Constantine the Philosopher University in Nitra
Faculty of Natural Sciences and Informatics
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Artificial Intelligence in Education: A Study on Using Bibliometric Systems

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Abstract

Artificial Intelligence (AI) is currently one of the fastest-growing areas, which shows a growing demand for experts with advanced knowledge and the ability to learn and discover new approaches. Commercial scientific databases Web of Science and Scopus, as well as the Dimensions platform, a product of Digital Science, were analysed as bibliometric systems supporting the monitoring of scientific trends and updating of research in various fields. An example is given of the use of Web of Science, Scopus and Dimensions tools to monitor the usefulness of research on the use of artificial intelligence in education as one of the tasks of the European Project "Future It Professionals Education In Artificial Intelligence" (FITPED-AI). In this secondary research, we limited ourselves to thematic publication activity and did not consider the contribution of individual scientists or publishers. The results of our work confirm the steady scientific interest in the problem of AI in a broad context, with a lack of research on the use of AI in the process of implementing personalized formal education, and actualize the need for additional research in the field of technical sciences and mathematics to provide technological support for the use of AI in education.

Keywords

Artificial Intelligence, Education, Scientometric Databases, Bibliometric Analysis, Scientific Research.

INTRODUCTION

Information technology has transformed virtually all significant spheres of people's daily lives, including education. In many fields, including education, artificial intelligence (AI) and machine learning (ML), mechanisms originally used for data management and process development, have made a special mark.

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Starting from 2017 enabling technologies of artificial Intelligence in educational practice has been considered by experts as important developments in educational technology for Higher Education (NMC Horizon Report: Higher Education Edition, 2017, 2018, 2019). It has fundamentally changed the way educational platforms and applications operate, henceforth tailored to the needs and knowledge of students, noticeably improving teaching effectiveness (Kuleto, Ilic´, Dumangiu, Rankovic´, Martins, Pa˘un, and Mihoreanu, 2021), in particular, to develop skills among students, a collaborative learning environment, and an accessible research environment (Ilic´ et al., 2021).

Because artificial intelligence is the focus of numerous studies and research by experts from different countries, its corresponding research community and scientific paper production are expanding considerably. As a result, there is a growing demand for secondary studies that address this huge number of publications, synthesising knowledge in the field by systematically processing and organising research. Secondary studies offer mutual benefit - they help researchers guide future work on research gap and enable practitioners to understand the effectiveness of, for example, a particular method or technology.

To our knowledge, there are not enough studies comparing the use of artificial intelligence in general and its application in education, especially for the implementation of personalised learning. However, there are other secondary studies (analysis of the results of primary research, thanks to work in scientific publications), which are partly related to the following studies.

Artificial Intelligence Methods and Algorithms for Human-Computer Intelligent Interaction is the subject of a secondary study by researchers from Slovenia (Šumak, Brdnik, Pušnik, 2022); Visual tools for teaching machine learning - from Brazil (Gresse von Wangenheim et al., 2021); Artificial Intelligence Techniques for Distance Education - from Cyprus (Aljarrah, Ababneh, Karagozlu, & Ozdamli, 2021). Other studies, such as Boundaries Between Research Ethics and Ethical Research Use in Artificial Intelligence Health Research (Samuel1, Chubb, & Derrick, 2021) or Exploring Opportunities and Challenges of Artificial Intelligence and Machine Learning in Higher Education Institutions (Kuleto, Ilic´, Dumangiu, Rankovic´, Martins, Pa˘un, and Mihoreanu, 2021), based on secondary research and document analysis (literature review), content analysis, and primary research (survey). To analyze the organization of personalized learning (Shemshack, Spector, 2020), researchers drew on several academic, scientific and commercial sources for insights into the research subject.

The aim of this paper - based on an analysis of scientific publications from the last decade - is to assess research activity in the use of artificial intelligence in general and its application to education, in particular, to implement personalized learning, and to use bibliometric methods to identify the main trends in this direction.

Objectives of the study:

1. Analyzing scientific databases and identifying bibliometric analysis tools for monitoring and supporting research in a specific subject area. The results obtained can be used by researchers to make decisions on the choice of source databases for bibliometric analysis.

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2. The use of tools embedded in various bibliometric systems to identify general trends and patterns of publication activity of researchers from different countries in the use of artificial intelligence in general and its application in education, including the implementation of personalized learning. The quantitative data obtained can be used by researchers to determine the state of development of a particular subject area in general, according to different research areas, countries of publication and qualitative analysis of research to determine its quality of effectiveness.

MONITORING PROGRESS IN RESEARCH ON THE USE OF ARTIFICIAL INTELLIGENCE IN EDUCATION USING BIBLIOMETRIC SYSTEMS

Research design

In the study, we relied on the methodological foundations of the literature review process as a research method (Creswell, 2014); research on a systematic literature review of terms related to personalized learning (Shemshack, Spector, 2020), comparison of bibliographic data sources (Visser, van Eck, & Waltman, 2021), (Martín-Martín, Thelwall, Orduna-Malea, et al., 2021), (Thelwall, (2018), and experience in applying bibliometric methods to assess subject areas (El Mohadab, Bouikhalene, Safi, 2020) or international research networks (Smyrnova-Trybulska, Morse, Kuzminska, & Kommers, 2018).

The *research methodology* recommended by the systematic literature review was chosen for this study. It consists of four main phases: planning (obviously, research questions and search strategy), selection (obtaining the source base and creating datasets), extraction (stopping the development of bibliometric systems) and data analysis (providing interpretability).

Research Questions

RQ1. What are the publication evolution and main publication venues on AI in education?

Rationale: One of the goals of this study is to guide the increasingly vast literature available on AI in education. The study will identify (i) the dynamics of growth in the number of publications by certain categories, following the objectives of the European Project "Future IT Professionals Education In Artificial Intelligence" (FITPED-AI), (ii) the state of development of the subject area and availability of research results the percentage of scientific articles compared to other types of scientific products, in particular conference proceedings, and support for the open access initiative in their publication, and (ii) the countries that have contributed most to the research area.

RQ2. In which research areas is AI applied, and are there any gaps that demand future research?

Rationale: The main goal of this study is to understand the pedagogical potential of AI use, e.g. on determinants of AI in the effectiveness of personalized learning and identify areas needed for its successful implementation in both pedagogy and engineering. To do so, it will identify (i) Research Areas where AI is being utilized, and (ii) the existing thematic focus of research based on the analysis of keywords of scientific publications (primary research).

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Source base. Methods of comparative analysis of the functionality of scientometric databases and analysis of literature sources on this issue were used to select data sources for bibliometric analysis of a specific subject area. As a result, Scopus, Web of Science and Dimensions scientometric databases were used as sources to identify trends and patterns of publication activity in the use of artificial intelligence in general and in education in particular for the effective introduction of personalized learning.

Search strategy. The search for published articles was conducted over the last ten years (from 2012 to 2021); all data were received on February 5, 2022. We used various search queries to explore the development of artificial intelligence in general ("artificial intelligence", query 1), narrowing the search to education ("artificial intelligence in education" or "(artificial intelligence) and education", query 2), considering ways to use artificial intelligence in the context of implementing personalized learning in general "(artificial intelligence) and (personalized learning)", query 3) and training in educational institutions in particular ("(artificial intelligence in education) and (personalized learning)").

As we were interested in research on the application of artificial intelligence rather than research on terminology, we searched for these keywords in the three selected databases Scopus, Web of Science and, respectively, "Topic" (Web of Science), "TITLE-ABS-KEY" Scopus) and “Title and Abstract” (Dimensions). Each query was subject to publication year restrictions: PUBYEAR> 2011 AND PUBYEAR <2022, i.e. we extracted publications from 2012 to 2021. This resulted in 12 datasets: Web of Science (W1-W4), Scopus (S1-S4) and Dimensions (D1-D4).

Bibliometric analysis. This analysis used mainly descriptive statistics. We used tools embedded in some scientific databases to classify and analyse trends in the thematic area of research by analysing publications. This included country distribution, research areas, publication types, support for the open access initiative and thematic focus.

RESULTS

1. Comparison of bibliographic data sources

Currently, there are several bibliographic platforms with scientometric tools (scientometric databases) that allow, in particular, quantitative research to identify long-term trends related to strategic monitoring of science. The value of a bibliographic data source also depends on many different elements.

Studying the statistics of bibliographic materials in different areas, such as countries, items, authors, etc., researchers in various fields of knowledge have tried to conclude the importance of research objects – the productivity of scientists, the scientific efficiency of publications, the scientific potential of the country and others. Since in bibliometric research the choice of tools depends on the object of analysis (the examined set of documents), it should be the basis for the classification of methods and selection of the source base.

By comparing source databases, in particular, Scopus, Web of Science, Dimensions, Crossref and Microsoft Academic, M. Visser and co-authors identified (Visser, van Eck, & Waltman, (2021)) strengths and weaknesses from different data sources and highlighted the need to combine different databases to achieve comprehensive coverage of the scientific literature. The results of a comparison of Digital Science’s new Dimensions

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database (launched in 2018), including its free version, with the commercial databases Scopus and Web of Science, conducted by M. Thelwall in Thelwall, M. (2018), show a high correlation between the indicators of all three sources.

As researchers consider the component of the Dimensions scientific database as an alternative to Scopus and Web of Science, we will consider the tools of these databases to determine the activity and scope of research in the field of AI in education, including personalized learning (our analysis). It should be noted that we have limited ourselves to the study of publishing activity, so the impact of individual authors, organizations, publishers or countries (through citation analysis) was not assessed in this study.

Another limitation is the ability to use the Scopus, Web of Science and Dimensions embedded tools for bibliometric analysis. For statistical analysis, visualization and mapping (e.g. co-author network maps, citations, keywords) you can use both the Dimensions embedded editor - VOSviewer online and export data (available in all databases) for further analysis in the desktop version of VOSviewer (Smyrnova-Trybulska, Morze, Kuzminska, & Kommers, (2018) or other similar programs (Smyrnova-Trybulska, Morze, Kuzminska, & Kommers, (2017)).

As can be seen from Table 1, the presence of common features of classification and, respectively, data filtering in the proposed databases, as well as some differences, confirms the proposal of M. Visser to use several databases for complex bibliometric analysis.

Table 1. Comparison of Scopus, Web of Science, Dimensions tools

Characteristics / Filters	Web of Science	Scopus	Dimensions
Publication Year	+	+	+
Document Types	+	+	+
Authors/ Researcher	+	+	+
Affiliations	+	+	-
Countries	+	+	-
Source Title / Publication Titles	+	+	+
Open Access	+	+	+
Fields of Research / Research Areas	+	+	+
KeyWords		+	
Sustainable Development Goals			+

2. Results of bibliometric analysis

What are the publication evolution and main publication venues on AI in education

The search strategy (execution of queries W1-W4, S1-S4, D1-D4) yielded a different number of publications from 2012 to 2021 in the different scientometric databases (Table 2). It should be noted that in the case of the analysis of the use of artificial intelligence, the Dimensions database has a larger coverage compared to Scopus and Web of Science databases, which confirms the feasibility (or at least the possibility) of using this base as an alternative to a commercial one. In other cases, the results of the analysis of the W, S and D sets have a sufficient correlation. In particular, it is possible to make assumptions about the smallest development of the topic of using artificial intelligence for the implementation of formal and non-formal learning: the number of publications in sets 3 and 4 on all scientometric databases is many times smaller than in the others.

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By type of publications, on average 50% are articles that support the assumption that the topic of artificial intelligence is sufficiently studied (results of W1, D1 analysis), but the use of artificial intelligence to implement personalized learning requires additional scientific research. The publications of sets W4, S4, and D4 are the lowest: 49.9%, 26.2% and 23% respectively). It should also be noted a slightly lower percentage of articles among the publications of sets S and D compared to W, which indicates different policies of different scientific databases and publishers, which, in turn, confirms the validity of using different sources (in this case Scopus, Web of Science and Dimensions) to analyze the research topic area.

As far as the support for the Open Access initiative is concerned, as many as 50% of the articles (regardless of data set) are in open access (All OA filter was applied). The situation is slightly worse with other types of publications, which may indicate the specificity of the presentation of research results in social sciences and educational sciences (among the publications of the D4 set only 19.5% are in the public domain, W4 - 39.8%).

The growth track over the last 10 years has gone through two stages: the first (2011-2018), which had a very slow period of development, and the second (2018-2021). In the period 2018-2019, there was a sharp increase in the number of publications on all datasets compared to previous years, which may indicate the relevance of the subject area (NMC Horizon Report: Higher Education Edition, 2017, 2018, 2019) and its prospects for its further study by researchers.

Table 2. Number of publications from 2012 to 2021

Query No.	Dataset	Publications	Open Access	Articles	Public Access
1	W1	68464	27395 (40%)	39808 (61.8%)	19171 (48.2%)
	S1	248783	65229 (26.2%)	73832 (29.7%)	30624 (41.5%)
	D1	1336032	457406 (34.2%)	679806 (50.9%)	345419 (50.8%)
2	W2	2695	1083 (40.2%)	1451 (53.8%)	745 (51.3%)
	S2	10733	2956 (27.5%)	2979 (27.6%)	1482 (49.7%)
	D2	492261	139399 (28.3%)	206756 (42%)	105909 (51.2%)
3	W3	866	456 (52.7%)	451 (52.1%)	275 (61%)
	S3	2364	979 (41.4%)	770 (32.6%)	438 (56.9%)
	D3	156054	40168 (25.7%)	50855 (32.6%)	28312 (55.7%)
4	W4	405	161 (39.8%)	202 (49.9%)	110 (54.5%)
	S4	386	112 (29%)	101 (26.2%)	57 (56.4%)
	D	110191	21514 (19.5%)	25286 (23%)	14067 (55.6%)

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Analysis of the research in terms of the countries from which their publications originate (Table 3) has identified several countries from which the authors' publications need particular attention when examining qualitative experiences in the application and development of artificial intelligence. Summarising the authors' contributions (the Top 3 prolific countries for each query were identified) over the period (2012-2021), the leaders are the United States and China - on average, researchers from each of these countries authored around 20% of all publications in each our sets. The contribution of researchers from England (the third country in the Top 3) is less than 10%. The publication activity of scientists from India (dataset analysis) S1 needs further research

Table 3. Distribution of authors by countries

Selection	USA	CHINA	ENGLAND (UK)	India
W1 (68464)	14292 (21%)	13038 (19%)	4967 (7.3%)	
S1 (248783)	45951 (18.3%)	50527 (20.3%)		21153 (8.5%)
W2 (2695)	590 (22%)	449 (16.7%)	204 (7.6%)	
S2 (10733)	2571 (24%)	1822 (17%)	670 (6.2%)	
W3 (866)	260 (30%)	120 (14%)	100 (11.5%)	
S3 (2364)	725 (30.7%)	393 (16.2%)	220 (9.3%)	
W4 (405)	85 (21%)	102 (25.2%)	35 (8.6%)	
S4 (386)	75 (19.4%)	97 (25.1%)	20 (5.2%)	

It should be noted that the Dimensions toolkit does not identify the most productive countries by the number of publications. However, our additional mapping with VOSviewer for the D4 set (Fig. 1) as the one most in need of additional research, confirmed the results of the analysis of sets from groups W and S (Table 3).

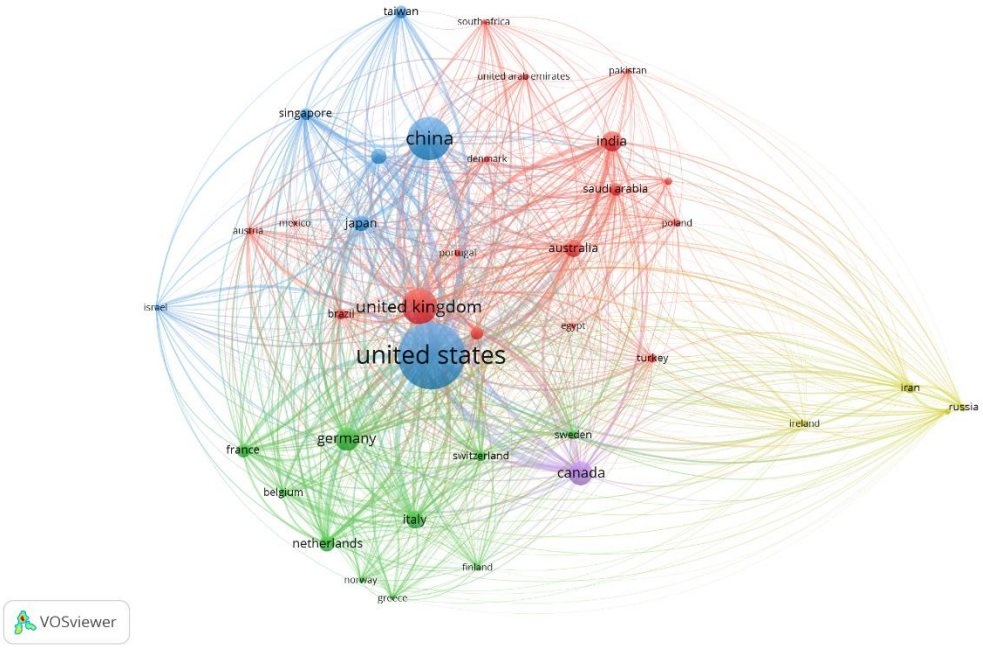

Figure 1. Mapping with VOSviewer for the D4 set

In which research areas is AI applied, and are there any gaps that demand future research?

Regarding Research Areas (Fields of Research in Dimensions), we have identified the most relevant Areas - those that cover more than 15% of the total number of publications

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(Table 4). We have set this percentage threshold because several publications (on average no more than 0.05%) do not contain data (metadata description) in this field.

Table 4. Distribution of authors' Research Areas

	Computer Science	Engineering	Education	Medical and Health Sciences	Mathematics
W1 (68464)	24 735(36.1%)	20 573 (30%)			
S1 (248783)	136351 (54.8%)	68399 (27.5%)			66036 (26.5%)
D1 (1336032)	561590 (42%)	199055 (15%)			
W2 (2695)	876 (32.5%)	509 (19%)	782 (29%)		
S2 (10733)	6976 (65%)	3050 (28.4%)	2259 (21%)		
D2 (492261)	139359 (28.3%)		75164 (15.3%)		
W3 (866)	225 (26%)	159 (18.4%)			
S3(2364)	1196 (50.6%)	465 (19.7%)		811 (34.3%)	
D3 (156054)	51285 (32.9%)			23795 (15.2%)	
W4 (405)	214 (52.8%)	84 (20.7%)	110 (27.2%)		
S4 (386)	270 (69.9%)	111 (28.8%)	96 (24.9%)		76 (19.7%)
D4 (110191)	26902 (24.4%)		16598 (15.1%)		

As can be seen, the main subject areas are Computer Science (Information and Computing Sciences in Dimensions), Engineering, Education Educational Research (Education in Dimensions, Social Sciences in Scopus), which indicates a comprehensive study of the application and development of artificial intelligence. Moreover, the category of educational sciences does not appear in any scientometric database in the general overview of this issue (analysis of W1, S1, D1 datasets), as well as when considering the use of artificial intelligence for personalized learning (W3, S3, D3 datasets). The appearance in the analysis of S3, D3 sets belonging to the category of Medical and Health Sciences (medicine in Scopus) may indicate the use of artificial intelligence in personalized medicine and prevention and appropriate training (mostly informal) medical staff, as evidenced by qualitative analysis of individual publications this dataset. Thus, based on the results obtained, it is possible to make assumptions about the use of artificial intelligence for the implementation of formal personalized learning as a promising area of research. It should also be noted that, considering various aspects of the use of artificial intelligence, about 20% of the publications in mathematics were found in the S1 and S4 datasets. This may indicate the high producibility of a particular subject area and the actualization of the strengthening of the mathematical apparatus to ensure it.

In order to identify frequent topics (frequency of specific keywords in each dataset), we used the corresponding Scopus toolbox (Table 1), i.e. we analysed keywords from sets S1-S4 (Table 5). As a result, not taking into account the highest frequency of "artificial intelligence" as a key term in all queries, the areas of development of artificial intelligence in education (sets S2, S4) include the application and development of Learning Systems, and the relevance of students' interest in using AI motivational component. Also of note is the development of algorithms and the use of machine learning in personalized medicine (set S3), which is in line with current trends in the digitalization of medical education.

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Table 5. Frequency of keywords according to the description of publications in Scopus

Selection	Learning Systems	Machine Learning	Human	Education	Students	Personalized Medicine
S1 (248783)	39655 (15.9%)	29575 (11.9%)	22620 (9.1%)			
S2 (10733)	2382 (22.2%)			3367 (31.4%)	2594 (24.2%)	
S3 (2364)		1058 (44.8%)	964 (40.8%)			763 (32.3%)
S4 (386)	134 (34.7%)			104 (26.9%)	126 (32.6%)	

CONCLUSIONS

The number of published studies on the development and application of AI technologies is constantly growing. Nevertheless, there is a need for additional research on the use of AI in social sciences and educational sciences and multidisciplinary research to develop algorithms, and technological and methodological solutions for the effective use of AI in education. A qualitative study of the experience of application and development of artificial intelligence (defined as a prospect for further research) should pay attention to the initial research of scientists from the United States and China. The high probability of the conclusions is confirmed by a strong source base of bibliometric analysis (total number of primary publications - 334696) and independence from the specific scientometric base or publisher policy: the same general trends are observed in the analysis of different sets of groups W, S and D. "Non-critical" differences, their detection in the process of this study may be accidental.

The identified need for additional research on the use of artificial intelligence in the implementation of personalized learning can be partially met in the teacher training system (Morze, Liakh, & Kuzminska, 2017) or in the implementation of projects – in particular, European Project „Future IT Professionals Education In Artificial Intelligence" (FITPED-AI) (2021-1-SK01-KA220-HED-000032095). For example, the main outcome of the project is an educational model for building highly specialized skills in AI-oriented university study programmes.

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