The Potential of AI in Health Higher Education to Increase the Students' Learning Outcomes

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Abstract **– The main goal of this article is to understand the potential learning applications based on AI technologies for health higher education students. We employed a Systematic Literature Review, contributing to explore to what extent AI technologies are currently influencing the Health learning processes in higher education and the skills developed during the learning path. The intent is to contribute to a more profound understanding of learning contexts, methodologies, technologies, and pedagogical processes with the application of AI technologies. The literature emphasizes that AI can be used to potentiate the learning process and the learning outcomes, especially in laboratory classes, and such contexts are still largely unstudied. To fulfil this gap, some practical applications based on AI technologies applied to health higher education studies were identified, highlighting AI's innovations and possible opportunities for health higher education.**

Keywords **– AI Technologies, Higher Education, Health, Students, Learning Contexts.**

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1. Introduction

In recent years, Artificial intelligence (AI) has been gaining more and more interest both from academics as well as practitioners [1–3], leading to new approaches and funding opportunities. Concepts such as machine learning (ML), deep learning (DL), and others are nowadays commonly used terms.

AI-based technologies have been improving the performance of the manufacturing and services sectors, while still keeping an enormous promise for future applications in several fields, with healthcare as a priority sector [4–6], affecting several medical disciplines including cardiology [7], pulmonary medicine [8], general surgery [9], endocrinology [10], radiology [11], gastroenterology [12], neurology [13], cancer diagnosis [14], and medical imaging [15]. This study presents a holistic literature review, namely, theoretical frameworks and practical experiences in the field of AI, especially related to health higher education. It reports the state-of-the-art on AI, in particular, and provides an extensive analysis of recent developments on AI and its possible educational applications, focusing on the healthcare sector.

Two factors are motivating this research in AI. First of all, there is a call to give an overview of the concept and its possible applications to the new entrants into the AI field. Moreover, there is an increasing interest in AI by researchers from several disciplines and by companies, who are keener and keener on adopting AI-related solutions [4,16,17], given the added value already proved by AI applications [5,9,18–20].

The first section of the paper presents a conceptual approach to AI. The following part offers a comprehensive review of the literature, while the final section is devoted to a potential model of application and insights for policies and future research avenues.

2. Artificial Intelligence Conceptualization and Technologies

AI refers to devices' or systems' ability to think as human beings, having the power and skills to learn, perceive, and decide rationally and intelligently [21]. The technologies which can be associated with AI are Machine Learning (ML), Deep Learning (DL), Natural Language Processing (NLP), among others.

ML refers to machines that learn from the data [22], reaching the outcomes in an autonomous way. ML allows building a mathematical model from data, leveraging on a significant number of variables that are not acknowledged in advance, providing data-driven predictions.

DL involves machines that use complex algorithms to imitate the neural network of the human brain and learn an area of knowledge with virtually no supervision [23].

NLP is connected to ML techniques to find patterns in big data sets (human-written sources), that recognize the natural language [24], [25]. Its use includes the analysis of customers' feelings with respect to some products or services, scouting posts on social media networks.

Such analytical tools allow organizations to integrate analytical models into their business processes, supporting the design of business strategies and enhancing decision-making capabilities [26]. By applying advanced AI technologies such as ML and cognitive services against the data coming in from the manufacturing process, organizations get value-added insights into data. As a result, organizations can improve operational efficiencies, speed production, optimize equipment performance, minimize waste, and reduce maintenance costs [27]. Other Industry 4.0's technologies such as cloud computing, automation, the blockchain, additive manufacturing, immersive technologies, robotics, and Internet of Things (IoT), integrate AI, to foster intelligent systems/devices, high-performing factories, smarter ecosystems, leading to the creation of new business models [1], [28–30] in different fields, including healthcare and education.

3. Artificial Intelligence Applied to Higher Education

AI application to Higher Education (HE) has been studied by several authors [31–36], who focused on the contributions of AI mainly to improve learning opportunities for students and management systems. AI technologies can be used to ensure equitable and inclusive access to education. AI provides opportunities for people with disabilities, refugees, and those living in isolated communities to access appropriate learning paths. The use of holograms and robotics allow students with special needs to attend schools at home or from the hospital or maintain continuity of learning in emergencies or crises, as during the pandemic situation caused by Covid-19 at the beginning of 2020 [37]. AI can help advance collaborative learning, personalization of tailored solutions to specific needs, smart contents, individualized solutions for people with disabilities (e.g., deaf or visually impaired), collaboration through intelligence tools, and exponential scalability (e.g. through MOOCs) [36], [38], [39]. One of the most revolutionary aspects of computer-supported collaborative learning is found in situations where learners are not physically in the same location. AI systems are used to monitor asynchronous discussion groups, thus affording teachers with information about learners' discussions and support for guiding learners' engagement and outcomes. AI can help personalize learning through algorithms, i.e. Intelligent Tutoring Systems are part of the new technological possibilities to expand educational learning [40]. Moreover, when considering the tremendous amount of time spent on grading tests and homework, AI can be an exceptional assessment tool, not only to grade multiple-choice tests but also to assess essays. At the same time, the need to deepen some topics and applications related to AI fosters new subjects and issues to be raised in class.

The interest, use, and potential applications of AI in education are increasing, even following the constraints and social distancing measures coming from the Covid-19 pandemic [41]. While education can embrace several fields, interesting insights can come from the healthcare sector, which is one of the most promising fields for AI applications [42]. Therefore, our Research Question (RQ) is:

RQ: Which are the main tentative applications for increasing the potential of AI in Health Higher Education Students learning processes?

4. Methodology

In this section, an overview of the research approach and methodology is presented for a better understanding of bibliometrics and bibliographic coupling analysis used for a systematic literature review. This research paper used VOSviewer [43],[44] as the selected methodology, being a sophisticated evidence-based platform that uses a reliable and structured method to perform the identification, analysis, and interpretation of co-occurrence and co-authorship matrices, such as co-citation, co-word, and co-link matrices. This paper also presents, during this section, the different studies performed for a better understanding of counting methods and network map analysis connected with co-authorship, co-occurrence, citations, and bibliographic counting, in which appropriate statistical techniques were applied to each of these matrices, respectively [44].

This study aims to offer a comprehensive and extensive systematic review of the literature with an advanced bibliometric data analysis from relevant keywords like Artificial Intelligence (AI) technologies, higher education, healthcare, and public health and learning contexts.

Hence this research investigates how AI in health higher education can be perceived as a valid education alternative to some of the current education challenges in higher education with efficient utilisation of resources, ideal data storage, and new methods and procedures.

In summary, this study consists of a deep understanding of a systematic quantitative literature review of academic articles indexed on the PubMed, Scopus, Google Scholar, and Microsoft Academic databases. For a useful network analysis based on co-authorship, co-occurrences, and co-citation maps we perform several analyses in terms of association strength networks to create intuitive, understandable network graphs to multivariate analysis and authors, keywords, and citations network analysis.

Co-occurrence matrices, such as co-citation, co-word, and co-link matrices, provide us with useful data for mapping and understanding many data links and connection structures.

The search terms were based on the research questions using synonyms and related terms. The following keywords were used to formulate the search string: a) Artificial Intelligence; b) Higher Education c) Students d) Healthcare.

Our target population was all relevant papers in a higher education context with the application of AI in the Students learning processes.

During the application of the correct search and identification criteria, the generic exclusion criteria were defined: a) published in non-peer-reviewed publication channels such as books, thesis or dissertations, tutorials, keynotes, and others. OR; b) Not available in English OR; c) A duplicate OR; d) published before 2000. The first two criteria were implemented in the search strings executed in PubMed, Scopus, Google Scholar, and Microsoft Academic libraries. As a result of the analysis, 171 articles were selected. Figure 1 summarises the process followed in the selection criteria.

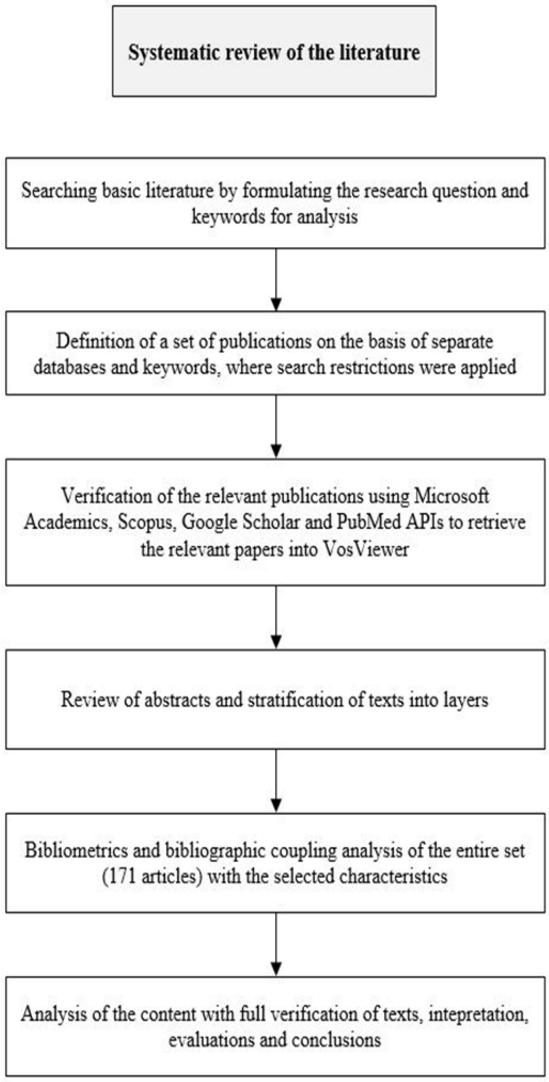

Figure 1. Research Design

5. Articles Search and Selection Strategy

The first criteria were based on the titles, content, abstract, language, year, and presented results of the papers, articles, or publications. These criteria were applied to the items that passed a generic exclusion criterion and were identified through the database search.

Following the procedure presented, the papers were classified and qualified, in which for a profound understanding of all the results, we selected two types of analysis: (1) co-authorship, citations analysis, and (2) co-occurrence.

(1) This type of analysis presented the relatedness of all selected authors and co-authors and was determined based on their number of documents and networks of relationships. In this paper and terms of the advanced search criteria, the type of analysis selected for the co-authorship followed the unit of analysis of authors with a full counting method and applying a minimum number of documents of an author to one, whereof the 432 authors all met the selection criteria and threshold. For each of the 432 authors from the 171 publications, the total strength of the co-authorship links with other authors was also calculated, and the authors with the greatest total link of strength were selected.
(2) Co-occurrence analysis: the relationship and relatedness of all presented items have a primary determinant of the number of documents and all related search terms and keywords in which they occur together.

In most of the presented analysis, the counting of the terms and keywords were presented as a full count and instead of fractional count analysis, where the full counting represents that each of the co-authorship or co-occurrence link has the same weight.

The advanced criteria were also related to the actual API data extraction from Microsoft Academic and PubMed platforms and uploaded into VOSViewer, in which some of the additional criteria for the data analysis were thoroughly applied. Some of those additional and final options were: (1) minimum occurrence of a keyword from the total of keywords; (2) total of the strength of the co-occurrence with other keywords calculations following a pre-defined selection of the number of keywords to be selected for all of the presented analysis (3) weight of occurrences for effective data visualisation; (4) analysis and validation of all of the selected clusters of the selected items from the VOSViewer algorithm; (5) usage of default values in association with the normalisation for data layout visualisation (6) merging of small clusters for an easy to understand visualisation of all the presented figures in this paper.

6. Results

In this section, the findings of the systematic review process are presented. All the results had as the main basis the bibliometric indicators from the 171 selected articles. As explained in the previous point, the whereof regarding the statistical analysis allowed us to understand better the results with concrete data and measurable indicators from the scientific network of all of the co-authorship analysis as well as of the co-occurrence analysis.

6.1. Co-Authorship Data Analysis

We based the data analysis on 171 selected documents that corresponded to all qualification and search criteria and we proceeded with the corresponding analysis on 432 authors with a total of 133 clusters combined with the research parameters.

In the analysis, the minimum number of documents for each author was two. Therefore, to proceed with the data visualisation graphs, we combined authors that had a certain level of linkage and connection that allowed us to understand the related graph maps and clustering.

For the initial analysis and each of the 432 authors, the total strength of the co-authorship links with other authors was also calculated, where only the authors with the greatest total link strength were selected. The final number of authors selected was 171 that demonstrated consistent link strengths.

In terms of the counting methods we selected the full counting technique and we considered as valid the publications and research articles that had more than 25 authors per document, as it was a relevant selection criteria within VosViewer.

6.2. Citation-Based Clustering of Publications

To better understand the data points, we also performed additional analysis on clustering scientific publications as it represents an important technique in the bibliometric analysis. We perform cluster publications to analyze the resulting clustering solutions, and VosViewer was able to support our key questions related to the key research items to perform citation clustering analysis using the original 171 articles selected from the already explained data sources and based on the pre-defined search terms. Then all the publications were clustered based on direct citation relations and citation relations between these publications, and the clusters to which the publications belong. The sources were selected based on the number of citations and the number of citation links that we were able to be included to better comply with the software algorithm and to offer a proper visualization from the selected documents with the largest number of links.

The citation analysis used the unit of analysis of sources, with many two documents from the selected source (95 sources selected).

We clustered the publications in our data set using the VosViewer clustering technique from our citation network of 171 publications. The choice of the most suitable level of detail is not a technical one but instead depends on the purpose of the cluster analysis, where we selected key 137 documents from the 171 total publications database and then even performed a more narrowed qualification of those documents to 65 mainly because of the total strength of the citation links with other sources and the related citation linkage levels.

6.3. Co-Occurrence of Terms and Keywords - Data Analysis

Using VOSviewer and the selected keywords valid for the documents and items selection (Artificial Intelligence, Higher Education, Students, Health), we performed an analysis based on qualified co-occurrence fields of study as a key unit for analysis. The below visualizations show 91 terms that met the VosViewer threshold in terms of the total strength of the co-occurrence links with other keywords.

The strongest co-occurrence relations between terms are then visible in the following figures and mainly as key concepts like the terms occurrence relationship and relatedness, in which from of all presented items and selection have the main determination of the number of documents and all related search terms and keywords in which they occur together.

The size of a term reflects the number of publications in which that specific term was found, and the distance between two terms offers an approximate indication of the relatedness of the terms. Hence the relatedness of terms was therefore determined based on co-occurrences, to what the larger the number of publications were defined, and the graphs shows the strongest relationship between the terms. For a better interpretation of the graphs, it is also important to clarify that all colors represent groups of terms that are relatively strongly related to each other. In the visualization, the strongest relations between terms are also indicated using curved lines.

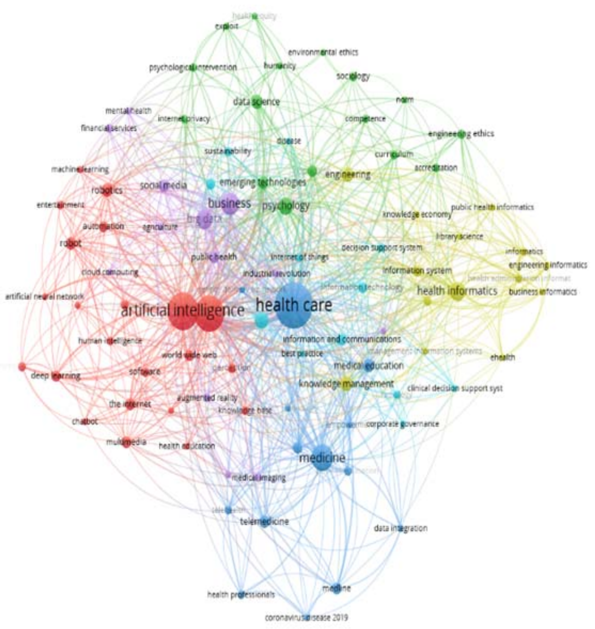

Figure 2. Co-occurrences visualization from the most relevant clusters

7. Learning Applications for Health Students Based on Artificial Intelligence

The learning application proposal is based on the results of the analysis, as shown in the previous Figure 2.

One first cluster refers more to competencies related to information technologies (the red dots and networks). Such cluster includes topics related to the world wide web, technologies, automation, robotics, among others, and highlights the importance of AI-related technologies for healthcare. Medical students and young researchers should gain competencies related to such subjects, although they have been considered far from healthcare disciplines up to now. Indeed, most of such skills are not included in medical curricula. The role of medical professionals is changing, becoming more technical and devoted to the analysis of healthcare data. Often, clinicians are overload with data and do not know how to make proper use of them [45]. One of the responsibilities of health professionals is to ensure that the right information is given to the right person, who should use it to increase the quality of the healthcare service provided to the patient [46]. Moreover, the importance of multidisciplinarity is gaining more interest in medical education, following the example of some disciplines like oncology [47,48]. Examples are the establishment of blended medical CV, like hybrid physicians, who merges competencies like information technology, engineering, and medicine [49]. Besides technical education, future MDs and other caregivers (like nurses or technicians) have to be ready to work in multidisciplinary and diverse teams [50], employing knowledge translation mechanisms to support the full implementation of AI-based solutions and software.

One second cluster includes topics related to big data and social media analysis (the purple dots and networks). Although this cluster looks smaller, in terms of relevance, than the others, it may offer fascinating new insights for medical education. There is a considerable debate going on about the relevance of social media to support medical disciplines, especially when it comes to the sharing of clinical news and advice for public health purposes [51]. The recent Covid-19 pandemic has proven the relevance of the sharing of correct scientific information about the pandemic, the recommended behaviours, and the possible outcomes. Social media networks and big data analytics play today a relevant role in several medical processes, including co-production of medical services and prevention. AI-related technologies like NLP can support these processes; therefore, they should be included in health higher education. AI systems may, for instance, support traditional syllabuses to create customized contents for different subjects, to help students to achieve the expected academic grades.

The third cluster, the blue one, is related to medical and clinical e-health. Telemedicine has been defined as the use of electronic information and communication technologies to provide healthcare services at a distance [52]. Although the topics of telemedicine or telehealth are not new, the recent COVID-19 pandemic has fostered an unprecedented request for remote care delivery because of the social-distancing requirements [52–54]. Telemedicine experiences have already proved to be successful along with a variety of medical specialities, including radiology, psychiatry, dermatology, cardiology [52], oncology, and internal medicine [52]. Telemedicine allows easier access to care, enhanced resource efficiency and fewer costs than the traditional in-person hospital or ambulatory visits [52]. AI solutions can support the development of telehealth, by improving quality and supporting practitioners while offering new resources, escalate and potentiate the benefits, enhance equity-related issues including triage [55], determining priorities, and tailoring resources. Therefore, such a topic looks particularly promising in higher medical education.

The fourth cluster, the yellow one, is related to business and health informatics. AI-related technologies can support clinical decision-making processes [3], [56] and boost the competitive advantage of healthcare organisations, through the development of the knowledge economy. Again, the multidisciplinarity of the healthcare sector [57] and the presence of an open healthcare ecosystem [58] call for a broader perspective, in which several stakeholders need to work together to ensure the clinical outcomes. Such a view offers new educational opportunities for health workers. As an example, AI and Industry 4.0-based solutions may support both clinicians as well as patients in deciding about possible treatment options, boosting shared-decision making [59], [60] and co-production processes.

Last but not least, one cluster (the green one) is devoted to ethics and sociology. The use of AI and the other Industry 4.0 technologies may sometimes bring some ethical concerns [45], despite their value in disrupting business processes [61]. Several problems arise, for instance, when it comes to privacy and the use of data [62–64]. Moreover, different rules are applied in different countries [45]. Such concerns may be particularly relevant in medicine and healthcare, including issues related, for instance, to informed consent and how its content is communicated to patients [65]. Therefore, there is a call to address such open questions, and this involves health students as well, opening thus to new educational opportunity.

The following Table 1 summarises the main educational areas identified, the main topics, and the possible learning applications and competencies.

Table 1. A learning model for Health Students

	Area of expertise	Main topics	Possible learning applications and competencies
	Information technologies	Cloud computing, robotics, automation, machine learning, deep learning, world wide web, software, multimedia	Use of AI to create blended or hybrid medical curricula Multidisciplinary education
	Big data and social media	Social media, public health, prevention	Use of AI and NLP to scout social media networks and use them to share meaningful medical news and advice, especially for public health purposes.
	Medical and clinical e-health	Telemedicine, telehealth, data integration	Use of AI to support telehealth applications
	Business and health informatics	Business and management, support system, decision making, knowledge economy	Use of AI to support clinical and shared decision-making
	Ethics and sociology	Sociology, norm, internet privacy, ethics, accreditation	Impacts and ethical concerns arising from the use of AI and Industry 4.0 solutions.

8. Discussions and Conclusions

The present study has identified the main educational opportunities for health students, based on the possibilities arising from AI and AI-related technologies. A systematic literature review has identified some clusters of interests, which allowed to spot the main topics concerning the applications of AI in healthcare and the following educational needs.

The main topics identified are related to information technologies, big data and social media, e- and telehealth, business and health informatics, and ethics and sociology. AI and Industry 4.0-related technologies are disrupting in several sectors, including healthcare. The role of health professionals may change, shifting to a more technical one related to the collection, storage, and use of healthcare data [45]. Therefore, their education should second the new competencies that are needed by the modern clinical ecosystem and its stakeholders. While there is a call to integrate clinical skills with those related to information technologies, engineering, and business development, ethical concerns arise, leading to a different way for clinicians to deal with patients. The new scenario calls for new paradigms for health higher education, employing modern tools and with amended learning outcomes than in the past.

AI may be useful both as a tool for modern education, but also as a goal, allowing healthcare professionals to get the right competencies to benefit from such new technologies, supporting developers and researchers in studying advanced solutions for a better-integrated healthcare system. AI applications look very promising in several healthcare specialities [9], [66], [67], and, although physicians and surgeons will not be replaced [67], [68], AI can represent a valid decision-making aid [67], supporting medical doctors in maximizing their outcomes and reducing burnout [69]. Therefore, its inclusion will become more and more crucial in medical education.

AI can enhance education on the go, at any time, anywhere (e.g., through mobile or atomic learning), using data to improve the educational experience (e.g., idle time or commuting time to offer micro-contents). AI can empower the creation of tailored contents: according to interests, weak points, level of knowledge, etc., adjusting the contents to the needs (smart contents). Last but not least, AI can support mentoring, to track students' progress.

Medical schools and postgraduate educational centres may consider reviewing part of their curricula and educational tools, in trying to integrate such subjects and competencies.

9. Limitations and Future Research

Like all pieces of research, our study has some limitations, which may represent new avenues for future investigation. First of all, the literature review that generated the potential learning applications and needs was conducted without analysing in-depth the content of the selected articles. A structured literature review [70] may offer new insights into the topic. Other inputs may also be provided by other publications than peer-reviewed articles, like books, or conference proceedings, which are sometimes used by scholars to disseminate pioneering ideas and share them within the scientific community. An in-depth analysis of the potential applications to enhance the learning process would also be recommended. Moreover, AI and Industry 4.0-related technologies are developing fast. New applications may offer new business processes and innovations, leading thus to new educational opportunities and needs.

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