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ORIGINAL

Emerging Technologies in Education: a Bibliometric Analysis of Artificial Intelligence and its Applications in Health Sciences

Tecnologías Emergentes en Educación: un Análisis Bibliométrico de la Inteligencia Artificial y sus Aplicaciones en Ciencias de la Salud

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ABSTRACT

Artificial Intelligence brings a new paradigm in health sciences related to using technologies capable of processing a large amount of patient information to strengthen prediction, prevention and clinical care. This research aimed to perform a bibliometric analysis of Artificial Intelligence and its applications in Health Sciences, particularly on Emerging Technologies in Educaetion. To this end, a search for articles related to "Artificial Intelligence and its Applications in Health Sciences" was conducted at the international level in the Scopus database with search parameters based on titles, abstracts and keywords. The results revealed that the network of the 100 most essential terms was grouped into four clusters, namely: the first cluster identified with red colour is related to artificial Intelligence; the second cluster identified with green colour is related to the controlled study; the third cluster identified with yellow colour is related to algorithm and, the fourth cluster identified with yellow colour is related to education. It was concluded that artificial Intelligence has experienced advances that are having an impact on health sciences education. Academics and researchers have tools that allow them to obtain information to deepen the diagnosis of diseases and present students with robust case studies that strengthen the teaching-learning process.

Keywords: Emerging Technologies; Education; Bibliometric Analysis; Artificial Intelligence; Health Sciences.

RESUMEN

La Inteligencia Artificial trae un nuevo paradigma en las ciencias de la salud en cual está relacionado con el uso de tecnologías capaces de procesar una gran cantidad de información de los pacientes, para fortalecer la predicción, prevención y la atención clínica. Esta investigación tuvo por objetivo realizar un análisis bibliométrico de la Inteligencia Artificial y sus aplicaciones en ciencias de la Salud, con especial énfasis en las Tecnologías Emergentes en Educación. Para ello, se realizó una búsqueda de artículos relacionados con la "la Inteligencia Artificial y sus Aplicaciones en Ciencias de la Salud" a nivel internacional en la en la base de datos Scopus con los parámetros de búsqueda basados en títulos, resúmenes y palabras clave. Los resultados revelaron que la red de los 100 términos más importantes se agrupó en cuatro clústeres a saber: el primer clúster identificado con el color rojo, está relacionado con la artifical intelligence; el segundo clúster identificado con el color verde está relacionado con controlled study; el tercer clúster identificado con el color amarillo está relacionado con algorithm y, el cuarto clúster identificado con el color amarillo está relacionado con education. Se concluyó que la Inteligencia artificial ha experimentado avances que está repercutiendo en la educación de las ciencias de la salud. Académicos e investigadores tienen en sus manos tienen en sus manos herramientas que les permiten obtener información para profundizar en el

diagnóstico de enfermedades y presentar a los alumnos casos de estudio robustos que fortalecen el proceso de enseñanza-aprendizaje.

Palabras clave: Tecnologías Emergentes; Educación; Análisis Bibliométrico; Inteligencia Artificial; Ciencias de la Salud.

INTRODUCTION

Since the 1990s, endeavors have been undertaken to develop computer systems capable of processing information in a manner akin to the human brain. Initially, in health sciences, the emphasis was on the management of patient information.[1] Currently, Artificial Intelligence (AI) has also achieved considerable advances in the field of health sciences education.[2]

Artificial Intelligence introduces a new paradigm in health sciences, which is related to the utilization of technologies capable of processing a large amount of patient information to strengthen prediction, prevention, and patient care, ultimately improving clinical care.[3]

Students in health sciences today have the opportunity to delve deeper into disease diagnoses with diverse case studies. Additionally, they have access to artificial images and detailed knowledge of drug components, providing an opportunity for profound learning in different contexts.[4]

The healthcare system and individual patient care are witnessing improvements in aspects such as the prediction of acute diseases and their diagnoses.[5] AI, leveraging its algorithms and applications, is playing a pivotal role in the development of research and treatment of diseases. Likewise, AI is facilitating patient monitoring, thereby enhancing medical attention and clinical practice.[6]

AI is significantly improving the health system worldwide, the investments in the sector have increased since 2018 aimed at facilitating public access to healthcare and enhancing the infrastructure of health centers for improved medical attention. The presence of adequate infrastructure is fundamental to ensure the successful implementation of AI and its compatibility with all systems.[7] Having said that, education plays a fundamental role in this context, as clinical staff needs to be trained in the operation of equipment and software, and patients must be educated to overcome cultural and generational barriers to efficiently utilize AI. It is noteworthy that remote analysis of results and telemedicine will enable virtual medical care, alleviating the workload on clinical staff.[8]

This research aimed to conduct a bibliometric analysis of Artificial Intelligence and its applications in Health Sciences, with a particular emphasis on Emerging Education Technologies. To achieve this, a search for articles related to “Artificial Intelligence and its Applications in Health Sciences” was conducted internationally in the Scopus database, with search parameters based on titles, abstracts, and keywords.

METHODS

The bibliometric analysis of Artificial Intelligence and its applications in Health Sciences involved the application of the necessary steps for this type of study.[9] In this context, a search for articles related to “Artificial Intelligence and its Applications in Health Sciences” was conducted internationally in the Scopus database, with search parameters based on titles, abstracts, and keywords.[10]

The search filter used was: (TITLE-ABS-KEY("Big Data") OR TITLE-ABS-KEY("Artificial Intelligence") OR TITLE-ABS-KEY("AI") OR TITLE-ABS-KEY("Machine Learning") OR TITLE-ABS-KEY("Neural Networks") OR TITLE-ABS-KEY("Natural Language Processing")) AND TITLE-ABS-KEY("education") AND SUBJAREA(MEDI OR NURS OR VETE OR DENT OR HEAL OR MULT) AND PUBYEAR > 1999 AND PUBYEAR < 2024. In this context, articles published in the period 2000-2023 were selected.

The analysis was conducted using the Visualization of Similarities (VOSviewer 1.6.18) software (www.vosviewer.com) with which international collaboration and keywords were examined.

DEVELOPMENT

Artificial Intelligence in Health Sciences

Since the 1950s, there have been discussions about AI, with efforts aimed at developing sophisticated intelligent machines capable of performing tasks and solving problems like a human being.[11] Clearly, at present, there is a consolidation of tools that ensure secure access to health, the diagnosis and treatment of diseases, and high-quality clinical care.[12]

AI is grounded in algorithms that interconnect through neural networks. Neural networks consist of processing elements arranged into layers, aiming to construct an artificial neural network capable of swiftly processing and analyzing a large amount of information.[13]

AI is exerting a positive impact on health sciences education by facilitating the study of real cases and

enabling the development of low-cost research with enhanced results. AI is also contributing to disease prevention, notably in fields such as cardiology and psychology, as well as infectious, cardiac, renal diseases, among others. This involvement is significantly improving the quality of life for patients.[14]

The swift data processing achieved with AI is empowering medical professionals to respond to patients in relatively short periods and with minimal risk in diagnosis. Therefore, the justification for the use of AI in healthcare lies in its capacity to enhance service delivery.[15]

The digitization of patient information ensures secure access and management. In this regard, the collection of data from patients through smartphones and other devices is contributing to the achievement of less costly exams. Once processed, this data facilitates decision-making in the healthcare domain.[16]

RESULTS

Figure 1 illustrates the trend of scientific production per year. It can be observed that from 2011, there is a notable first inflection point, signifying the emergence of increased interest among researchers in artificial intelligence and its applications in health science. A second important inflection point occurs in 2017, with the number of publications escalating from approximately 300 to over 1800 by the year 2023.

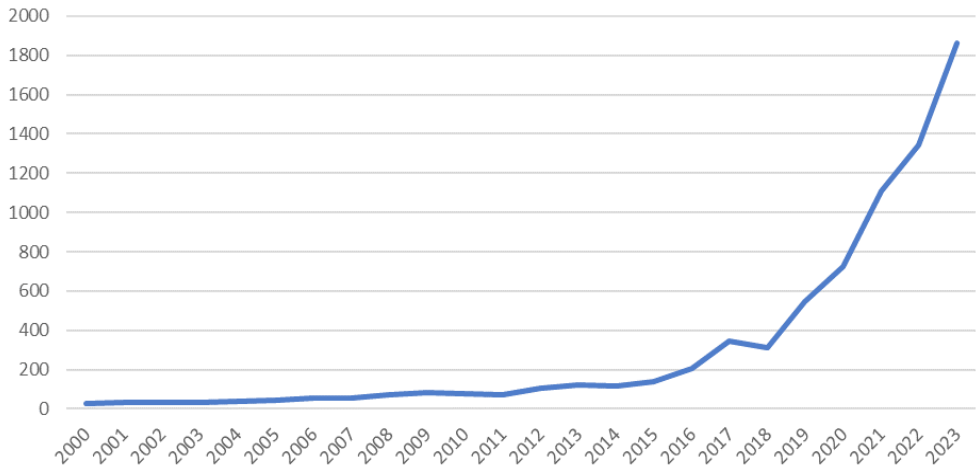

Figure 1. Articles per year

Regarding the topics addressed by the investigations, figure 2 illustrates that a total of 2163 topics were identified concerning Artificial Intelligence and its applications in health sciences. The visualization indicates that the topics are fundamentally clustered in yellow, blue, red, and green colors.

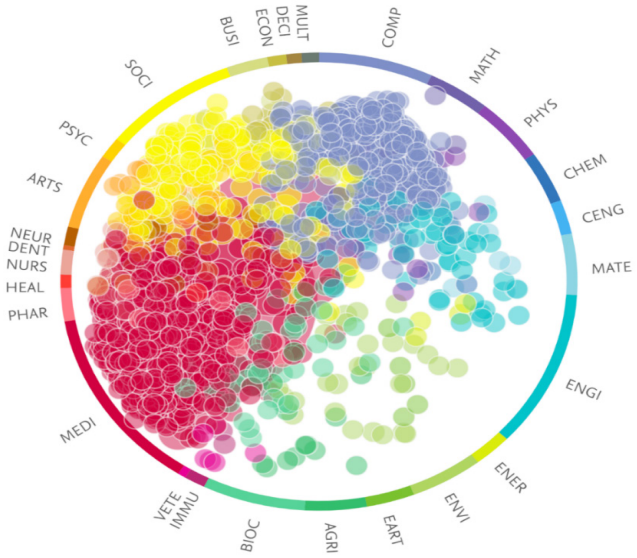

Figure 2. Distribution of topics according to thematic categories

To simplify the analysis, the 100 most investigated topics were identified. Table 1 showcases the top 100 most important topics addressed by researchers, featuring the number of documents (Ndoc) and the *Field-*

weighted Citation Impact (FWCI), which is the normalized impact from Scopus. According to the number of documents, the top ten positions are occupied by: Students; Medical Students; Education (380), Electronic Health Records; Medical Informatics; Delivery Of Health Care (352), Algorithms; Computer Vision; Models (330), Students; Teaching; Education; E-Learning (181), COVID-19; SARS-CoV-2; Coronavirus (152), Semantics; Models; Recommender Systems (131), Alzheimer Disease; Dementia; Amyloid (111), Health Literacy; Patients; Internet (111), Robots; Robotics; Human Robot Interaction (91), and Radiology; Physicians; Patients (77).

On the other hand, when considering the FWCI, the order of topics changes. The top ten positions based on FWCI are: Pervasive Child Development Disorders; Autistic Disorder; Child (14,15), Heart Arrest; Cardiopulmonary Resuscitation; Out-Of-Hospital Cardiac Arrest (10,80), Electronic Health Records; Medical Informatics; Delivery Of Health Care (6,80), Fuzzy Systems; Fuzzy Inference; Neural Networks (6,10), Publications; Periodicals As Topic; Research (4,55), Robots; Robotics; Human Robot Interaction (4,47), Eye; Glaucoma; Cataract (3,97), Cytology; Image Segmentation; Medical Imaging (3,69), Emergencies; Patients; Hospitals (3,67), and Industry; Research; Marketing (3,44).

Table 1. Top 100 topics

Topic Cluster	Ndoc	FWCI
Students; Medical Students; Education	380	2,60
Electronic Health Records; Medical Informatics; Delivery of Health Care	352	6,80
Algorithms; Computer Vision; Models	330	2,74
Students; Teaching; Education; E-Learning	181	2,97
COVID-19; SARS-CoV-2; Coronavirus	152	2,81
Semantics; Models; Recommender Systems	131	2,10
Alzheimer Disease; Dementia; Amyloid	111	1,20
Health Literacy; Patients; Internet	111	1,95
Robots; Robotics; Human Robot Interaction	91	4,47
Radiology; Physicians; Patients	77	1,72
Obesity; Motor Activity; Child	76	1,02
Telemedicine; Technology; Patients	76	1,64
Surgery; Needles; Robotics	57	2,31
Eye; Optical Coherence Tomography; Macular Degeneration	55	2,75
Neoplasms; Patients; Palliative Care	53	2,00
Insulin; Type 2 Diabetes Mellitus; Glucose	51	1,62
North American Indians; Residence Characteristics; Health	51	0,88
Sports; Students; Athletes	50	0,63
HIV; HIV Infections; HIV-1	42	0,85
Colorectal Neoplasms; Rectal Neoplasms; Patients	42	1,61
Speech; Speech Recognition; Models	42	1,49
Breast Neoplasms; Genetic Testing; Risk	42	1,17
Industry; Research; Marketing	39	3,44
Publications; Periodicals as Topic; Research	39	4,55
Industry; Information Systems; Research	36	0,86
Melanoma; Skin Neoplasms; Neoplasms	35	2,51
Design; Human Computer Interaction; Augmented Reality	32	1,76
Students; Teaching; Education; Computer Science	32	0,63
Delivery Of Health Care; Patients; Hospitals	31	0,94
Magnetic Resonance Imaging; Brain; Diffusion	31	1,10
Cytology; Image Segmentation; Medical Imaging	31	3,69
Health; Disease Outbreaks; Diseases	31	2,06
Research; Meta-Analysis as Topic; Guidelines as Topic	29	0,95
Wireless Sensor Networks; Sensor Nodes; Routing Protocols	28	2,45

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Pheochromocytoma; Paraganglioma; Hydrocortisone	27	1,44
Vaccination; Vaccines; Immunization	27	2,14
Epilepsy; Seizures; Electroencephalography	26	1,23
Child; Adolescent; Schools	26	0,91
Sepsis; Acute Kidney Injury; Patients	26	2,58
Fuzzy Systems; Fuzzy Inference; Neural Networks	26	6,10
Sleep; Obstructive Sleep Apnea; Sleep Apnea Syndromes	25	0,77
Non-Small-Cell Lung Carcinoma; Lung Neoplasms; Patients	25	3,08
Research; Clinical Trials as Topic; Patients	25	0,61
Oral Health; Periodontitis; Dental Caries	24	0,82
Pervasive Child Development Disorders; Autistic Disorder; Child	24	14,15
Emotions; Anxiety; Depression	24	0,87
Pharmacists; Pharmaceutical Preparations; Pharmacy	24	1,49
Cryptography; Authentication; Data Privacy	23	1,93
Atrial Fibrillation; Patients; Catheter Ablation	22	3,02
Human Influenza; Orthomyxoviridae; Influenza Vaccines	22	1,29
Breast Neoplasms; Patients; Mammography	21	1,48
Classification (Of Information); Learning Systems; Algorithms	21	0,72
Sarcopenia; Patients; Aged	21	2,26
Schizophrenia; Psychotic Disorders; Antipsychotic Agents	20	1,48
Nurses; Nursing; Students	20	1,93
Computer Crime; Network Security; Intrusion Detection	20	1,17
Health; Delivery of Health Care; Women	20	0,67
Suicide; Suicidal Ideation; Wounds and Injuries	20	1,13
Electroencephalography; Brain Computer Interface; Electrophysiology	20	0,99
Chronic Obstructive Pulmonary Disease; Asthma; Patients	19	0,95
Stroke; Patients; Cerebral Hemorrhage	19	1,37
Heart Failure; Patients; Brain Natriuretic Peptide	19	1,65
Students; Education; Teaching	19	0,98
Estimator; Models; Variable Selection	18	1,19
Coronary Artery Disease; Patients; Echocardiography	18	2,24
Stroke; Gait; Rehabilitation	17	1,43
Hearing; Hearing Loss; Cochlear Implants	17	1,54
Pregnancy; Pre-Eclampsia; Women	17	1,11
Magnetic Resonance Imaging; Image Segmentation; Medical Imaging	17	1,29
Health; Socioeconomic Factors; Mortality	17	0,43
Emergencies; Patients; Hospitals	17	3,67
Eye; Glaucoma; Cataract	16	3,97
Cloud Computing; Clouds; Distributed Computer Systems	16	2,68
Gambling; Internet; Students	16	2,11
Sensors; Accelerometers; Smartphones	16	0,94
Spine; Patients; Low Back Pain	15	2,53
Industry; Innovation; Entrepreneurship	15	0,71
Heart Arrest; Cardiopulmonary Resuscitation; Out-Of-Hospital Cardiac Arrest	15	10,80
Laboratories; Patients; Medicine	15	1,15
Work; Personality; Psychology	14	0,73
Language; Reading; Semantics	14	1,52
Depression; Bipolar Disorder; Major Depressive Disorder	14	1,65

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Radiation; Tomography; Medical Imaging	14	1,67
Particulate Matter; Air Pollution; Air Pollutants	14	2,51
Parkinson Disease; Deep Brain Stimulation; Patients	13	0,70
Alcohols; Cannabis; Drinking	13	1,29
Smoking; Tobacco Products; Smoking Cessation	13	0,50
Models; Social Networking (Online); Algorithms	13	0,61
Electrocardiography; Heart; Monitoring	13	1,44
Research; Data; Information Dissemination	13	2,13
Helicobacter Pylori; Gastroesophageal Reflux; Helicobacter Infections	12	1,10
Arthroplasty; Hip; Knee	12	2,29
Hypertension; Blood Pressure; Patients	12	1,54
Students; Science; Learning	12	0,83
Students; Engineering; Education	12	0,25
Radiotherapy; Radiation; Intensity-Modulated Radiotherapy	12	2,27
Students; Teacher; Learning	12	1,66
Science; Risks; Nanotechnology	12	1,28
Student; Ethics; Integrity	12	3,24
Software Engineering; Models; Software Design	11	1,72

Table 2. International collaboration

Metric	%Ndoc	Ndoc	Ncit	Cpd	FWCI
International collaboration	24,60	1858	18765	10,10	2,84
Only national collaboration	37,00	2794	20734	7,42	2,27
Only institutional collaboration	24,30	1835	9577	5,22	1,82
Single authorship (no collaboration)	12,90	974	3727	3,83	2,73

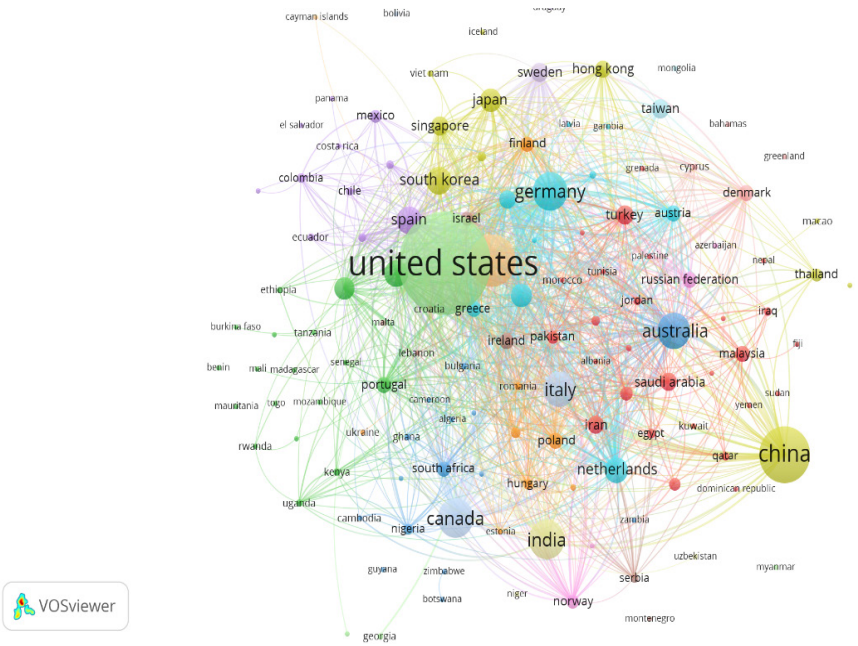

Figure 3. International collaboration

Concerning international collaboration, table 2 provides information related to %Ndoc (percentage of the number of documents), Ndoc, number of citations (Ncit), citations per document (Cpd), and FWCI. A notable international collaboration is evident, represented by 1858 documents, 18765 citations, and an impact level of 2,84. Similarly, national collaboration is observed with 794 documents, 20734 citations, and an impact level of 2,27 (Table 2). Although international collaboration is less than national collaboration, it highlights the

researchers' interest in the topic and their approach within an international context.

Figure 3 depicts the formation of several clusters, emphasizing those identified with the green, blue, and violet colors. The cluster identified with the green color, is composed of Rwanda, Senegal, Kenya, Uganda, Tanzania, Cameroon, and Ghana. The cluster identified with the blue color includes Germany, Austria, Greece, the Netherlands, Latvia, and Gambia. The cluster identified with the violet color comprises Spain, Chile, Colombia, Costa Rica, El Salvador, Panama, Mexico, and Ecuador.

DISCUSSION

In figure 4, the network of the 100 most important terms and the generation of four clusters are depicted. The first cluster, identified with red color, is associated with artificial intelligence and comprises terms such as human, priority journal, methodology, systematic review, physician, letter, clinical practice, health care, decision making, internet, editorial, practice guideline, social media, medical society, patient education, health care personnel, health education, awareness mental health, health care delivery, coronavirus disease 2019, COVID-19, quality of life, and mental health.

In recent years, artificial intelligence has significantly improved and is increasingly being employed in healthcare. For instance, ChatGPT has enabled patients and physicians to interact in order to provide coherent responses to inquiries related to medications, symptoms, and clinical practice in general.[17] In this regard, ChatGPT facilitates medical professionals in writing clinical reports within a short timeframe. Furthermore, ChatGPT-4 is contributing to the improvement of medical education and facilitating access to a vast amount of information.[18] Moreover, one of the benefits of artificial intelligence lies in generative networks, which can be employed in medical education and the in-depth exploration of diagnoses.

The second cluster, identified with the green color, is associated with controlled study and consists of terms such as physiology, cohort analysis, cognition, male, female, age, assessment, follow up, risk factor, China, hypertension, diabetes mellitus, surveys and questionnaires, United States, epidemiology, attitude to health, American Indian, adolescent, young adult, child, cross-sectional study, middle age, clinical article, and very elderly.

AI researchers are exploring innovative tools and methods to apply AI in different contexts, aiming to leverage its advantages in the diagnosis, prevention, and treatment of diseases.[19] AI tools, including virtual medical simulators, are anticipated to significantly impact research quality and facilitate the analysis of project contents or the study of clinical cases.[20] Ultimately, these tools will contribute to the development of cognitive skills and critical thinking among students.[21]

The third cluster, identified with the yellow color, is associated with algorithms and includes terms such as radiologist, radiology, automation, deep learning, algorithms, artificial neural network, procedures, retrospective study, sensitivity and specificity, nuclear magnetic resonance imaging, and diagnostic imaging.

AI algorithms are facilitating the rapid identification of medical codes for clinical trials and drug development at a low cost.[22] Presently, researchers and students have access to generative AI tools that create useful content for the learning process, for example, ChatGPT developed by OpenAI, BingGPT developed by Microsoft, and Bard developed by Google.[23] AI tools are making significant contributions to medical education, opening up a range of opportunities for the development of updated content and materials that contribute to the enhancement of academic performance.[24] Over time, algorithms will continue to evolve, aiming to become more precise and guarantee the quality of information, while considering the ethical implications of the data used. However, the adoption of new algorithms poses a challenge for academics, necessitating training to take full advantage of the capabilities of these tools and ensure their proper utilization.[25]

The fourth cluster, identified with the yellow color is associated with education and includes terms such as medical school, medical student, curriculum, simulation, skill, learning, big data, machine learning, resident, human, experiment, software, student, data mining, and diagnosis.

Education in health sciences is experiencing substantial transformations through the utilization of AI.[26] For instance, machine learning is facilitating the management of patient information to recommend treatments; and it is also enabling the observation of vital signs in patients in intensive care in order to the detection of complex infections.[27] Furthermore, AI is supporting real-time and virtual patient care based on medical history and individual needs.[28]

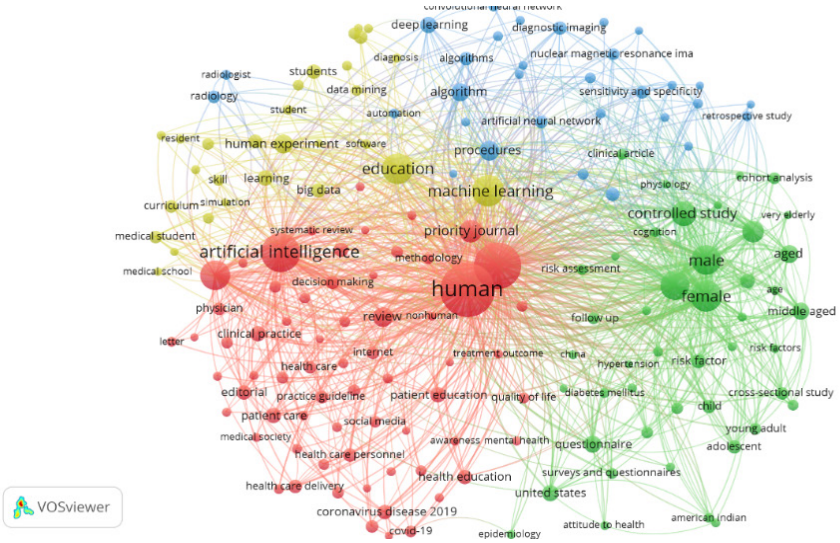

Figure 4. Network of the 100 most important terms

The overlay in figure 5 indicates the distribution of terms by the year of publication, highlighting that a majority of terms are present in publications from the year 2020. Hence, research has been directed towards exploring diverse topics such as human, artificial intelligence, medical education, controlled study, among others. At present, there is an interest in the study of topics such as pandemic, radiologist, and ChatGPT.

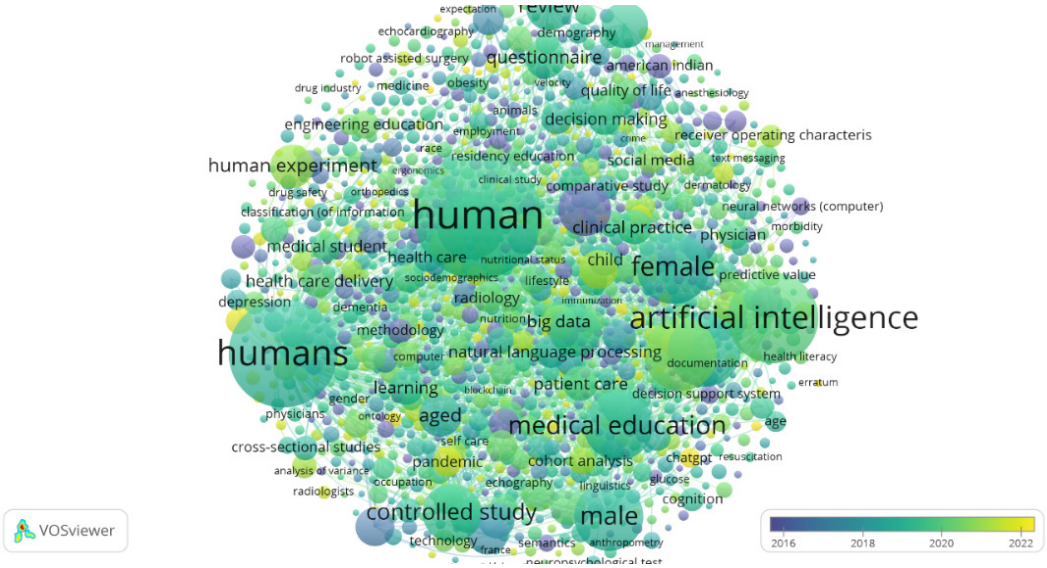

Figure 5. Distribution of terms by year of publication

CONCLUSIONS

AI has undergone advancements that are influencing education in health sciences. Academics and researchers now have tools at their disposal that enable them to obtain information for in-depth exploration of diseases diagnosis. These tools also facilitate the presentation of a variety of robust case studies to students, thereby strengthening the teaching and learning process.

With the support of AI, preventive medicine is being strengthened to ensure effective disease prevention. Furthermore, participatory medicine is being promoted, as patients can actively provide information and monitor indicators related to their health status. Likewise, personalized medicine is being enhanced, emphasizing the genetic and individual aspects of each patient based on information from their health history. Moreover, preventive medicine is being reinforced, as digital tools facilitate the diagnosis and early detection of diseases to enable the development of effective treatments.

There are challenges that need to be addressed in health sciences education. For instance, biases in AI algorithms can have implications for the doctor-patient relationship. Currently, despite organizations such as the UN and the European Union defining standards for AI use, particularly in areas like transparency and data protection, there is still no formal legal framework regulating their utilization.

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CONFLICT OF INTEREST

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