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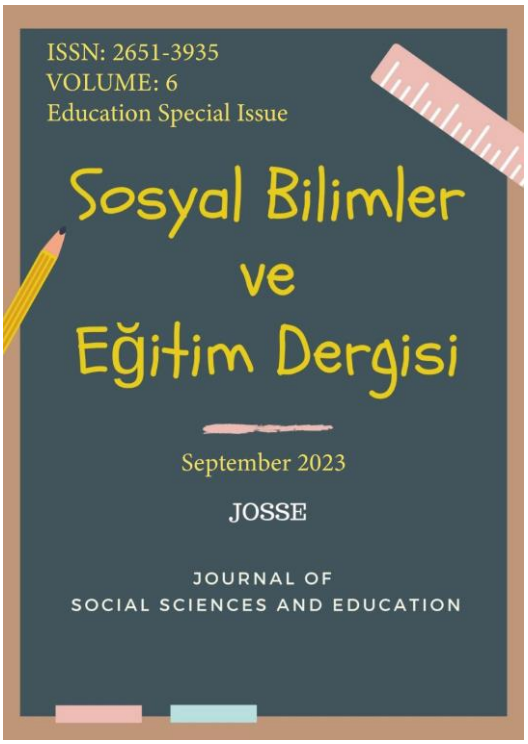

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Articles on Education and Artificial Intelligence: A Bibliometric Analysis

Akın METLİ[1]
SEV American College
Dr.
dr.akinmetli@gmail.com
Orcid ID: 0000-0002-7117-9189

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Akın METLİ[1]

SEV American College

ABSTRACT

In our rapidly evolving technological landscape, the educational sector is undergoing a profound transformation with the integration of artificial intelligence (AI). This study undertakes a comprehensive investigation at the intersection of education and AI to shed light on emerging trends and intricate relationships. By employing advanced bibliometric techniques, an analysis of 6498 articles spanning the years 1980 to 2022 is conducted, revealing core thematic areas, influential author networks, and the dynamic evolution of keywords. The remarkable annual growth rate of 22.68% in published articles underscores the rapid expansion of this field. Noteworthy contributors include prominent countries such as China, the US, the UK, Australia, and India. Predominant themes like Machine Learning and AI permeate the discourse, while visually engaging word clouds highlight the most prominent keywords. Through meticulous thematic analysis, this study categorizes themes into core, niche, emerging, and declining categories, providing a nuanced understanding of focal points and underserved areas. The insights gained from this analysis hold significant implications for both researchers and policymakers, helping to shape future directions in the realm of education and AI. This study takes a forward-looking perspective, envisioning the dynamic future where education and AI intertwine, offering guidance for research endeavors and strategic decision-making. In essence, this study not only encapsulates the historical and current landscape of education and AI but also forecasts their potential trajectories. The rich insights into evolving trends, dominant themes, and research priorities position this work as a resource for both academia and industry.

Keywords: Artificial ıntelligence, education, bibliometric analysis, web of science, vosviewer

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[1] Corresponding author:
Dr.
dr.akinmetli@gmail.com
Orcid ID: 0000-0002-7117-9189

Introduction

Artificial Intelligence is an ever-evolving technological field that has the potential to completely transform how we interact with one another in various ways. This rapidly advancing technology has the capability to make significant changes and improvements in our daily lives. It does this by allowing machines to replicate human cognitive functions and perform tasks that were previously only possible for humans. As AI continues to develop, its influence on society is expected to grow even more, leading to changes in how we engage with technology, communicate with each other, and navigate the world around us (Pedro, 2019).

Rapid advances in artificial intelligence technologies have had profound impacts on all areas of human society, from economics to politics, science to education. These technological advances have caused radical changes in a wide range of fields and have fundamentally affected human society. In this context, big data and artificial intelligence technologies have reshaped economic structures, transformed political processes, accelerated scientific discoveries, and radically changed educational approaches. These developments have changed not only the way business is done, but also the way people interact with each other, the way they learn, and the way they access information (Luan et al., 2020).

Artificial Intelligence in Education is a field that deals specifically with the development of computer systems that perform cognitive tasks associated with the human mind, such as learning and problem-solving. Artificial Intelligence in Education aims to make modern educational processes more effective, efficient, and personalized. In this context, it aims to enable computers to mimic human-like intelligence and learning abilities. Artificial Intelligence in Education includes technologies such as learning analytics, personalized learning materials, and student progress tracking, which are developed to provide better guidance to teachers and education professionals while monitoring students' learning paths (Baker et al., 2019). Actually, AI-powered computer systems interact with the world using human-like abilities and intelligent behaviors, aiming to make implicit knowledge explicit in education (Luckin & Holmes, 2019).

Artificial Intelligence technologies are making a huge impact through applications and tools that are increasingly being used in the field of education today. In particular, AI-powered tools such as intelligent robots and adaptive learning systems are being used between instructors and learners by educational institutions from primary school to university level.

These technologies have the potential to make educational processes more effective, efficient, and customized. AI technologies have great potential to provide students with personalized learning opportunities. Every student is a different individual with unique learning styles, abilities, and needs. While traditional educational methods often fail to fully accommodate these differences, AI technologies aim to maximize the potential of each student by providing customized solutions to individual needs. This enriches the learning experience by enabling students to be better motivated, show more interest, and gain independence (Ventura et al., 2017).

AI in Education explores the use of Artificial Intelligence methods to understand human teaching practices and create systems that enhance the process of human learning. It involves the application of AI technologies to improve and analyze teaching methods and educational systems (Woolf, 1991). Furthermore, AI technologies have great potential to support students with learning difficulties to become more engaged in the educational process. AI-supported applications can be used to understand the specific needs of students and provide appropriate learning material or methods. In this way, students with learning disabilities can be more supported and included. AI technologies can provide students with a more personalized, interactive and efficient learning experience, while providing instructors with better guidance and student tracking (Wang, 2017).

Especially the COVID-19 pandemic has forced traditional teaching models to change rapidly and turn to online learning. At this point, artificial intelligence plays an important role in education. Online learning platforms and AI-powered tools have the potential to provide students with a more effective and personalized educational experience. AI-powered tools such as smart assistants are designed to enable teachers to use their time more efficiently. They can take on a range of administrative tasks, from tracking student attendance to lesson planning and organizing classroom activities. This provides teachers with more time and energy, giving them the opportunity to give more individual attention to students (Nemorin et al., 2023).

Despite the positive impacts of AI in education, some concerns and caveats have also been raised. Ethical issues may arise, especially in areas such as data privacy, student assessment and student-teacher interaction. Therefore, the role of AI in education needs to be carefully considered and developed (Baker et al., 2019). Thus, the positive effects of AI in commercial and societal areas are visibly increasing. Especially in the field of education, online learning platforms and AI-powered tools can provide a more effective and accessible

learning experience. However, the ethical and practical aspects of these developments should be carefully considered (Miao et al., 2021).

With the increasing use of AI technologies in education, the number of published studies in the field has increased. However, no large-scale analysis has been conducted to comprehensively investigate the various aspects of this field (Chen et al., 2022). Hence, this research aims to thoroughly examine the relationship between education and artificial intelligence. It explores how AI is changing education, improving learning outcomes, and enabling new ways of sharing knowledge. Through a comprehensive analysis of academic literature at the intersection of education and AI, this study uncovers the various aspects of this transformative connection. It identifies key research, influential scholars, and pioneering studies that have driven progress in this interdisciplinary field. Additionally, the research seeks to understand the emerging trends in education and AI. It looks for patterns in research, technology advancements, and educational practices that shape this dynamic field. This is not just a retrospective analysis but a forward-looking exploration, anticipating the future of research and innovation in education.

This study positions itself at the crossroads of education and AI, recognizing the potential and significance of their integration. It emphasizes the importance of understanding and utilizing AI's transformative power in education. Ultimately, it aims to guide researchers, educators, and policymakers toward a future where AI-driven educational methods and technologies play a vital role in creating a more informed, equitable, and innovative educational landscape.

One of the expected outcomes of this study is a comprehensive understanding of the interaction between the fields of education and AI, hypothesizing that the impact and collaboration between these two disciplines will continue to grow rapidly. The remarkable annual growth rate in the number of published articles reflects the significance of this expansion, indicating that it will provide a fertile ground for future collaborations and innovations. Moreover, it is anticipated that the insights gained from this analysis, which categorizes themes into core, niche, emerging, and declining categories, will offer a nuanced understanding of focal points and areas that require further attention. This, in turn, will hold substantial implications for researchers and policymakers alike, guiding their strategic decisions in the dynamic landscape where education and AI intersect. In essence, this study not only encapsulates the historical and current landscape of education and AI but also

forecasts their potential trajectories, setting the stage for further research endeavors and informed decision-making.

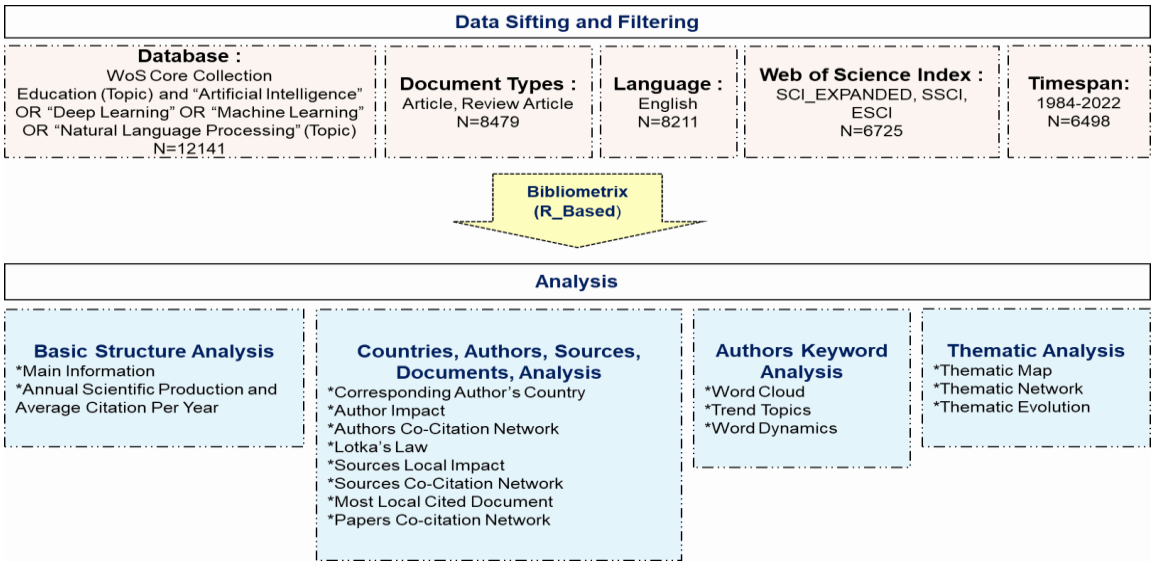
Method

This study embraced the science mapping method. Science mapping is a method generally used to understand and visualize publications in academic literature and the relationships between these publications. This method is used to examine the literature on a particular subject or field of science, to show the relationships between topics, and to present these relationships in visual maps or graphs. This study utilized bibliometric analysis method. The bibliometric analysis is one of the important techniques that provides a macroscopic examination of the literature and offers a projection to the reader. For this reason, those who want to follow the characteristics and development process of scientific outputs in a particular research field can apply this analysis method (Kurutkan & Orhan, 2018).

The study framework that has been determined for the study topic titled Education and Artificial Intelligence is shown in Figure 1.

Figure 1

Workflow of Science Mapping



The Web of Science (WoS) database, which is widely preferred for bibliometric analyses or literature searches (Leydesdorff, 2012) was used. WoS has a large database covering many disciplines and indexes various scientific journals, conferences, patents, and

other information sources. Although full texts of scientific articles are often not available on the platform, citation data and abstracts are accessible. Citation data can be used as an important indicator to assess how often a study is cited by other studies and its impact.

The data search was conducted in the WoS database in May 2023. In the next stage, the data retrieved from the database were extracted and filtered. When publications on [Education (Topic) and "Artificial Intelligence" OR "Deep Learning" OR "Machine Learning" OR "Natural Language Processing" (Topic)] were searched in the WoS database, 12141 articles were identified. "Article, Review Article" was selected as the publication type and 8479 articles were found. When the publication language was selected as "English", 8211 articles were found and when the WoS index was selected as "SCI_EXPANDED, SSCI, ESCI", 6725 articles were found. Since new publications are still entering the database, articles from 2023 were excluded from the scope and a total of 6498 articles were analyzed. The Bibliometrix program was used to analyze the data obtained. The Bibliometrix program is one of the recent open-source software developed on the basis of R to perform science mapping (Aria & Cuccurullo, 2017). There are many packages and libraries written in the R language, and R Studio makes it easy to manage and use these packages. Users can use these packages to perform the analytical tasks they want and make the data analysis process more effective.

In the review, 6498 articles were analyzed in four sections. The first part is a basic structure analysis of articles in the field of Education and Artificial Intelligence, the second part is an analysis of countries, authors, journals and articles, the third part is an analysis of author keywords, and the fourth part is a thematic analysis. No word combinations were made during the analysis.

Findings

Basic Structure Analysis

6498 articles on Education and Artificial Intelligence were produced between 1980 and 2022. These articles were published in 2217 different journals. 14275 author keywords were used. 246887 articles were used as references in bibliographies. The annual article growth rate is 22.68%. It is seen that the article production rate from year to year is quite high. The number of authors with single-author articles is 1016 and the number of single-author articles is 1079. Other statistics are presented in Table 1.

Table 1

Main Information

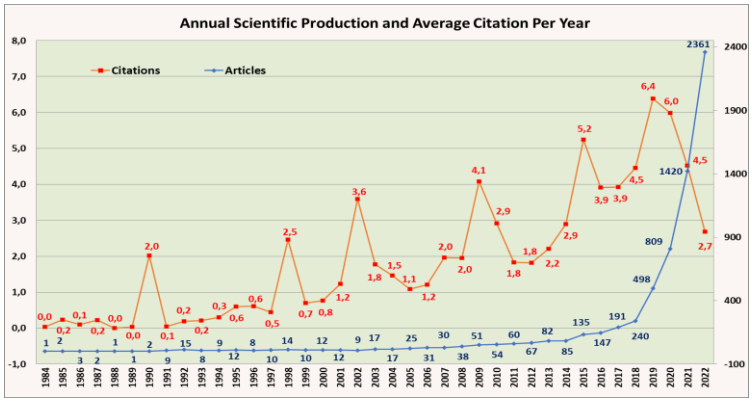
Description	Results	Description	Results
MAIN INFORMATION ABOUT DATA		AUTHORS COLLABORATION	
Timespan	1984:2022	Single-authored docs	1079
Sources (Journals, Books, etc)	2217	Co-Authors per Doc	3.97
Documents	6498	International co-authorships %	23.35
Annual Growth Rate %	22.68	DOCUMENT TYPES	
Document Average Age	3.85	article	5699
Average citations per doc	13.07	article; book chapter	11
References	246877	article; data paper	14
DOCUMENT CONTENTS		article; early access	150
Keywords Plus (ID)	6067	article; proceedings paper	81
Author's Keywords (DE)	14275	article; retracted publication	1
AUTHORS		review	523
Authors	21502	review; book chapter	2
Authors of single-authored docs	1016	review; early access	17

The annual number of scientific publications produced in the field of Education and Artificial Intelligence between 1984 and 2022 and the annual average citation amounts were obtained using Bibliometrics as presented in Figure 2.

When the annual production amounts of articles on Education and Artificial Intelligence are analyzed, while 1 article was produced in 1984, 2361 articles were produced in 2022. While the annual article productions exhibited an increasing graph between 1-240 from 1984 to 2018, 498 articles were produced in 2019, 809 in 2020, 1420 in 2021 and 2361 in 2022. In recent years, there has been an increase in article production above the standards. The number of articles produced in 2022 is 9.84 times the number of articles produced in 2018.

Figure 2

Annual Scientific Production and Average Citation Per Year



When the annual average citations are analyzed, the articles published in 2019 received the most citations with an average of 6.4. The second highest citation average occurred in 2020 with 6.0. From 1984 to 2022, when the annual average citations are analyzed, it is seen that publications in certain years received more citations than other years. This situation shows that the articles published in those years are more qualified articles in the field. In 1990, 2.0, in 1998, 2.5, in 2002, 3.6, in 2009, 4.1, in 2015, 5.2 annual average citation values were obtained. 6.4 in 2019, 6.0 in 2020, and 4.5 in 2021 is very valuable for articles published in recent years. These articles are influential articles in the field. However, the large number of articles produced in recent years should also be taken into consideration. Although the articles published in recent years have the disadvantage of receiving citations, they have reached a very good citation value.

Countries, Authors, Sources, Documents Analysis

The top 20 countries of the responsible authors for our field of study on Education and Artificial Intelligence are shown in Table 2. The table was obtained from Bibliometrix in order of total publications. China (1529), USA (1248), UK (390), Australia (298) and India (230) are among the top five leading countries in terms of total number of articles in the field of Education and Artificial Intelligence. Among single-country authors, China (1288), USA (1032), UK (287), Australia (223) and India (186) stand out, while among multi-country authors, China (241), USA (216), UK (103), Australia (75) and Canada (54) stand out.

MCP ratio is obtained from the ratio of the number of multi-country publications to the total number of country publications. Pakistan has the best MCP ratio value with a value of 0.55. After Pakistan, the country with the highest MCP ratio value is France with a value of 0.397.

Table 2

Corresponding Author's Country

Country	TPC	SCP	MCP	MCP_Ratio
CHINA	1529	1288	241	0,158
USA	1248	1032	216	0,173
UNITED KINGDOM	390	287	103	0,264
AUSTRALIA	298	223	75	0,252
INDIA	230	186	44	0,191
CANADA	204	150	54	0,265
SPAIN	184	134	50	0,272
KOREA	155	101	54	0,348
GERMANY	153	103	50	0,327

SAUDI ARABIA	135	93	42	0,311
TURKEY	128	116	12	0,094
ITALY	103	68	35	0,34
BRAZIL	79	61	18	0,228
MALAYSIA	78	52	26	0,333
NETHERLANDS	72	48	24	0,333
MEXICO	69	58	11	0,159
FRANCE	68	41	27	0,397
JAPAN	68	54	14	0,206
SOUTH AFRICA	65	59	6	0,092
PAKISTAN	60	27	33	0,55

TPC = Total number of publications by the corresponding author's country, SCP = Single country publications, MCP = Multiple country publications, MCP_Ratio=MCP/TCP

Turkey ranked 11th on the list with a total of 128 publications, including 116 single-country and 12 multi-country publications. The h-index, g-index, m-index, total citations (TC), total number of publications (NP), and year of first publication in the field of Education and Artificial Intelligence (PY-Start) of the top 20 authors who contributed the most to the field are presented in Table 3.

The h-index of an author is the maximum number of publications of this person with at least the same number of citations. The value of this indicator, "h", indicates that an academic has at least an "h" number of publications with at least an "h" number of citations. More important than the total number of citations, the h-index measures how stable the citations are.

The h-index, first introduced to science by Jorge E. Hirsch, is a measure of the productivity and impact of a scientific researcher (Hirsch, 2005) (Kamdem et al., 2019). The authors with the highest H-index are Hwang GJ (9), Lee S (8) and Wang J (8). The G-index was determined regarding the performance of the author's most read articles. The authors with the highest G-index are Li Y (18), Kumar A (16) Liu Y (16). It generally takes more than 5 years for publications to be cited. One way to compare academics with academic careers in different time periods is to divide the h-index by the number of years of academic activity. This index is defined as the m-index (Harzing, 2012). The authors with the highest m-index are Chen Y (1.75), Chai CS (1.5) and Zhang C (1.5). The authors who are among the top 20 influential authors and started publishing closest to the present day are Chen Y (2020), Chai CS (2020) and Zhang C (2020).

Author Co-citation Network analysis was conducted to examine the co-citations of the authors of the Education and Artificial Intelligence articles. As shown in Figure 3, the co-citation network is divided into three sets of nodes consisting of circles. The first 30 authors were analyzed. Louvain algorithm was used.

Table 3

Author Impact

Author	h_index	g_index	m_index	TC	NP	PY_start
HWANG GJ	9	15	0,9	360	15	2014
LEE S	8	13	0,889	284	13	2015
WANG J	8	13	1,333	172	13	2018
CHEN Y	7	10	1,75	115	17	2020
KOTSIANTIS S	7	10	0,5	222	10	2010
KUMAR A	7	16	1,167	263	16	2018
LI Y	7	18	1	338	22	2017
LIU X	7	14	1,167	360	14	2018
ZHANG J	7	12	0,333	153	12	2003
ZHANG W	7	11	1,167	293	11	2018
CHAI CS	6	7	1,5	156	7	2020
CHEN F	6	10	1,2	197	10	2019
CUI Y	6	7	1,2	103	7	2019
KOEDINGER KR	6	6	0,667	185	6	2015
KOSTOPOULOS G	6	6	1	88	6	2018
LI J	6	13	1,2	192	17	2019
LIU Y	6	16	0,375	265	21	2008
YANG Y	6	12	1,2	359	12	2019
ZHANG C	6	9	1,5	208	9	2020
ZHANG Y	6	8	1	82	16	2018

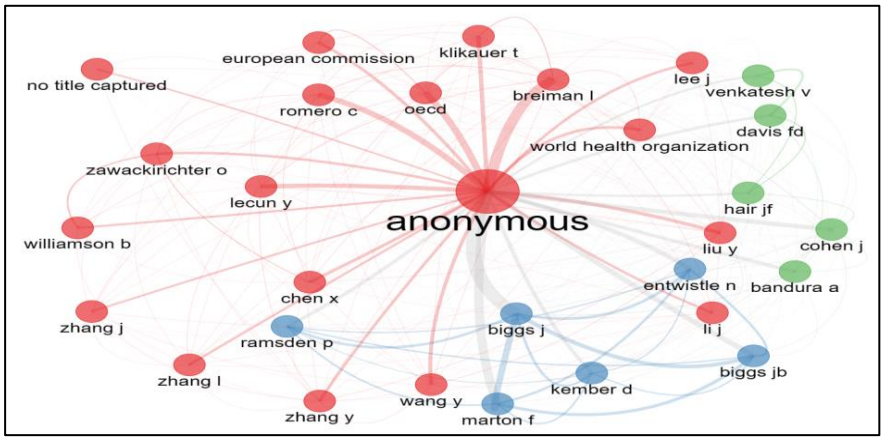
NP = Number of publications, TC = Total citations, PY_start = Publication year starting.

The red cluster became the largest cluster. The red cluster consisted of 19 authors, the blue cluster of 6 authors and the green cluster of 5 authors. In the red cluster, Anonymous, which represents publications of official institutions with no central author, is the most cited author. When the WOS database was examined, it was seen that the authors of publications whose author names were not entered in the bibliography were entered as Anonymous. Except for the author registered as Anonymous in the red cluster, there is no prominent author in the blue and green clusters. However, when the line thickness between them is analyzed, it is seen that the authors named Breiman L, Romero C, Oecd, Lecun Y in the red cluster, Biggs J, Biggs JB, Marton F in the blue cluster, Cohen J, Bandura A in the green cluster stand out.

When the authors with the highest number of co-citations together are analyzed; Anonymous - Breiman L, Anonymous - Biggs J, Anonymous - Marton F, Anonymous - Romero C, Anonymous - Oecd, Anonymous - Lecun Y, Anonymous - Cohen J, Anonymous - Bandura A, Anonymous - Biggs JB, Biggs J - Marton F, Biggs J - Biggs JB, Biggs J - Biggs JB are the author duos that have been cited the most by the authors after them.

Figure 3

Authors Co-Citation Network



The publications of the authors working in the field of Education and Artificial Intelligence according to Lotka's Law are presented in Figure 4. According to Lotka's Law, 60% of the authors contribute to a field of study with one article, 15% with 2 articles, and 7% with 3 articles (Birinci, 2008).

A total of 21502 authors have contributed to the field of Education and Artificial Intelligence. When the articles and authors are analyzed within the framework of Lotka's law, 88.13% of the authors contributed to the field of Education and Artificial Intelligence with one article, 8.16% with two articles, 2.15% with three articles, 0.71% with four articles, and 0.31% with five articles.

It is understood that the author distribution of the articles in the field of Education and Artificial Intelligence does not comply with Lotka's law. Nevertheless, authors with more than five publications can be considered to have deepened in the field of Education and Artificial Intelligence and should be considered as core authors.

Figure 4

Lotka's Law

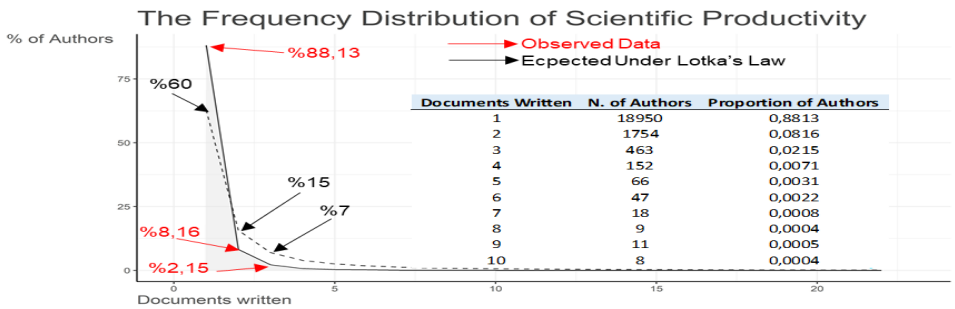


Table 4 shows the top 20 h-index ranked journals (Source Local Impact). These top 20 journals publish 15.97% (1038/6498) of the total articles. The journal with the highest h-index value of 33, g-index value of 66, and m-index value of 4.125 is Engineering.

IEEE Access represents 2.26% (147/6498) of all articles and Sustainability represents 2.00% (130/6498) of all articles. The journal with the highest number of citations for publications on Education and Artificial Intelligence is Engineering with 3183 citations. The second most cited journal is Computers & Education with 30726 citations.

The number of citations per article, which shows the ratio between the number of citations and the number of documents for each journal, was analyzed. With a value of 66.65%, Engineering offers the highest average citation value per article.

When evaluated according to the year of publication, the Sustainability journal, which started its publication life in 2018, has become influential in the field in a short time with 130 publications, 1204 citations, 19 h-index, 29 g-index, and 3,167 m-index values.

Sources Co-citation Network analysis was conducted to examine the co-citations of the sources of Education and Artificial Intelligence articles. Louvain algorithm was used and the first 30 articles were analyzed. As seen in Figure 5, the co-citation network is divided into three node clusters consisting of circles. Each circle in the clusters represents a source.

Table 4

Source Local Impact

Source	H-Index	G-Index	M-Index	TC	NP	TC/NP	PY_start
ENGINEERING	33	66	4,125	4399	66	66,65	2016
COMPUTERS & EDUCATION	29	56	0,906	3183	57	55,84	1992
IEEE ACCESS	21	44	2,1	2324	147	15,81	2014
SUSTAINABILITY	19	29	3,167	1204	130	9,26	2018
INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE IN EDUCATION	18	33	2	1179	54	21,83	2015
COMPUTERS IN HUMAN BEHAVIOR	17	27	0,63	1114	27	41,26	1997
EDUCATION AND INFORMATION TECHNOLOGIES	17	24	2,125	721	48	15,02	2016
APPLIED SCIENCES-BASEL	16	27	2,286	901	86	10,48	2017
BRITISH JOURNAL OF EDUCATIONAL TECHNOLOGY	16	24	0,485	613	27	22,70	1991
JOURNAL OF MEDICAL INTERNET RESEARCH	16	32	0,941	1042	38	27,42	2007
PLOS ONE	14	23	1,75	575	46	12,50	2016
INTERACTIVE LEARNING ENVIRONMENTS	13	20	1	430	35	12,29	2011
NURSE EDUCATION TODAY	13	22	0,464	522	22	23,73	1996
EDUCATIONAL TECHNOLOGY &	12	20	0,6	446	33	13,52	2004

SOCIETY							
IEEE TRANSACTIONS ON EDUCATION	12	19	0,375	379	21	18,05	1992
MEDICAL EDUCATION	12	15	0,5	663	15	44,20	2000
MEDICAL TEACHER	12	22	0,429	646	22	29,36	1996
COMPUTER APPLICATIONS IN ENGINEERING EDUCATION	11	20	0,407	431	35	12,31	1997
INTERNATIONAL JOURNAL OF EMERGING TECHNOLOGIES IN LEARNING	11	18	1,222	444	59	7,53	2015
JOURNAL OF INTELLIGENT & FUZZY SYSTEMS	11	14	1,571	409	70	5,84	2017

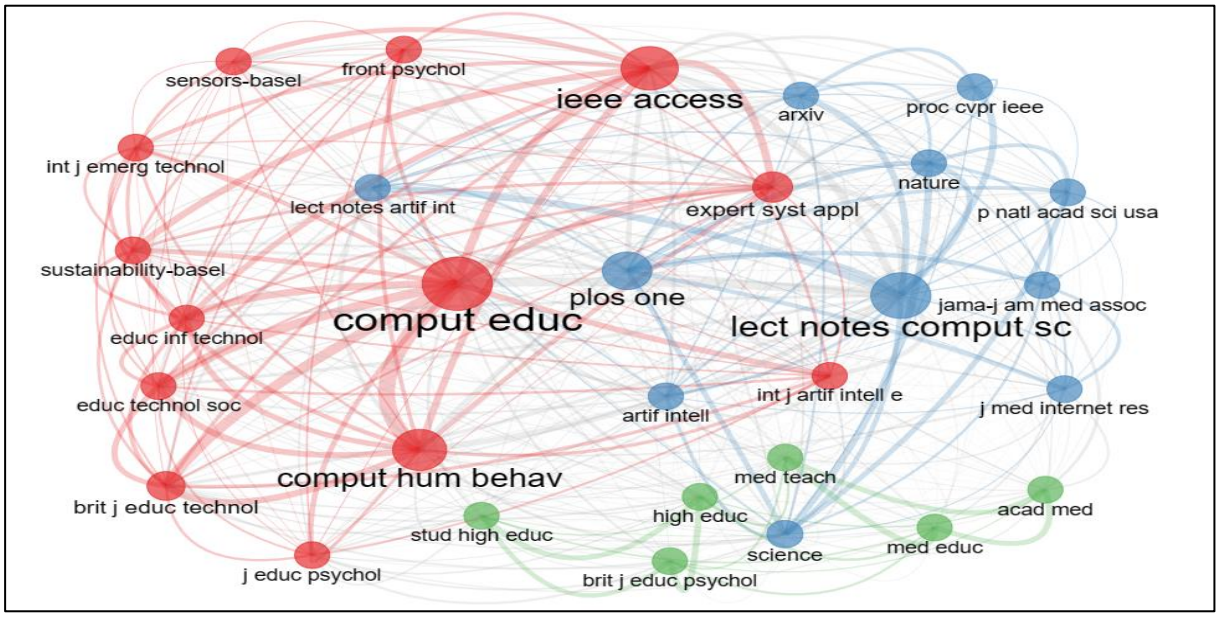
NP = Number of publications, TC = Total citations, TC/NP = Citations per paper, PY_start = Publication year starting

The red cluster is the central cluster with high centrality and has 13 journals. Comput Educ journal is located in the center. It has co-citation links with resources in its cluster and other clusters. Other journals with the highest number of co-citations in the red cluster are Ieee Access, Comput Hum Behav, Expert Syst Appl, Brit J Educ Technol.

There are 11 journals in the blue cluster. The most cited journal in the blue cluster is Lect Notes Comput Sc. The other most cited journal is Plos One. The green cluster consists of 6 journals. The predominantly most cited journal is not in the green cluster.

Figure 5

Sources Co-Citation Network



The thickness of the line between them shows that the journals Comput Educ - Comput Hum Behav, Comput Educ - Brit Educ Technol, Comput Educ - Educ Technol Soc, Comput Educ - Educ Inf Technol, Lect Notes Comput SC - Lect Notes Artif Int, Comput Educ - Ieee Access, Ieee Access - Sustainability-Basel received the most co-citations.

Citation analysis was conducted to identify the most cited articles and the links between these articles in the field of Education and Artificial Intelligence. Citation analysis is commonly used to investigate the underlying intellectual structure and developmental dynamics of the field of study. The 20 most cited publications in the field of Education and Artificial Intelligence are presented in Table 5 in descending order according to the number of local citations (LC).

Table 5

Most Local Cited Documents

Document	YP	LC	LC/YYP	GC	GC/YYP	LC/GC Ratio%
ZAWACKI-RICHTER O, 2019, INT J EDUC	2019	100	25,000	302	75,500	33,11
DOS SANTOS DP, 2019, EUR RADIOL	2019	64	16,000	194	48,500	32,99
ROLL I, 2016, INT J ARTIF INTELL E	2016	53	7,571	128	18,286	41,41
JORDAN MI, 2015, SCIENCE	2015	47	5,875	3046	380,750	1,54
CHEN LJ, 2020, IEEE ACCESS	2020	43	14,333	144	48,000	29,86
LYKOURENTZOU I, 2009, COMPUT EDUC	2009	38	2,714	187	13,357	20,32
GONG B, 2019, ACAD RADIOL	2019	38	9,500	109	27,250	34,86
COSTA EB, 2017, COMPUT HUM BEHAV	2017	36	6,000	168	28,000	21,43
SIT C, 2020, INSIGHTS IMAGING	2020	34	11,333	92	30,667	36,96
TIMMS MJ, 2016, INT J ARTIF INTELL E	2016	33	4,714	99	14,143	33,33
KOLACHALAMA VB, 2018, NPJ DIGIT MED	2018	29	5,800	87	17,400	33,33
WAHEED H, 2020, COMPUT HUM BEHAV	2020	27	9,000	132	44,000	20,45
HUSSAIN MT, 2019, ARTIF INTELL REV	2019	26	6,500	80	20,000	32,50
HINOJO-LUCENA FJ, 2019, EDUC SCI	2019	25	6,250	59	14,750	42,37
HUSSAIN M, 2018, COMPUT INTEL NEUROSC	2018	24	4,800	116	23,200	20,69
CHUI KT, 2020, COMPUT HUM BEHAV	2020	24	8,000	82	27,333	29,27
SCOULLER K, 1998, HIGH EDUC	1998	22	0,880	416	16,640	5,29
GRAY CC, 2019, COMPUT EDUC	2019	22	5,500	71	17,750	30,99
MASTERS K, 2019, MED TEACH	2019	22	5,500	67	16,750	32,84
KAPLAN A, 2019, BUS HORIZONS	2019	22	5,500	583	145,750	3,77

Year of Publication (YP), YYP= Year 2023-Year of Publication, Global Citations (GC), Local Citations (LC),

Local citation is the number of times an article is cited by 6498 articles in the dataset retrieved from WoS, while global citation is the number of times a publication is cited in the WoS database. Zawacki-Richter O 2019 article received 100 local citations, Dos Santos DP 2019 article 64, Roll I 2016 article 53, Jordan MI 2015 article 47 and Chen LJ 2020 article 43. Jordan MI 2015 article received 3046 global citations, Kaplan A 2019 article 583, Scouller K 1998 article 416, Zawacki-Richter O 2019 article 302 and Dos Santos DP 2019 article 194.

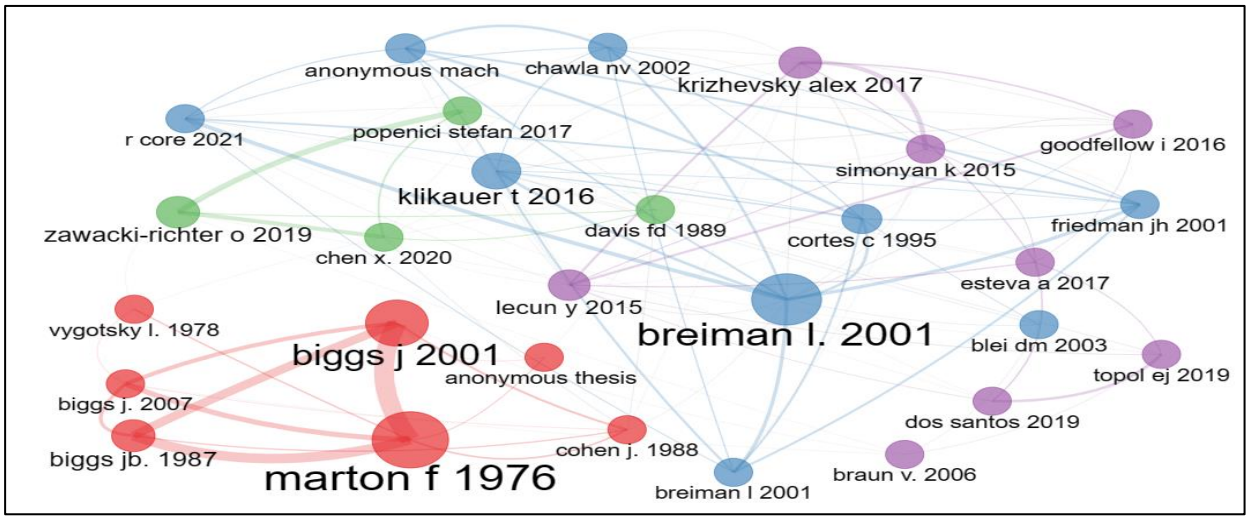
The first publications in the review timeframe have more time to receive citations. On the other hand, publications included in the process at the end of the time interval do not have enough time to receive enough citations. In order to eliminate the negative effects of the short post-publication periods of publications published in the last years of the process and to show the effect of the years in which the articles were published, the definitions of Annual Local Citations (LC/YYP) and Annual Global Citations (GC/YYP) were developed. Zawacki-Richter O 2019 has the highest LC/CYP value (25,000) and Jordan MI 2015 has the highest GC/CYP value (380,750).

Another concept produced for the most cited authors is the Local Citation Percentage. The article with the highest local citation percentage is Hinojo-Lucena FJ 2019 with 42.37%. The local citation percentage is obtained from the ratio of the local citation amount to the overall citation amount. Chane LJ 2020, Sit C 2020, Waheed H 2020 and Chui KT 2020, published in 2020, have been the most influential articles in recent times.

A Paper Co-citation Network analysis was conducted by examining the co-citations of the publications of the Education and Artificial Intelligence literature. The first 28 papers were analyzed using the Louvain algorithm. As shown in Figure 6, the co-citation network is divided into four node clusters consisting of circles. Each circle in the clusters represents an article. The presence of a connecting line between the circles indicates that there is a relationship between them. The thicker the line, the more related they are.

Figure 6

Papers Co-Citation Network



The blue cluster consists of 9 articles, the purple cluster 8, the red cluster 7 and the green cluster 4. Marton F 1976 in the red cluster is the most co-cited article. The other most co-cited articles are Breiman L 2001, Klikauer T 2016 in the blue cluster, Biggs J 2001, Biggs JB 1987 in the red cluster, Zawacki-Richter O 2019 in the green cluster, Krizhevsky Alex 2017 in the purple cluster.

When the thickness of the line between them is analyzed, Marton F 1976 - Biggs J 2001, Marton F 1976 - Biggs JB 1987, Biggs J 2001 - Biggs JB 1987, Zawacki-Richter O 2019 - Popenici Stefan 2017, Marton F 1976 - Biggs J 2017, Biggs J 2001 - Biggs J 2017, Breiman L 2001 - R Core 2021 are the most cited article pairs by subsequent articles.

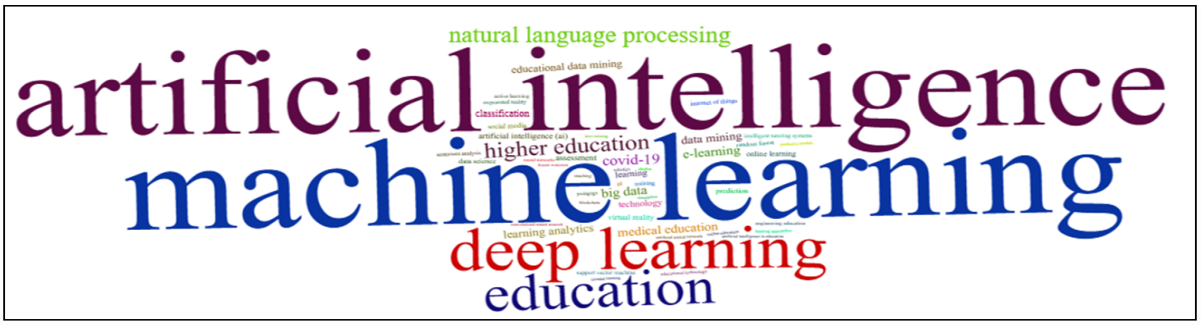
Authors Keyword Analysis

Keywords are determined by the authors to define the article. Considering that these keywords represent the article, it is considered remarkable to analyze with these words and to identify the current topics and themes of the study area (Zheng et al., 2016). The keyword frequency (amount of repetition) of the field of Education and Artificial Intelligence was obtained using Bibliometrix. The word cloud is a graphical representation of the most recent concepts in the field of Education and Artificial Intelligence. The word cloud makes it easier to identify intertwined fields and analyze the trending words of these fields over the years (Orimoloye, & Ololade, 2020).

The larger the keywords appear, the more frequently they are used in the dataset. The top 50 most frequently occurring keywords identified by the authors of the articles are shown in Figure 7 as a word cloud and the top 40 as a frequency table. In order to analyze all author keywords, word merging was not performed. As seen in the word cloud and frequency table, the most repeated author keywords are Machine Learning, Artificial Intelligence, Deep Learning, Education, Natural Language Processing, Higher Education, Covid-19, Big Data, E-Learning, Medical Education. In addition, the presence of keywords such as Virtual Reality, Social Media, Training, Pedagogy, Neural Networks together with Artificial Intelligence terms draws attention.

Figure 7

Word Cloud



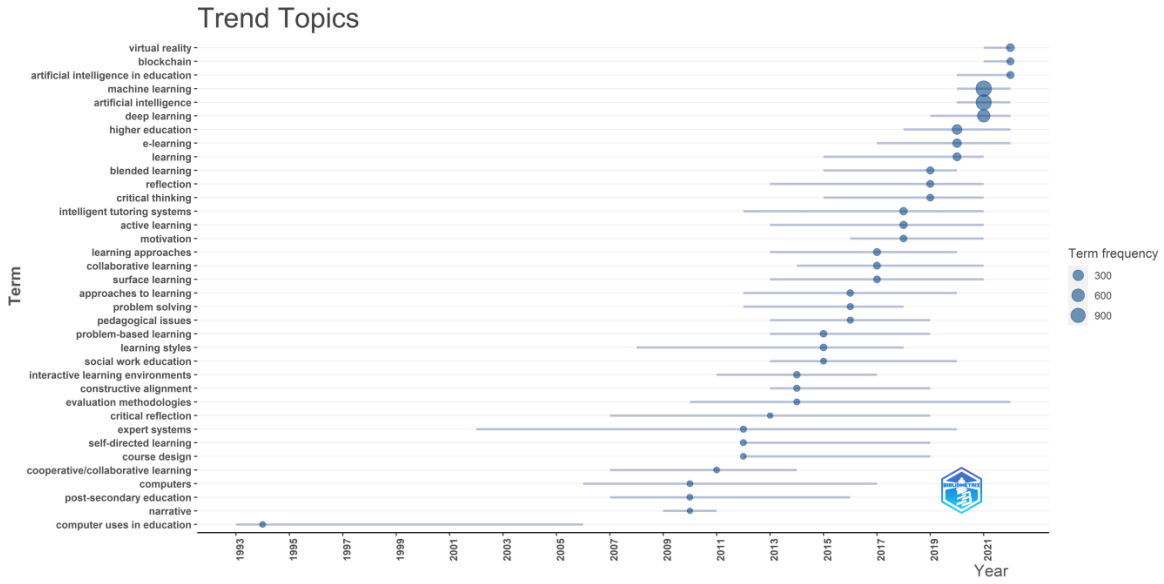
Terms	f	Terms	f	Terms	f	Terms	f
machine learning	1175	data mining	104	prediction	64	sentiment analysis	49
artificial intelligence	1132	learning analytics	104	social media	63	active learning	48
deep learning	568	educational data mining	94	data science	62	engineering education	46
education	484	classification	83	ai	59	pedagogy	44
natural language processing	205	learning	80	internet of things	56	robotics	42
higher education	201	technology	80	random forest	55	text mining	42
covid-19	131	assessment	75	training	53	educational technology	41
big data	117	artificial intelligence (ai)	73	intelligent tutoring systems	51	teaching	41
e-learning	115	virtual reality	69	support vector machine	51	artificial neural network	39
medical education	112	online learning	67	augmented reality	49	neural networks	39

f=Frequency

The graph in Figure 8 shows which of the keywords identified by the authors became popular in which years. The first three keywords used at least five times in each year are visualized.

Figure 8

Trend Topics



While the keywords Computer Uses in Education, Narrative, Post-Secondary Education, Computers, Cooperative/Collaborative Learning, Course Design, Self-Directed Learning, Expert System, Critical Reflection were used more between 1993-2013 in the study of Education and Artificial Intelligence, the keywords Virtual Reality, Blockchain, Artificial Intelligence in Education, Machine Learning, Artificial Intelligence, Deep Learning, Higher Education, E-Learning have become trendier.

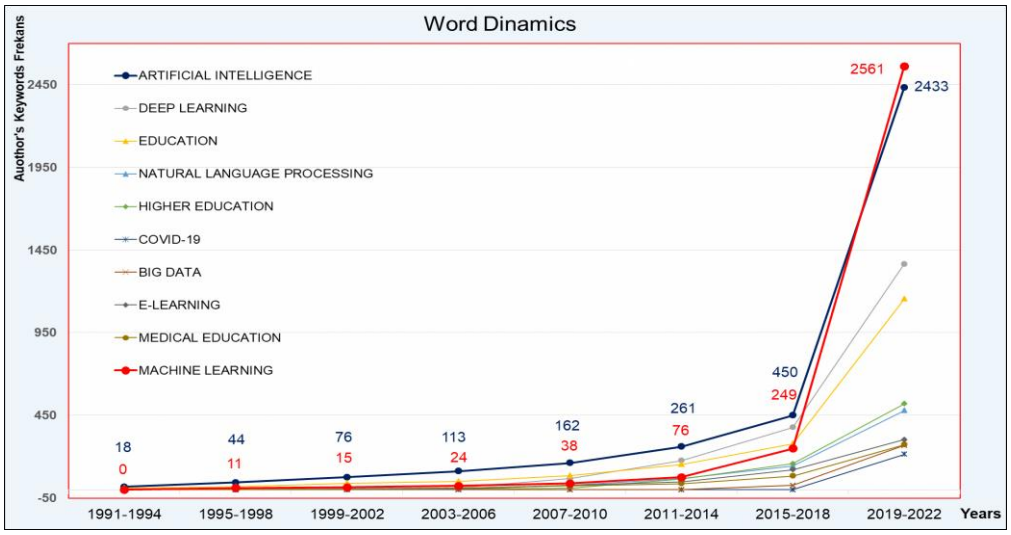
Looking at the size of the circles, Machine Learning, Artificial Intelligence, Deep Learning keywords reached the highest usage volume in 2021, Higher Education, E Learning, Learning keywords in 2020. Figure 8 shows which other keywords were trending in which years. The change of the authors' keywords over time in the process is presented in Figure 9. In order to examine the topic of Education and Artificial Intelligence in different time periods, the 32-year period from 1991 to 2022 was divided into 8 equal time periods of 4 years each (1991-1994, 1995-1998, 1999-2002, 2003-2006, 2007-2010, 2011-2014, 2015-2018, 2019-2022). The first 10 keywords used by the authors were analyzed.

Between 1991 and 2022, the usage of all keywords increased in the process. While Artificial Intelligence keyword was used more prioritized than other keywords until 2015-2018 period, Machine Learning keyword started to be used more than other keywords in 2019-2022 period. In recent studies in the field of Education and Artificial Intelligence, the word Machine Learning has overtaken the word Artificial Intelligence. Along with the keywords Artificial Intelligence and Machine Learning, the keywords Deep Learning and Education also exhibited an upward trend.

While the keyword Artificial Intelligence was used 18 times in the period 1991-1994, it was used 2433 times in the period 2019-2022, and while the keyword Machine Learning was used 0 times in the period 1991-1994, it was used 2561 times in the period 2019-2022.

Figure 9

Word Dynamics



Thematic Analysis

The Strategic Diagram for each sub-period of Education and Artificial Intelligence research generated by Bibliometrix using the top 250 author keywords repeated at least five to three times is presented in Figure 10. The most repeated keywords are grouped into theme clusters. Each cluster is represented by the top three most repeated words. The size of the circles is proportional to the frequency of use of the keyword representing the circle.

In analyses conducted through thematic mapping, research themes are visualized through networks that are resolved over multiple time periods, making it possible to identify their dynamics (Schöggl et al., 2020). A strategic diagram reflects the interactions of factors in a given research topic over time. This diagram is a static description of the network structure of a study area (Shaikevich,1973).

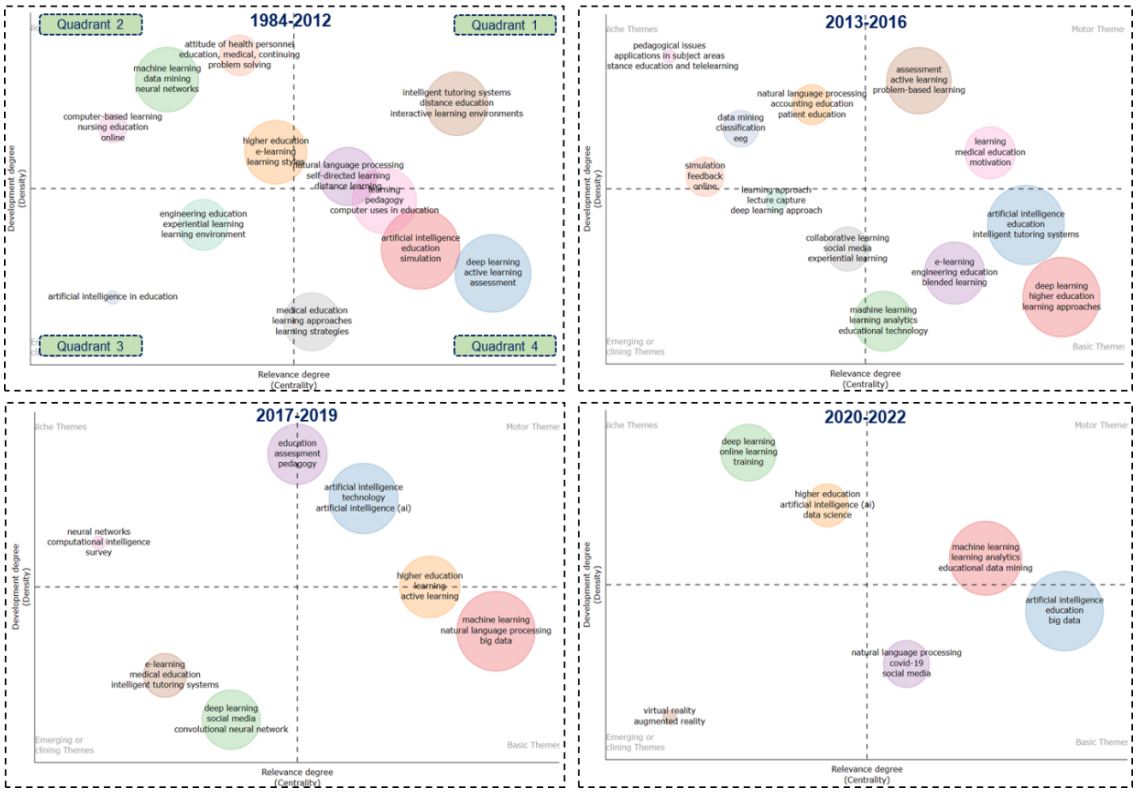
The strategic diagram is divided into four slices expressing themes. Each slice is interpreted in its own way. For this purpose, two parameters including centrality and density were determined. The intensity parameter represents the thematic map as y-axis and the centrality parameter as x-axis. The more central the selected theme is, the more important it is, and the more intense it is, the more developed it is (Nasir et al., 2020).

Between 1984 and 2022, the thematic development of Education and Artificial Intelligence research was analyzed from a dynamic perspective. The research period (1984-2022) is divided into four consecutive sub-periods, taking into account the number of documents and the time window. Although it is more common to define sub-periods with equal time segmentation, the first sub-period is 29 years (1984-2012), the second sub-period

is 4 years (2013-2016), the third sub-period is 3 years (2017-2019) and the fourth sub-period is 3 years (2020-2022) due to limited publications in the early years.

Figure 10

Thematic Map



The Motor Themes, which is developed and expresses the high density and high centrality required for the study area, is the 1st quadrant theme and is located in the upper right part. Niche Themes, which represent highly developed but isolated high density and lower centrality, are the 2nd quadrant theme and are located in the upper left part of the thematic map. Emerging or Declining Themes, which are emerging or declining low centrality and low-density values, are the 3rd quadrant themes and are located in the lower left part of the thematic map. Basic Themes, which have been extensively researched and have well-developed internal links, low intensity and high centrality, are the 4th quadrant themes and are located in the lower right part of the Thematic map (Cobo et al., 2011).

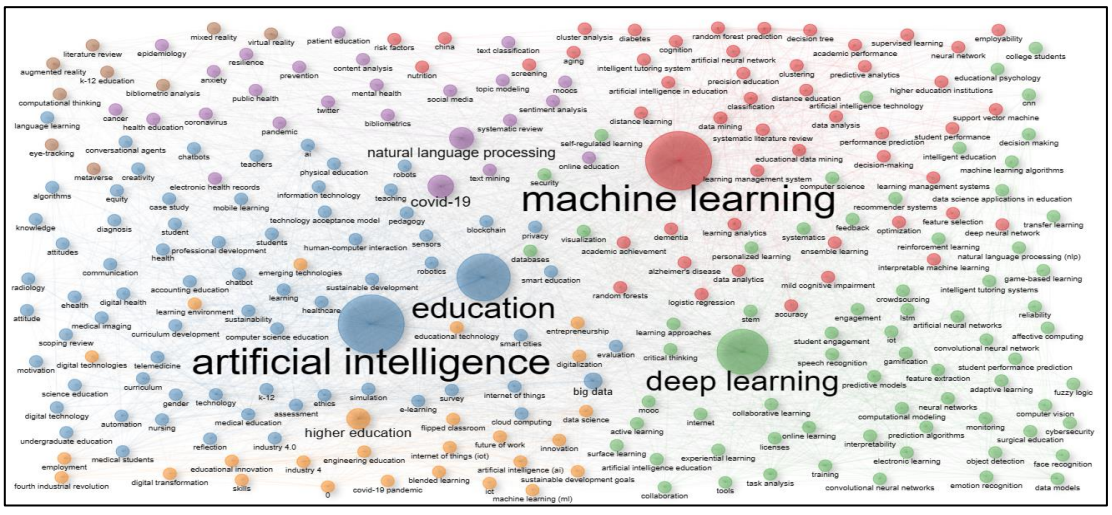
Since motor themes are both very central and very dense, a lot of work has been done on these themes and they have reached sufficient maturity. Niche themes have low centrality and high intensity, so they have not been the main area of study, but have been focused on but

outside the research framework. Rising or falling themes are themes that have neither centrality nor intensity. These themes have been studied but have not received sufficient attention. Core themes are themes with high centrality and low intensity. It is at the center of the study topic, but still not enough work has been conducted in the field. For this reason, themes are the main focus of the Education and Artificial Intelligence research topic.

When the main themes that are active research topics are analyzed, in 1984-2012, the first theme was Deep Learning, Active Learning, Assessment, the second theme was Artificial Intelligence, Education, Simulation, the third theme was Learning, Pedagogy, Computer Uses in Education. In 2013-2016, the first theme was Deep Learning, Higher Education, Learning Approaches, the second theme was Artificial Intelligence, Education, Intelligent Tutoring System, the third theme was E-Learning, Engineering Education, Blended Learning, the fourth theme was Machine Learning, Learning Analytics, Educational Technology. In 2017-2019, the first theme was Machine Learning, Natural Language Processing, Big Data, and the second theme was Higher Education, Learning, Active Learning. In 2020-2022, the first theme was Artificial Intelligence, Education, Big Data, and the second theme was Natural Language Processing, Social Media. Core themes are the most valuable themes for the field. It refers to the themes that are currently being actively studied for the relevant time period. The relationship network of the themes for the 2020-2022 period is given in Figure 11. When the themes between 2020-2022, which is the last period and best represents today, are examined in more detail.

Figure 11

Thematic Network (2020–2022)



The theme of Machine Learning was included under motor themes and there have been enough studies on this theme. Under the Machine Learning theme, the keywords Learning Analytics, Educational Data Mining, Data Mining, Classification, Prediction, Random Forest, Support Vector Machine, Artificial Neural Network, Artificial Intelligence in Education were included. In the network relationships, Machine Learning theme is seen in red color.

Higher Education, Deep Learning themes were included under niche themes. They were intensively studied but could not take place in the center of the field of Education and Artificial Intelligence. Artificial Intelligence (ai), Data Science, 0, Industry 4, Educatioanal Technology, Engineering Education, Machine Learning (ml), Online Learning, Training, Task Analysis, Predictive Models, Feature Extraction, Convolutional Neural Network, Neural Networks, Computer Vision, Convolutional Neural Networks keywords were included under the Higher Education theme. In network relationships, the Higher Education theme was colored orange and the Deep Learning theme was colored green.

The Virtual Reality theme was included under the rising or falling themes and did not create sufficient density and centrality. The keywords Augmented Reality, Metaverse, Mixed Reality, K-12 Education, Computatioanal Thinking, Eye Tracking were included under the Virtual Reality theme. Virtual Reality theme is seen in red color in network relations.

Artificial Intelligence and Natural Language Processing themes were included under the core themes. Education and Artificial Intelligence are the main areas of study as they have high centrality. Under the Artificial Intelligence theme, the keywords Education, Big Data, Medical Education, E-Learning, Technology, Ai, Internet of Things, Assesment, Learning, and under the Natural Language Processing theme, the keywords Covid-19, Social Media, Sentiment Analysis, Text Mining, Online Education, Systematic Review were included. In network relations, Artificial Intelligence is seen in blue and Natural Language Processing keyword is seen in purple.

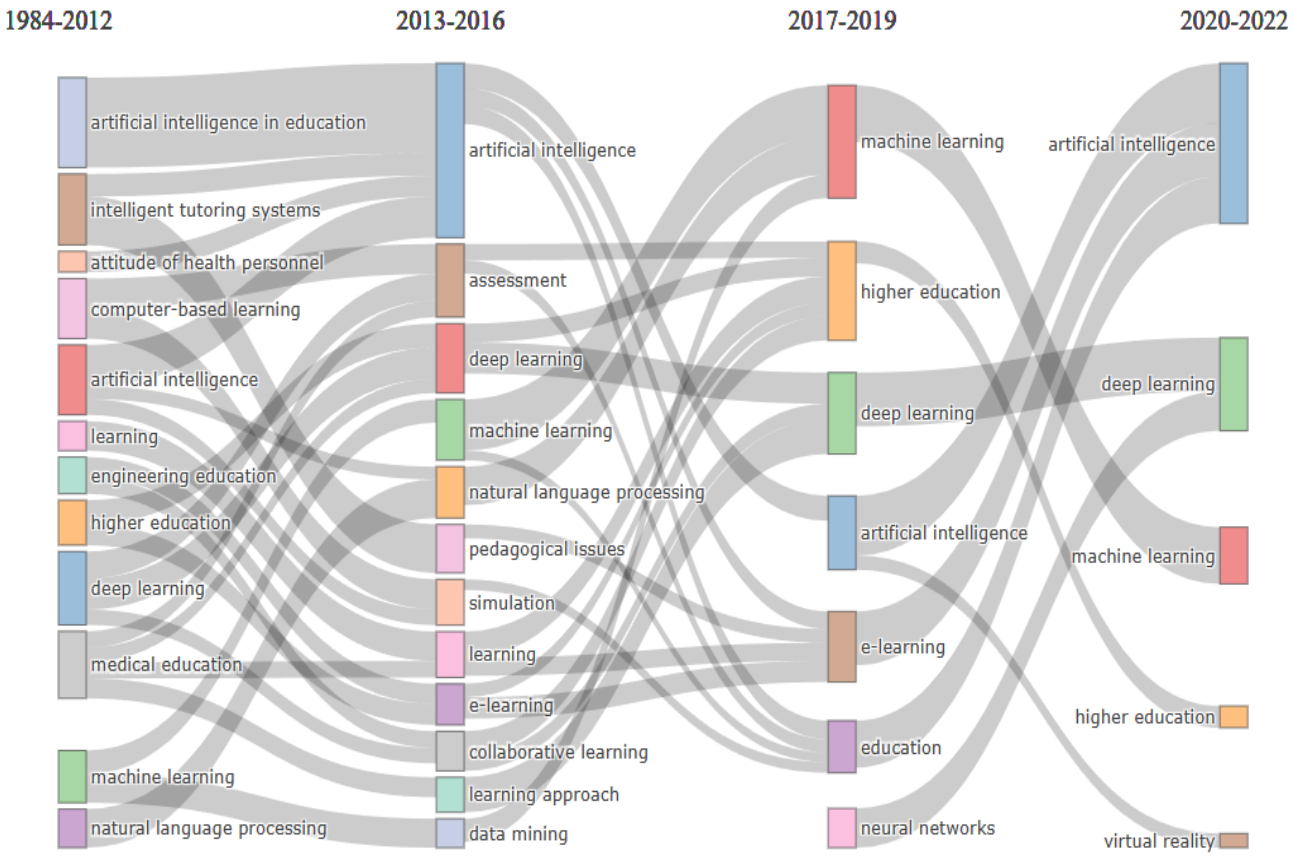
In order to examine the change and development of the Education and Artificial Intelligence themes over the years, in addition to the four-period Strategic Diagram, a four-period Thematic Evolution Mapping, visualized in Figure 12, was created. The size of the nodes indicates the number of keywords and the flow lines between the nodes indicate the direction of evolution of the theme clusters over time. A theme that evolves over sub-periods can be considered a thematic area (Shi et al., 2020). When the diagram is analyzed, there are 12 themes in the first period, 12 themes in the second period, 7 themes in the third period and

5 themes in the fourth period. Artificial Intelligence, Deep Learning, Machine Learning themes were included in all 4 periods.

The Artificial Intelligence theme, which is the dominant theme of the 2013-2016 period, was fed by the sub-themes of Artificial Intelligence, Intelligent Tutoring Systems, Attitude of Health Personnel, Artificial Intelligence, and fed the themes of Artificial Intelligence, E Learning, Education. Machine Learning, the dominant theme of the 2017-2019 period, was fed by Machine Learning, Natural Language Processing, Data Mining sub-themes and fed the Machine Learning theme. Artificial Intelligence, the dominant theme of the 2020-2022 period, was fed by Artificial Intelligence, E-Learning, Education sub-themes. In the 2020-2022 period, Deep Learning, Machine Learning, Higher Education, Virtual Reality themes were formed together with the Artificial Intelligence theme.

Figure 12

Thematic Evolution (1984–2022)



Discussion and Results

This study examines the literature on education and artificial intelligence using the science mapping method. The data collection, analysis, relationship identification, visualization and interpretation steps were performed on 6498 articles in the Web of Science database. The analysis using the R-based "Bibliometrix" program was carried out in four sections including basic structure, countries, authors, journals, articles, author keywords and themes. This study aims to understand and visualize the literature in the field of education and artificial intelligence.

This study was conducted by analyzing 6498 articles on education and artificial intelligence. The review period covers the years 1980-2022. These articles were published in 2217 different journals and used a total of 14275 different author keywords. In addition, 246887 articles were used as references in the bibliographies. The annual article growth rate was calculated as 22.68%. This shows that article production has increased rapidly over the years. In single-author articles, 1016 authors contributed with 1079 articles. The top five countries producing the most articles are China, USA, UK, Australia and India, respectively. In addition, by examining the average annual citations, it was seen that in certain years, quality articles received more citations. The analysis identified the most influential authors and journals through indicators such as h-index, g-index and m-index. Furthermore, the study presented results on identifying authors who do not comply with Lotka's Law and considering authors with more than five publications as "core authors".

While this study delved into the extensive analysis of education and artificial intelligence articles, shedding light on various aspects of this field, it is also essential to consider the broader landscape of educational technology research. In this context, Destereci et al. (2023) conducted a notable bibliometric analysis, offering valuable insights into the trends and developments within the application of critical technology areas in educational research. They found that the number of such articles has been steadily increasing since 2015, with keywords like learning analytics, machine learning, and artificial intelligence being frequently used. The study identified key authors, collaborations, and funding sources in this field, highlighting strong international partnerships. The research provides valuable insights into the landscape of educational technology research.

In the pursuit of comprehending the current landscape and trends within the field of Artificial Intelligence in Education, Baek and Doleck (2020) conducted a bibliometric

analysis focused on articles published in the "International Journal of Artificial Intelligence in Education" between 2015 and 2019. This rigorous examination drew from a dataset comprising 135 articles, retrieved from the Web of Science database, and encompassed an exploration of prolific countries, collaborative networks, influential authors, keywords, and the extent of citations received by these articles. The examination of keywords underscored a predominant focus among authors on students and learning, shedding light on the central themes that have captivated the attention of researchers in this field during the specified period.

The investigation into prolific authors and countries revealed the active participation of corresponding authors primarily hailing from the United States, the United Kingdom, Canada, and Germany. This geographical concentration of contributors signals the global reach and engagement of these nations in shaping the discourse surrounding AI in education. Furthermore, Baek and Doleck's findings unveiled an intricate web of international collaboration among researchers and institutions. Notably, a robust collaborative network was identified between the United States and Canada. This collaborative synergy between nations signifies the collective effort to advance research in AI in education, leveraging the strengths and expertise of various institutions and individuals.

The effectiveness of the journals was evaluated by criteria such as h-index, g-index and m-index. In these analyses, Engineering was found to have the highest h-index value. Local and global citations were analyzed to show the impact of the articles. In this context, prominent articles and journals were identified. Document Co-Citation Network and Source Co-Citation Network analyses were used to identify the relationships between articles and sources. Through these analyses, it was seen which links the prominent articles and sources carry.

This study also examined the role and importance of keywords by conducting an in-depth analysis of academic research in the field of Education and Artificial Intelligence. The keywords identified by the authors represent the essence and focus areas of an article. The frequency analysis of these keywords was performed using a tool called Bibliometrix. Through this analysis, it was determined how often certain keywords were used within the articles and which aspects of the field they emphasized.

The paper also uses word clouds to understand the emerging topics and trends of the Education and Artificial Intelligence workspace. Word clouds graphically visualize the most prominent concepts and terms. These visualizations help us understand how different subject

areas intertwine and influence each other. The most frequently used keywords include Machine Learning, Artificial Intelligence, Deep Learning, Education, Natural Language Processing, Higher Education, Covid-19, Big Data, E-Learning, Medical Education. In addition, the presence of keywords such as Virtual Reality, Social Media, Training, Pedagogy, Neural Networks draws attention.

Another important part of the study is the analysis of how keyword popularity has changed over the years. This analysis reveals how certain concepts evolve over time, in which years they become prominent and in which periods they receive less attention. In particular, concepts such as Machine Learning, Artificial Intelligence, Deep Learning increased in popularity in 2021, while concepts such as Higher Education, E-Learning became prominent in 2020.

Building upon this comprehensive review, it is imperative to consider the broader landscape of research in Artificial Intelligence in Education (AIED). In accordance with the comprehensive review and bibliometric study conducted by Prahani et al. (2022) on Artificial Intelligence in Education (AIED), research in this field has experienced a rapid upsurge in recent years. The study aimed to provide a nuanced understanding of the evolving trends within AIED and their developmental trajectories. The specific objectives of Prahani et al.'s investigation encompassed an in-depth examination of various facets of AIED research, including document types, source documents, contributing countries, languages, affiliations, funding sources, source titles, subject areas, research focal points, and the identification of the top 50 cited publications within the field over the past decade. Drawing upon the Scopus database and employing VOSviewer for visualization purposes, Prahani et al.'s analysis scrutinized a dataset comprising 457 documents. The bibliometric outcomes delineated a remarkable and exponential upsurge in the trajectory of AIED research, particularly within the preceding five years. Notably, articles published in academic journals emerged as the predominant document type, reflecting the academic rigor and scholarly discourse surrounding AIED. Furthermore, China emerged as the leading nation in terms of research productivity within the field, underlining its pivotal role in shaping the AIED landscape. The linguistic domain of AIED research was overwhelmingly dominated by the English language, reflecting the global reach and dissemination of research findings in this language. The prolific author Kalles, D., stood out as a significant contributor to the field. Several affiliations demonstrated notable prolificacy, each contributing four publications, and the

National Natural Science Foundation of China and the National Science Foundation were identified as the primary sources of sponsorship funding.

Within the realm of source titles, the "Journal of Physics: Conference Series" held a prominent position, signifying its relevance as a platform for disseminating AIED research findings. Furthermore, Computer Science emerged as the predominant subject area, elucidating the interdisciplinary nature of AIED research and its integration with computational sciences. Holmes, W., emerged as the top-cited author within the AIED domain, attesting to the recognition of their contributions to the field. A comprehensive mapping of research trends over the past decade illuminated several key focal points, including the application of AIED in student education, its relevance to engineering education, innovative teaching methodologies, the evolution of e-learning-based education, the transformation of educational systems, and the infusion of AI into curricula. In conclusion, the insights gleaned from the meticulous bibliometric analysis conducted by Prahani et al. (2022), as presented in their study, underscore the transformative potential of AIED integration within the education system. These findings serve as a crucial foundation for future research endeavors and policy initiatives aimed at harnessing the power of AI to revolutionize education and enhance pedagogical practices for the betterment of learners worldwide.

In the realm of research on the utilization of artificial intelligence in education, multiple studies have explored the bibliometric properties of this field. Talan (2021) conducted a noteworthy investigation in this regard, aiming to provide insights into the literature's characteristics concerning artificial intelligence in education. Talan's study relied on the Web of Science (WoS) database as the primary data source. An extensive search using various keywords was undertaken to retrieve pertinent literature, resulting in the identification of a substantial dataset comprising 2,686 publications spanning the years 2001 to 2021. This comprehensive inquiry unveiled that a significant portion of these studies originated from the United States.

Moreover, the findings of Talan's study highlighted that the most frequently published journals in the domain of artificial intelligence in education included "Computers & Education" and "International Journal of Emerging Technologies in Learning." In terms of institutional contributions, Carnegie Mellon University, University of Memphis, and Arizona State University emerged as the most prolific organizations, based on the number of publications produced. Among the researchers in the field, Vanlehn, K., and Chen, C. M.

were identified as the most influential and productive scholars. Talan's analysis further revealed the co-authorship network structure, which was predominantly characterized by collaborations among researchers from the United States, Taiwan, and the United Kingdom. Additionally, when examining the keywords frequently used in conjunction with each other, it was evident that terms such as "artificial intelligence," "intelligent tutoring systems," "machine learning," "deep learning," and "higher education" were among the most commonly employed, reflecting the key themes and areas of focus within the literature on artificial intelligence in education. Incorporating the findings of Talan's bibliometric study (2021) alongside those of Prahani et al. (2022) in our discussion allows for a broader understanding of the trends and characteristics of research in the field of artificial intelligence in education. These studies collectively contribute to a comprehensive picture of the evolution, key contributors, and notable themes within this rapidly advancing domain, offering valuable insights for future research and policy initiatives.

In addition to keyword analysis, thematic analysis is also an important part of the study. This analysis shows how keywords evolve over time and how they relate to each other. Motor themes represent the most intensively studied topics that are at the center of the field, while niche themes represent topics that have been intensively studied but have received more limited attention. Emerging or declining themes include topics that are not yet of sufficient importance or have lost popularity. Core themes represent the main focal points of the study area.

This study provides a very comprehensive analysis to understand the dynamics and evolution at the intersection of Education and Artificial Intelligence. By deeply examining the evolution of keywords and themes over time, it allows us to understand how these two important fields are integrated and where they stand out. By following these evolutionary trends, the research allows us to better predict the future development directions of the field of Education and Artificial Intelligence.

The findings of this analysis resonate with the conclusions drawn by Hinojo-Lucena, F. J., Aznar-Díaz, I., Cáceres-Reche, M. P., and Romero-Rodríguez, J. M. (2019) in their study titled "Artificial Intelligence in higher education: A bibliometric study on its impact in the scientific literature," published in Education Sciences. Hinojo-Lucena and colleagues conducted a comprehensive bibliometric study to explore the impact of artificial intelligence in higher education as reflected in the scientific literature. Their research encompassed a detailed analysis of relevant publications, and it aligns with the present study's findings.

In particular, the popularity cycles of keywords and themes show how trends and priorities change. This perspective provides academic researchers and experts with guidance to understand which topics are growing the fastest, which areas require more focus, and how to go about setting future priorities. It also provides an opportunity to understand the growth of the field in a broader context.

Furthermore, the study conducted an extensive analysis of 6,498 articles within the field of education and artificial intelligence using the science mapping method, encompassing data collection, analysis, relationship identification, visualization, and interpretation of articles in the Web of Science database. This analysis spanned the years 1980 to 2022 and drew from 2,217 different journals, employing a total of 14,275 unique author keywords and referencing 246,887 articles. Notably, the annual article growth rate was calculated at 22.68%, indicating a rapid increase in research output over the years. Furthermore, the study revealed that China, the USA, the UK, Australia, and India were the top five countries contributing to research articles in the field. The analysis also identified influential authors and journals based on indicators such as h-index, g-index, and m-index, while highlighting collaborative networks, including a strong partnership between the United States and Canada. Additionally, thematic and keyword analyses shed light on central themes and emerging trends, with word clouds visually representing prominent concepts like Machine Learning, Artificial Intelligence, Deep Learning, and more. Furthermore, the research examined the evolution of keyword popularity, emphasizing the dynamic nature of research priorities. Overall, this study provides a comprehensive overview of the field, offering valuable insights into the past, present, and future of education and artificial intelligence research, which can guide decision-making for academia, industry, and policy makers alike.

As a result, this study stands out as a valuable resource that not only examines the past and current state of the field of Education and Artificial Intelligence, but also sheds light on future development directions. The findings of the research can guide strategic decision-making for those in academia and industry alike and provide an important vision of how the field of Education and Artificial Intelligence will develop more broadly. This analysis is also extremely valuable in identifying general trends and interests in the academic world. Understanding the development of the field of Education and Artificial Intelligence is critical for both improving learning methods and creating more effective solutions for the technological requirements of the future. Research results can help optimize teaching and

implementation strategies in this field, while also providing guidance to policymakers and stakeholders.

Based on the comprehensive analysis of 6,498 articles spanning the years 1980 to 2022, it is evident that the field of education and artificial intelligence has experienced rapid growth and evolution. To further advance this field, several key recommendations can be made. First, researchers should focus on emerging trends such as E-Learning, Virtual Reality, and Social Media, as these topics have gained prominence and are likely to shape the future of AI in education. Additionally, while the quantity of research output has increased significantly, it is essential to maintain a strong emphasis on the quality of articles. Understanding the factors that contribute to the impact of certain articles can guide future research efforts. Collaborative networks, particularly those involving researchers from underrepresented regions, should be encouraged to enrich the field's diversity and global perspective. Furthermore, exploring the interdisciplinary integration of AI concepts like Machine Learning and Deep Learning with education can lead to innovative approaches in teaching and learning. Policymakers and educators should consider utilizing research findings to inform decisions related to technology integration and curriculum development. Additionally, investigating the sustainability of the rapid research growth in this field is crucial to ensure its long-term impact. Comparative analyses with other fields can provide insights into unique challenges and opportunities. Lastly, core themes within AI in education should be thoroughly examined to understand their long-term significance and evolution. By addressing these recommendations, researchers, policymakers, and educators can collectively contribute to the continued development of AI in education, ultimately benefiting learners worldwide.

References

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

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, 2*(1). https://doi.org/10.3991/ijai.v2i1.14481

Baker, T., Smith, L., & Anissa, N. (2019). Educ-AI-tion rebooted? Exploring the future of artificial intelligence in schools and colleges. https://media.nesta.org.uk/documents/Future_of_AI_and_education_v5_WEB.pdf.

Birinci, H. G. (2008). Turkish Journal of Chemistry'nin Bibliyometrik Analizi. *Bilgi Dünyası, 9*(2), 348-369. https://doi.org/10.15612/BD.2008.310

Chen, X., Zou, D., Xie, H., Cheng, G., & Liu, C. (2022). Two decades of artificial intelligence in education. *Educational Technology & Society, 25*(1), 28-47. https://www.jstor.org/stable/48647028

Cobo, M.J., López-Herrera, A.G., Herrera-Viedma, E., & Herrera, F. (2011). An Approach for Detecting, Quantifying, and Visualizing the Evolution of a Research Field: A Practical Application to The Fuzzy Sets Theory Field. *J. Informetr.* 5, 146–166. https://doi.org/10.1016/j.joi.2010.10.002.

Destereci, Z., Karaca, G. G., Baybaş, B., & Tosun, C. (2023). Eğitim Araştırmalarında Kritik Teknoloji Alanlarının Uygulamaları Kapsamında Yayınlanan Makalelerin Eğilimlerinin İncelenmesi: Bibliyometrik Haritalama Analizi. *Bilgi ve İletişim Teknolojileri Dergisi, 5*(1), 20-45. https://doi.org/10.53694/bited.1261406

Egghe, L. (2006). Theory and Practice of the G-Index. *Scientometrics, 69*(1), 131-152, https://doi.org/10.1007/s11192-006-0144-7

Harzing, A.W. (2012). Reflections on the H-Index. *Business & Leadership, 1*(9), 101-106. https://harzing.com/publications/white-papers/reflections-on-the-h-index

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, 9(1). https://doi.org/10.3390/educsci9010051

Hirsch, J. E. (2005). An index to quantify an individual's scientific research output. *National Academy of Sciences United States of America, 102*(46), 16569–72. https://doi:10.1073/pnas.0507655102

Holmes, W., Bialik, M., & Fadel, C. (2023). *Artificial intelligence in education.* Globethics Publications.

Kamdem, J.P, Duarte, A.E, Lima, K.R.R, Rocha, J.B.T, Hassan, W., & Barros, L.M, et al., (2019). Research trends in food chemistry: A bibliometric review of its 40 years anniversary (1976–2016). Food Chemistry, 294, 448–457. https://www.sciencedirect.com/science /article/pii/S0308814619308167

Kurutkan, M., N., & Orhan, F. (2018). Sağlık politikası konusunun bilim haritalama teknikleri ile analizi. Iksad Publishing House.

Leydesdorff, L. (2012). World shares of publications of the USA, EU-27 and China compared and predicted using the new web of science ınterface versus SCOPUS. *Profesional de la Información, 21*(1). https://doi.org/10.3145/epi.2012.ene.06

Luan, H., Geczy, P., Lai, H., Gobert, J., Yang, S. J., Ogata, H., & Tsai, C. C. (2020). Challenges and future directions of big data and artificial intelligence in education. *Frontiers in Psychology*, 11, 580820. https://doi.org/10.3389/fpsyg.2020.580820

Luckin, R., & Holmes, W. (2016). Intelligence Unleashed: An argument for AI in education, UCL Knowledge Lab.

Miao, F., Holmes, W., Huang, R., & Zhang, H. (2021). *AI and education: A guidance for policymakers*. UNESCO Publishing.

Nasir, A., Shaukat, K., Hameed, I. A., Luo, S., Alam, T. M., & Iqbal, F. (2020). A Bibliometric Analysis of Corona Pandemic in Social Sciences: A Review of Influential Aspects and Conceptual Structure. *IEEE Access, 13*(8), 133377–133402. https://doi.org/10.1109/ACCESS.2020.3008733

Nemorin, S., Vlachidis, A., Ayerakwa, H. M., & Andriotis, P. (2023). AI hyped? A horizon scan of discourse on artificial intelligence in education (AIED) and development. *Learning, Media and Technology*, *48*(1), 38-51. https://doi.org/10.1080/17439884.2022.2095568

Orimoloye, I. R., & Ololade, O.O. (2020). Potential Implications of Gold-Mining Activities on Some Environmental Components: A Global Assessment (1990 to 2018). *Journal of King Saud University-Science, 32*(4), 2432-2438. https://doi.org/10.1016/j.jksus.2020.03.033

Pedro, F., Subosa, M., Rivas, A., & Valverde, P. (2019). Artificial intelligence in education: Challenges and opportunities for sustainable development. UNESCO.

Prahani, B. K., Rizki, I. A., Jatmiko, B., Suprapto, N., & Amelia, T. (2022). Artificial Intelligence in Education Research During the Last Ten Years: A Review and Bibliometric Study. *International Journal of Emerging Technologies in Learning, 17(*8). https://10.3991/ijet.v17i08.29833

Schöggl, J.P., Stumpf, L., & Baumgartner, R.J. (2020). The Narrative of Sustainability and Circular Economy - A Longitudinal Review of Two Decades of Research. *Resources, Conservation & Recycling*, 163, 105073. https://10.1016/j.resconrec.2020.105073

Shaikevich, I.M. (1973). System of Document Connections Based on References. *Scientific and Technical Information Serial of VINITI, 6*(2), 3-8. https://garfield.library.upenn.edu/marshakova/marshakovanauchtechn1973.pdf

Shi, J., Duan, K., Wu, G., Zhang, R., & Feng, X. (2020). Comprehensive metrological and content analysis of the public–private partnerships (PPPs) Research field: A new bibliometric journey. *Scientometrics*, 124, 2145-2184. https://doi.org/10.1007/s11192-020-03607-1

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

Ventura, Michele. (2017). Creating Inspiring Learning Environments by means of Digital Technologies: A Case Study of the Effectiveness of WhatsApp in Music Education. *EAI Endorsed Transactions on e-Learning, 4*(14), 152906. https://10.4108/eai.26-7-2017.152906.

Wang, F. H. (2017). An exploration of online behaviour engagement and achievement in flipped classroom supported by learning management system. Computers & Education, 114, 79-91. https://doi.org/10.1016/j.compedu.2017.06.012

Woolf, B. (1991). AI in education [Doctoral dissertation, University of Massachusetts at Amherst]. ProQuest Dissertations & Theses Global.