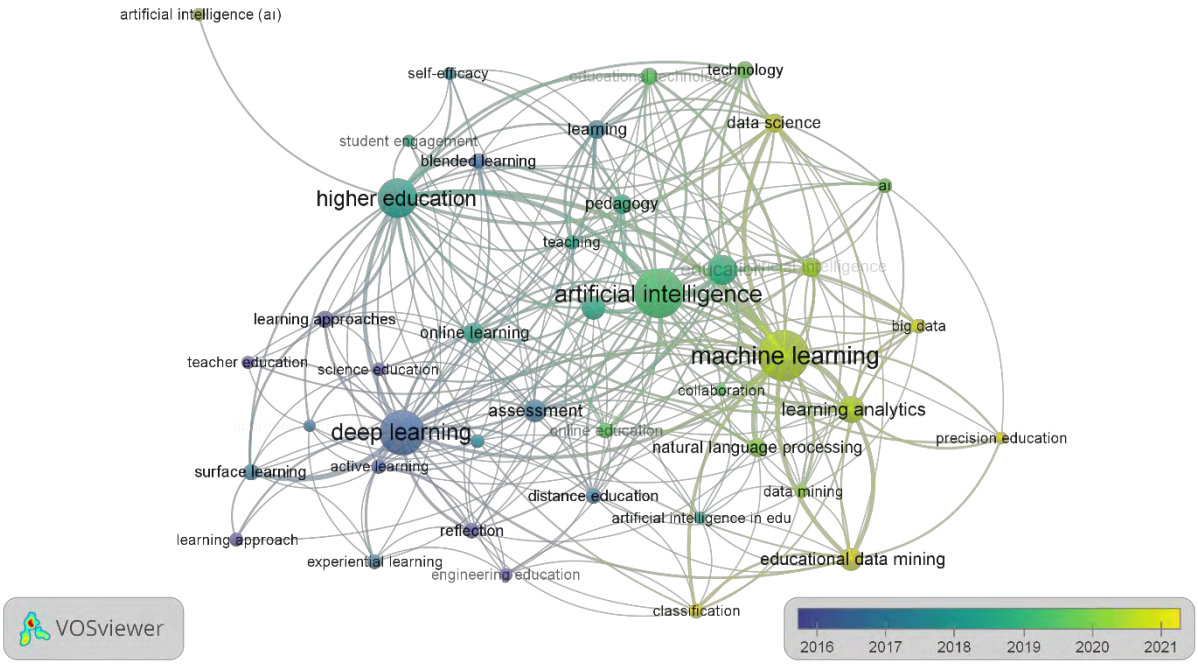

Figure 6. Overlay Visualization of Authors' Keywords Co-occurrences

Discussion

This study it is aimed to examine the studies on artificial intelligence in education from a bibliometric perspective. For this purpose, it was tried to determine the journals, authors, and documents that published the most on the subject. The citation status of the publications has been comprehensively discussed. In education, keywords and trending topics related to artificial intelligence were examined. The keywords stated by the authors were analyzed, and the relationship between the concepts was revealed.

The International Journal of Emerging Technologies in Learning had the most publications and the most link strength based on bibliometric coupling. Computers & Education was the most cited journal for its articles on artificial intelligence in education. According to the number of articles, the first five journals are the Education and Information Technologies, International Journal of Emerging Technologies in Learning, Computers & Education, Education Sciences, and Interactive Learning Environments. When the common features of these

journals are examined, it is seen that they generally focus on the subjects that different technologies are studied at various levels of education. However, having the most publications does not mean that it will receive the most citations. Therefore, when the most cited journals and the link strength in bibliometric coupling are examined, it is seen that the ranking has changed. Talan (2021) concluded that Computers & Education and the International Journal of Emerging Technologies in Learning were the journals that have the most publications. Baek and Doleck (2020), on the other hand, concluded that the most cited journal is the International Journal of Artificial Intelligence, due to the bibliometric analysis they conducted on the articles published in the Journal of Artificial Intelligence. As the number of publications and citations change over time, these rankings can change at any time. When examining the authors of articles published on the use of artificial intelligence in education, the number of citations, rather than the number of publications, was used to determine how much they contributed to the field. Individually, Scouller K. is the most cited author. Biggs, J. was the most cited author in terms of co-citations. Finally, Hwang, G. J. had the most links in terms of bibliometric matching. This situation sheds light on future studies. Indeed, pioneering academics who have contributed to the field with their work have produced new findings that have significantly influenced further widespread research in this field. This study demonstrates the critical nature of continuous improvement and knowledge renewal on a highly complex issue with significant implications for society. Azza Abdullah (2022) gave first place to Hwang G. J. in the list of the most active authors in the field in his study. On the other hand, Baek and Doleck (2020) concluded that Koedinger produced the most publications due to the bibliometric analysis of the articles published in the Journal of Artificial Intelligence.

Scouller's 1998 article titled “The influence of assessment method on students' learning approaches: Multiple choice question examination versus assignment essay” has been the most cited study since the year it was published. The most cited work included in the bibliography section of the articles examined within the scope of the study was Marton and Saljo's book "On qualitative differences in learning: I-Outcome and process" published in 1976. In the study, Scouller (1998) wanted to determine the effect of the assessment methods on students' learning approaches by comparing written homework methods against multiple-choice question exams. The study was conducted with 206 second-year Education students and the strengths and weaknesses of both methods were revealed. Higgins et al. (2002) investigated the meaning and impact of assessment feedback for students in higher education. The study argues that formative assessment feedback, which adopts aspects of a constructivist theory of learning, is essential to foster the type of 'deep' learning desired by teachers. Chen et al. (2010) investigated the effect of web-based learning technology on the participation of university students. In the study, it was concluded that there is a generally positive relationship between the use of learning technology and student participation and learning outcomes.

Both the Keywords Plus terms of the articles on the subject and the keywords of the authors were analyzed. While the terms “education,” “students,” and “performance” came to the fore in the KeyWord Plus analysis, the terms “artificial intelligence”, “machine learning”, and “deep learning” came to the fore in the analysis of author keywords. When the trending topics according to the years are examined, it is seen that the topics related to artificial intelligence are more popular than other topics after 2019. Although the studies on the use of artificial intelligence in education date back a long time ago, it is seen that other subjects were popular in those years. Agbo et al. (2021), as a result of their bibliometric analysis, concluded that the most repeated words in keywords are

“students”, “e-learning” and “learning systems”. It was concluded that the main themes in the thematic mapping in the study mentioned above were the concepts of education and e-learning, and the concepts of intelligent learning and learning analytics were heavily related to these themes. P. Song and Wang (2020) concluded in their study that the concepts of intelligent tutoring systems, learning systems, and students are frequently used.

As a result of the thematic clustering analysis, it was seen that the authors' keywords were divided into five basic clusters. Although each cluster has its own characteristics, it is understood that it has strong ties with other clusters. This is clearly seen when the co-occurrence network (Figure 4) is examined. In fact, the three maps (Figures 4-6) allow us to draw some objective conclusions about research gaps in the literature that would otherwise be impossible. These observations are tried to be explained in more detail below. The first finding is cluster-1, in which the concept of "deep learning" is at the center. When the concepts in this cluster are examined, it is understood that the studies are not related to deep learning, which is a sub-branch of artificial intelligence. For example, in Lee and Choi's (2017) article titled "What affects learner's higher-order thinking in technology-enhanced learning environments? The effects of learner factors", the factors affecting the student's high-level thinking were examined and it was tried to reveal whether the learning was deep or superficial. Although the density (Figure 5) is seen in this cluster, it is understood that its popularity remained in 2016-2017. When Figure 4 is examined, it is understood that Cluster 1 (red) is separated from Cluster 2 (green) and Cluster 3 (blue), and it is closely related to Cluster 4 (yellow) and distantly related to Cluster 5 (purple). From this point of view, although the studies in cluster 1 focus on various learning styles, it is seen that there are studies far from the technology dimension and artificial intelligence. When Figure 5 is examined, it is seen that all other clusters except Cluster 3 (blue) are dense. However, each cluster has been popular in different periods. When Figure 6 is examined, it has evolved into studies in 2016 in which education prioritizes teaching styles (cluster 1), over the years technology is used in education (cluster 3), and finally artificial intelligence is used in education today (cluster 2). Considering the keywords of Cluster 2, Khan et al. (2021), their study titled "An artificial intelligence approach to monitor student performance and devise preventive measures" can be given as an example regarding the use of artificial intelligence in education.

Conclusions and Recommendations

This study, which aims to examine the studies on artificial intelligence in education from a bibliometric perspective, has tried to determine the journals, authors, and documents with the most publications on the subject. As a result of the review, it was seen that the most published journal and the journal have the most link strength is the International Journal of Emerging Technologies in Learning, and the most cited journal is Computers & Education. The most cited author is Scouller, the most co-cited author is Biggs, and according to a bibliographic coupling, the most relevant author is Hwang. According to citation analysis, Scouller (1998) wrote the most cited article titled “The influence of assessment method on students' learning approaches: Multiple choice question examination versus assignment essay”. According to co-citation analysis, Marton (1976) had the highest citation amount. According to the bibliometric match analysis performed in this study, the study with the highest link strength was the book chapter of Neimann and Wang (2017). In the keyword analysis, it was concluded that the most repeated terms are artificial intelligence, machine learning, deep learning, education, and learning. In

addition, in the analysis of keywords, it is seen that the concepts related to artificial intelligence continue to be a trend today. When the co-occurrence analysis on author keywords is examined, it is concluded that the authors' keywords are divided into 5 clusters. The most visible concepts in each cluster are deep learning, machine learning, education, artificial intelligence, and higher education respectively.

Considering the results outlined above, several recommendations can be made for future studies for researchers to focus on addressing current research gaps and ultimately reduce field fragmentation. The first suggestion to those who will do research on the subject may be integrating pedagogy into artificial intelligence studies. In this regard, researchers can examine how the responsibility for developing AI applications can be incorporated into educational activities, which can help bridge the research gap between AI and formal education. Another suggestion might be to design artificial intelligence models to objectively evaluate the impact of classroom activities on student performance. When applying trends in AI studies to various activities in education, researchers may consider focusing on learning analytics, and predicting success or drop-out rates, among other current technological developments. These investigations can provide insightful intellectual work.

References

Agbo, F. J., Oyelere, S. S., Suhonen, J., & Tukiainen, M. (2021). Scientific production and thematic breakthroughs in smart learning environments: a bibliometric analysis. *Smart Learning Environments*, *8*(1), 1–25. https://doi.org/10.1186/S40561-020-00145-4/FIGURES/12

Al-Sudani, S., & Palaniappan, R. (2019). Predicting students' final degree classification using an extended profile. *Education and Information Technologies*, *24*(4), 2357–2369. https://doi.org/10.1007/S10639-019-09873-8/TABLES/6

Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, *11*(4), 959–975. https://doi.org/10.1016/J.JOI.2017.08.007

Aydoğdu, Ş. (2020). Predicting student final performance using artificial neural networks in online learning environments. *Education and Information Technologies*, *25*(3), 1913–1927. https://doi.org/10.1007/s10639-019-10053-x

Azza Abdullah, A. (2022). Artificial intelligence in education: A bibliometric analysis (2010–2021). *International Journal of Computer Science and Information Security (IJCSIS)*, *20*(2), 27–32. https://zenodo.org/record/6379786#.Y0kiyHZBy3A

Baek, C., & Doleck, T. (2020). A bibliometric analysis of the papers published in the Journal of Artificial Intelligence in Education from 2015-2019. *International Journal of Learning Analytics and Artificial Intelligence for Education (IJAI)*, *2*(1), 67. https://doi.org/10.3991/ijai.v2i1.14481

Bañeres, D., Rodríguez, M. E., Guerrero-Roldán, A. E., & Karadeniz, A. (2020). An early warning system to detect at-risk students in online higher education. *Applied Sciences 2020, Vol. 10, Page 4427*, *10*(13), 4427. https://doi.org/10.3390/APP10134427

Basnet, R. B., Johnson, C., & Doleck, T. (2022). Dropout prediction in Moocs using deep learning and machine learning. *Education and Information Technologies*, 1–15. https://doi.org/10.1007/S10639-022-11068-7/TABLES/6

Chen, P. S. D., Lambert, A. D., & Guidry, K. R. (2010). Engaging online learners: The impact of Web-based learning technology on college student engagement. *Computers & Education*, *54*(4), 1222–1232. https://doi.org/10.1016/J.COMPEDU.2009.11.008

Clarivate. (2022, May 9). *KeyWords Plus generation, creation, and changes*. https://support.clarivate.com/ScientificandAcademicResearch/s/article/KeyWords-Plus-generation-creation-and-changes?language=en_US

Ferreira, F. A. F. (2018). Mapping the field of arts-based management: Bibliographic coupling and co-citation analyses. *Journal of Business Research*, *85*, 348–357. https://doi.org/10.1016/j.jbusres.2017.03.026

Good, R. (1987). Artificial intelligence and science education. *Journal of Research in Science Teaching*, *24*(4), 325–342. https://doi.org/10.1002/TEA.3660240406

Higgins, R., Hartley, P., & Skelton, A. (2002). The conscientious consumer: Reconsidering the role of assessment feedback in student learning. *Studies in Higher Education*, *27*(1), 53–64. https://doi.org/10.1080/03075070120099368

Hinojo-Lucena, F. J., Aznar-Díaz, I., Cáceres-Reche, M. P., & Romero-Rodríguez, J. M. (2019). Artificial intelligence in higher education: A bibliometric study on its impact in the scientific literature. *Education Sciences 2019, Vol. 9, Page 51*, *9*(1), 51. https://doi.org/10.3390/EDUCSCI9010051

Jokhan, A., Sharma, B., & Singh, S. (2018). Early warning system as a predictor for student performance in higher education blended courses. *Studies in Higher Education*, *44*(11), 1900–1911. https://doi.org/10.1080/03075079.2018.1466872

Kasemodel, M. G. C., Makishi, F., Souza, R. C., & Silva, V. L. (2016). Following the trail of crumbs: A bibliometric study on consumer behavior in the Food Science and Technology field. *International Journal of Food Studies*, *5*(1), 73–83. https://doi.org/10.7455/ijfs/5.1.2016.a7

Khan, I., Ahmad, A. R., Jabeur, N., & Mahdi, M. N. (2021). An artificial intelligence approach to monitor student performance and devise preventive measures. *Smart Learning Environments*, *8*(1), 1–18. https://doi.org/10.1186/S40561-021-00161-Y/TABLES/7

Lawler, R. W. (1984). Designing computer based microworlds. In M. Yazdani (Ed.), *New horizons in educational computing*. John Wiley & Sons.

Lee, J., & Choi, H. (2017). What affects learner's higher-order thinking in technology-enhanced learning environments? The effects of learner factors. *Computers & Education*, *115*, 143–152. https://doi.org/10.1016/J.COMPEDU.2017.06.015

López-Fernández, M. C., Serrano-Bedia, A. M., & Pérez-Pérez, M. (2016). Entrepreneurship and Family Firm Research: A Bibliometric Analysis of An Emerging Field. *Journal of Small Business Management*, *54*(2), 622–639. https://doi.org/10.1111/JSBM.12161

Lykourentzou, I., Giannoukos, I., Nikolopoulos, V., Mpardis, G., & Loumos, V. (2009). Dropout prediction in e-learning courses through the combination of machine learning techniques. *Computers & Education*, *53*(3), 950–965. https://doi.org/10.1016/J.COMPEDU.2009.05.010

Manesh, M. F., Pellegrini, M. M., Marzi, G., & Dabic, M. (2021). Knowledge Management in the Fourth Industrial Revolution: Mapping the Literature and Scoping Future Avenues. *IEEE Transactions on Engineering Management*, *68*(1), 289–300. https://doi.org/10.1109/TEM.2019.2963489

Martí-Parreño, J., Méndez-Ibáñez, E., & Alonso-Arroyo, A. (2016). The use of gamification in education: a bibliometric and text mining analysis. *Journal of Computer Assisted Learning*, *32*(6), 663–676. https://doi.org/10.1111/JCAL.12161

Marton, F., & Säljö, R. (1976). On qualitative differences in learning: I-Outcome and process. *British Journal of Educational Psychology*, *46*(1), 4–11. https://doi.org/10.1111/J.2044-8279.1976.TB02980.X

Nahar, K., Shova, B. I., Ria, T., Rashid, H. B., & Islam, A. H. M. S. (2021). Mining educational data to predict students performance: A comparative study of data mining techniques. *Education and Information Technologies*, *26*(5), 6051–6067. https://doi.org/10.1007/S10639-021-10575-3/FIGURES/9

Neimann, T., & Wang, V. C. X. (2017). Deep learning and online education as an informal learning process: Is there a relationship between deep learning and online education as an informal learning process? In *Adult Education and Vocational Training in the Digital Age* (pp. 37–57). IGI Global. https://doi.org/10.4018/978-1-5225-0929-5.CH003

O'Shea, T., & Self, J. (1983). *Learning and teaching with computers*. Harvester Press.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Harvester Press.

Romero, C., & Ventura, S. (2010). Educational data mining: A review of the state of the art. *IEEE Transactions on Systems, Man and Cybernetics Part C: Applications and Reviews*, *40*(6), 601–618. https://doi.org/10.1109/TSMCC.2010.2053532

Scouller, K. (1998). The influence of assessment method on students' learning approaches: Multiple choice question examination versus assignment essay. *Higher Education 1998 35:4*, *35*(4), 453–472. https://doi.org/10.1023/A:1003196224280

Sharma, P., & Harkishan, M. (2022). Designing an intelligent tutoring system for computer programing in the Pacific. *Education and Information Technologies*, *27*(5), 6197–6209. https://doi.org/10.1007/S10639-021-10882-9/FIGURES/5

Shen, G., Yang, S., Huang, Z., Yu, Y., & Li, X. (2022). The prediction of programming performance using student profiles. *Education and Information Technologies*, 1–16. https://doi.org/10.1007/S10639-022-11146-W/FIGURES/6

Sleeman, D., & Brown, J. S. (Eds.). (1982). *Intelligent tutoring systems*. Academic Press.

Small, H. (1999). Visualizing science by citation mapping. *Journal of the American Society for Information Science*, *50*(9), 799–813. https://doi.org/10.1002/(SICI)1097-4571(1999)50:9<799::AID-ASI9>3.0.CO;2-G

Song, P., & Wang, X. (2020). A bibliometric analysis of worldwide educational artificial intelligence research development in recent twenty years. *Asia Pacific Education Review*, *21*(3), 473–486. https://doi.org/10.1007/S12564-020-09640-2/FIGURES/3

Song, Y., Chen, X., Hao, T., Liu, Z., & Lan, Z. (2019). Exploring two decades of research on classroom dialogue by using bibliometric analysis. *Computers & Education*, *137*, 12–31. https://doi.org/10.1016/J.COMPEDU.2019.04.002

Talan, T. (2021). Artificial Intelligence in Education: A Bibliometric Study. *International Journal of Research in Education and Science*, *7*(3), 822–837. https://doi.org/10.46328/ijres.2409

Taş, N. (2021). Artificial intelligence in education: Literature review. *International Conference on Studies in Education and Social Sciences (ICSES)*.

Thanuskodi, S. (2010). Journal of social sciences: A Bibliometric study. *Journal of Social Sciences*, *24*(2), 77–80. https://doi.org/10.1080/09718923.2010.11892847

Yazdani, M., & Lawler, R. W. (1986). Artificial intelligence and education: An overview. *Instructional Science 1986 14:3*, *14*(3), 197–206. https://doi.org/10.1007/BF00051820

Author Information

Abdullatif Kaban

https://orcid.org/0000-0003-4465-3145

Ataturk University

Erzurum

Turkiye

Contact e-mail: *abdullatif.kaban@gmail.com*