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Artificial Intelligence in Higher Education Research: Insights from Co-occurrence Analysis

Luka Tomat
University of Ljubljana, School of Economics and Business, Slovenia
luka.tomat@ef.uni-lj.si

Abstract

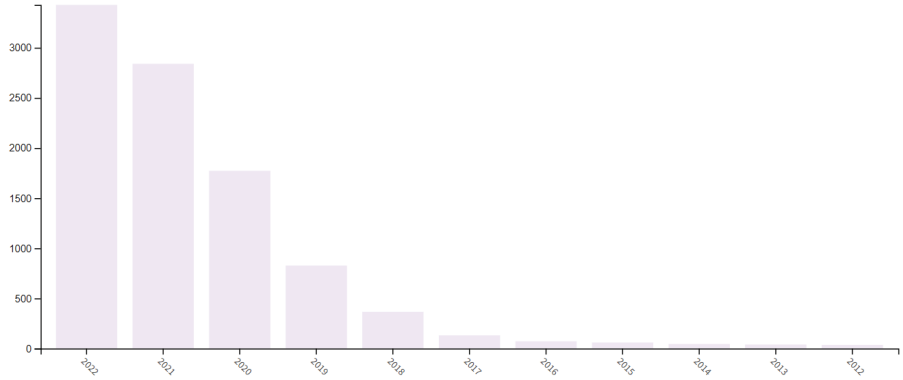
Artificial intelligence (AI) in higher education has attracted much attention in academia, and numerous research papers have been published in this area in recent years. Many papers offer literature reviews of studies on AI in higher education, but none of them identifies research trends by applying co-occurence analysis. To highlight current study areas in AI in higher education research, this study extracts the relevant publications from the last ten years from the Web of Science database and performs a co-occurrence analysis to identify the clusters that appear in the analysed publications. A VOSviewer, a specialised bibliometrics software, was used to identify the relationships among the main items. The analysis identified three clusters, which are explained and presented graphically. Utilizing bibliometrics approach, this study presents the current research agenda and trends in AI in higher education research. Additionally, it offers a methodological support to be used in similar future studies.

Keywords: artificial intelligence, higher education, bibliometrics, co-occurrence analysis, visualization

INTRODUCTION

In recent years, there has been a growing focus on the development of artificial intelligence (AI) tools and applications across various industries (Oke, 2008; Toorajipour, Sohrabpour, Nazarpour, Oghazi, and Fischl, 2021). AI offers many benefits encouraging its adoption in businesses and is opening up new avenues for its successful use, enhancing users' perceptions, and positively impacting work environments. AI is being used in a variety of fields, such as smart mobility, agriculture, supply chain management, cyber security, and education (Haenlein & Kaplan, 2019). Academic research in AI has also gained momentum, with many papers being published on the topic in recent years, as shown in Figure 1.

Figure 1: Number of artificial intelligence publications (review articles) from 2012-2022



Clarivate Analytics, 2023; own analysis.

The literature offers many definitions of AI. For example, Simmons and Chappell (1988) states that the term AI denotes a behaviour of a machine which is considered intelligent, if a human behaves in the same way, Ghosh, Chakraborty, and Law (2018) simply define AI as a technology that targets at making computers do human-like reasoning, while Ballester (2021) refers to AI as a collection of technologies that empower machines to independently learn, reason, interact, and handle uncertain situations by themselves. Kok, Boers, Kosters, Van der Putten, and Poel (2009) consider AI from broader perspective explaining AI as research area in the field of computer science focusing on the development of smart computers that generate thought processes that are similar to human brain processes, such as learning, reasoning and self-correction.

Recently, there has been a huge increase in online learning practices worldwide. Hence, AI has become increasingly important in higher education as it offers new opportunities to improve teaching and learning providing opportunities and challenges for improving higher education quality (Ouyang, Zheng, and Jiao, 2022). More particularly, AI supports development and design of course curriculums and instructions by providing computer based learning resources, such as automatic assessments of the specific assignments or automatic learning paths (Aluthman, 2016). Moreover, AI can be used to predict student performance towards their final grades (Moreno-Marcos, Muñoz-Merino, Alario-Hoyos, Estévez-Ayres, and Delgado Kloos, 2018).

However, many papers research the area of AI in higher education, but not many studies can be found in the literature that would apply the bibliometric approach towards revealing the current body of knowledge and trends. There exist papers that conduct critical literature review in AI in the higher education (Zawacki-Richter, Marín, Bond, and Gouverneur, 2019) but they do not provide insights based on quantitative approach and are thus biased towards subjectivity of the findings.

When creating a science map to understand the specific research domain, both qualitative and quantitative approach can be applied, however, the latter is prevailing in the recent years (Zupic and Čater, 2015). The quantitative science mapping is based on different bibliometrics methods focusing on the extraction of important factors from the classified scientific papers, which are then categorized into different interrelated groups (Tranfield, Denyer, and Smart, 2003). Nowadays, bibliometrics is widely used in many areas and all kinds of sciences, such as mathematics, economics, social sciences, arts, and engineering (Glanzel, 2003). The bibliometric methods can be divided into two groups, performance analysis and the science mapping, while there are five major methods that are being applied in the

modern bibliometric research (Zupic and Čater, 2015). Citation analysis considers documents, authors and journals by assessing the citations from the tackled papers. Co-citation analysis considers documents, authors and journals and assess the occurrence of the papers in the references in the tackled papers. Bibliographic coupling identifies relationships between documents, authors and journals based on familiar references used in those papers. Co-author analysis identifies relationships among co-authors of the tackled papers. Co-word analysis links words from the titles, abstracts and keyword lists in the tackled papers.

The proposed paper applies a special type of co-word analysis, namely co-occurrence analysis, which is one of the most widely used bibliometrics methods. Co-occurrence analysis evaluate the terms that occur in the analysed papers and counts the frequency of their co-appearances within the papers. More times the two terms appear in the specific paper more close relationship exist between those two terms (Deng and Xia, 2020). Moreover, co-occurrence analysis enables a graphical representation of the relationships between the identified terms allowing for a clear identification of the important research areas and trends in the observed area (Xu and Yu, 2019). By performing the co-occurrence analysis, this study thus identifies the key clusters in the AI in higher education pointing out the conceptual perspectives of future research agenda.

The rest of the paper is structured in the following way. A short literature review of AI in higher education research is presented in the next section. A methodological approach including provision of data collection, selection of an appropriate computer software and explanation of the appliance of the co-occurrence analysis is given in the third section. The interpretation of the identified clusters and main results is given in the fourth section. Finally, the final thoughts, limitations and avenues for further research are given in the last section.

SHORT LITERATURE REVIEW ON AI IN HIGHER EDUCATION

Recently, the use of digital technologies in companies is becoming more and more important. Digital technologies and tools affect almost all areas of modern society. For example, searching for information has never been easier, and communication flows in all possible directions. The development of new digital technologies also has a great impact on higher education institutions, and many educational institutions have already introduced learning management systems for their students and professors (Chassignol, Khoroshavin, Klimova, and Bilyatdinova, 2018).

Anyway, it all started in the 1950s when John McCarthy coined the term "artificial intelligence," which soon became very popular in various fields and offered possibilities for the further development of certain areas. By the 1980s, the use of technology in higher education institutions was being integrated into some processes and curricula, and the first publications on the subject were appearing. For example, Stratil, Hayball, and Jarratt (1989) published a study of the College of Business & Technology (CBT), which was widely used to create learning materials. CBT technology was based on the latest AI development of the time, namely intelligent computer-based instructional methods that allowed for direct questions and informative responses, unlike traditional computer-based approaches. Next, Williams (1992) evaluated ten demonstration projects designed to explore and accelerate the use of AI technologies in learning and found that AI could enrich training systems with visualizations and enable a faster pace of training at a lower cost. In the same year, Kranch (1992) conducted research on the use of AI-enhanced systems in library instruction and found that the higher the level of the program of study, the more relevant the use of AI. Kranch concluded that AI-based content should be included in all

doctoral and master's degree programs and that the practical application of AI programs should be emphasized in courses.

Ten years later, McCardle (2002) examined the challenges and problems posed by the introduction of new technologies in design education. He proposed a new model for introducing AI into the education of industrial design students and showed that AI tools can increase creativity and the degree of innovation in design solutions. King and Wu (2014) analysed the development of different e-learning phases and concluded that AI-enhanced learning is a new paradigm in e-learning 4.0. Furthermore, Repanta and Walton (2016) showed how AI can support the assessment of teaching reasoning skills by using AI in the educational process. Zhao (2017) explored the use of AI and multimedia in ideological and political education, and looked for connections between AI and the education system. He showed that such an approach can enhance the quality of education. Interestingly, Perez et al. (2017) investigated the incorporation of intelligent virtual reality into the teaching process to engage and guide students in authentic virtual reality and game-based learning environments and found that students' satisfaction with the course as well as their understanding of the topics studied increased dramatically.

Another comprehensive review of AI in higher education was conducted by Aoun (2017), who looked at the topic from different perspectives, focusing on the automation of educational processes. Isaias (2018) proposed a model for selecting and using new learning technologies to enhance learning in higher education contexts. He found that AI can significantly meet the needs of modern students for personalized, ubiquitous, collaborative, lifelong, and authentic learning. Given the constant and accelerating changes currently facing higher education, Ocaña-Fernández, Valenzuela-Fernández, and Garro-Aburto (2019) explored the needs for planning, designing, and developing digital literacies for faculty and indicated that it is paramount for the higher education institution to implement a digital language supported by programs developed with AI formats. Higher education institutions should systematically use AI approaches and integrate them into their teaching processes, as AI offers fast solutions with high accuracy to assist humans, for example, in predicting and classifying student performance (Sekeroglu, Dimililer, and Tuncal, 2019). More recently, Hooda, Rana, Dahiya, Rizwan, and Hossain (2022) have shown how AI can be used to evaluate teaching methods and thus improve student learning outcomes. Also, Ahmad, Alam, Rahmat, Mubarik, and Hyder (2022) have shown the importance of AI applications in supporting processes in higher education and improving their performance.

Anyhow, AI is transforming education in almost all aspects and perspectives. For example, the AI is used for observation of student’s behaviour, teaching students how to code, reading documents to visually impaired students, developing curricula, writing essays or theses, preparing students schedules, cybersecurity, managing online and blended learning, creation of gamification approaches for students, etc. (Lynch, 2019). AI is also used for plagiarism detection, exam integrity, chatbots, transcription of lectures, enhanced discussions, and analysing success metrices (Newton, 2021). However, based on the initial literature review, it can be argued that AI brings various benefits to higher education institutions, from developments in personalized learning to better utilization of organizational resources and improvements in student learning outcomes.

METHODOLOGY

First, the co-occurrence analysis performed in this study is explained. In the next section, the selection of software for the analysis is justified. Finally, the methodology used to identify relevant papers and extract artefacts for analysis is explained.

Co-occurrence analysis

As explained in the introduction, a widely used bibliometric technique is co-word analysis, which can take on various forms and types. In this study, a co-occurrence analysis was selected to uncover the knowledge structure of the AI in higher education research. This co-occurence analysis can effectively reveal major themes in specific areas by identifying clusters of main terms and expressions that frequently co-occur in the studied publications (Glanzel, and Thijs, 2011). Unlike other bibliographic methods, co-occurrence analysis relies on the actual content and words used in the analysed documents to establish relationships and build a conceptual structure of the studied field. Words that appear together more frequently are considered closely related, and these co-occurrences are used to construct conceptual networks (Börner et al., 2003).

Software selection

There are many different software tools, with BibExcel, Sitkis, and SciMat among the most used (Zupic and Čater, 2015). The selection of software for this study was primarily guided by the ease of use and the ability to visualize the identified clusters. VOSViewer, a user-friendly and freely available tool, was chosen as it offers the necessary functionalities to create and visualize bibliometric networks. VOSViewer facilitates text mining analysis to examine the co-occurrence of significant terms and phrases from the scientific literature.

Extraction of relevant publications and their data

Web of Science is an online academic service that comprises diverse publication databases of scientific journals from various fields worldwide. It is recognized as the largest platform for researching the scientific publications. To carry out the bibliometric analysis, it was imperative to first identify the relevant papers from this comprehensive source.

First the relevant publications have been identified in the Web of Science. The search string was set to TI= ("artificial intelligence" AND "higher education") OR TS= ("artificial intelligence" AND "higher education") OR AK=("artificial intelligence" AND "higher education") OR AB=("artificial intelligence" AND "higher education"), based on which the publications that contain the terms "artificial intelligence" and "higher education" in the title, topic, keywords list or abstract has been recognized. The time period was set to include publications form January 1st 2012 to December 31th 2022. The document types have been set to include scientific articles, review articles, book chapters and proceeding papers. Thus, 562 publications have been identified to be further used for the co-occurence analysis.

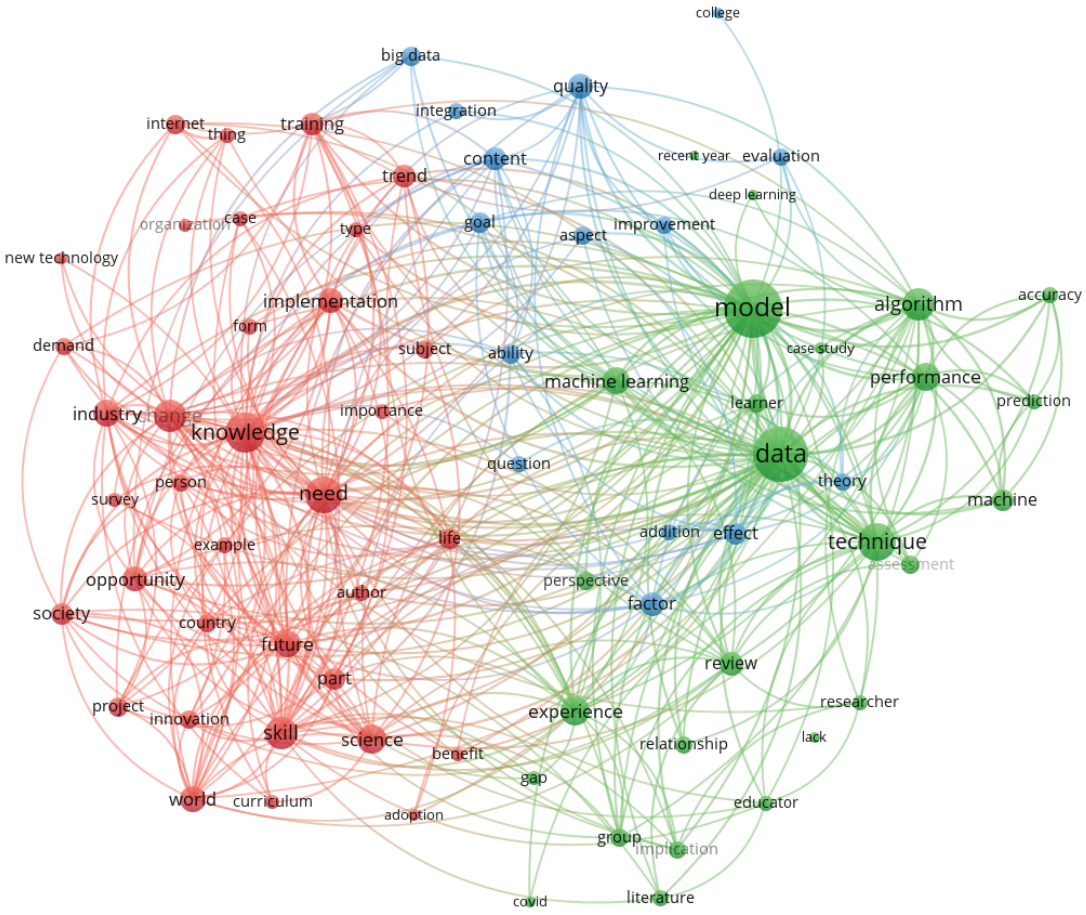
The titles and the abstracts of identified publications have been imported into VOSviewer, where the co-occurrence analysis has been performed. Based on binary coupling 13.540 terms have been found. After setting the minimum occurrences of a term within analysed data to be at least 25, 126 out of all identified terms have been used for the network analysis. The scores for each of the identified terms

have been calculated and 60% of the most relevant terms (terms with the highest scores) have been used for the final data set.

RESULTS

The co-occurrence analysis revealed 3 clusters that can be seen in Figure 2. The biggest is coloured in red and consists of 35 items. Next is the green cluster consisting of 26 items. The smallest cluster is coloured in blue and consists of 15 items.

Figure 2: Number of artificial intelligence publications (review articles) from 2012-2022



VOSviewer, 2023; own analysis.

The biggest cluster (coloured in red) is dominated by the "knowledge", "need", "industry" "implementation", "importance", "opportunity", "skill" and "change", which signifies that the publications from this cluster are oriented more towards organizational perspective of the AI usage offering different opportunities arising from the current happening in the market. The publications in this cluster are more practically oriented and tackle application of AI in the real cases. Hence, this cluster can be labelled as the "AI organizational research cluster".

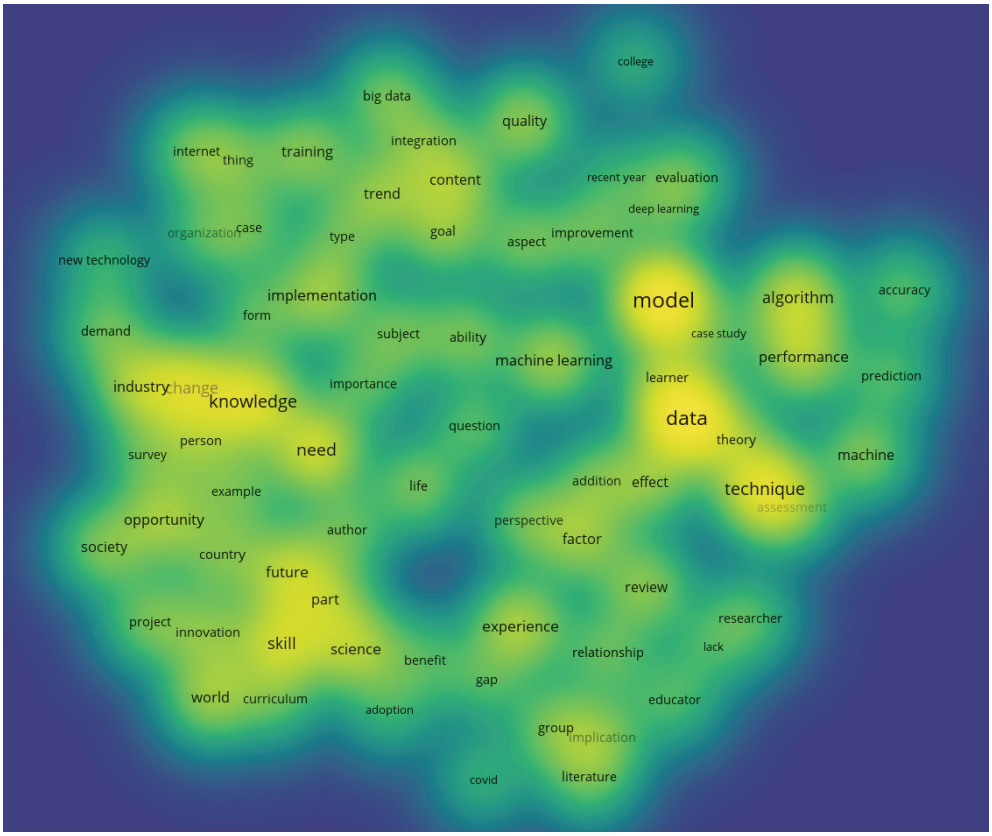
Second biggest cluster (coloured in green) consists of publications that are more technically oriented with the main terms in this cluster being "model", "data", "technique", "algorithm", "machine learning", "performance" and "prediction". The publications in this cluster explore different approaches toward AI development and are mostly theoretical. Terms "researcher", "review" and "literature" signify that AI

studies in this cluster have been tackled from academic perspective. Given the above, the green cluster can be named as “AI technology research cluster”.

The smallest circle (coloured in blue) is conquered by the terms “content”, “improvement”, “quality”, “integration”, “goal” and “evaluation” implying that the AI research is correlated with the studies on the AI tools that can boost performance and increase quality of student’s outcomes. Publications in this cluster are more content oriented putting focus on the benefits of AI as opposed to the technology itself. Thus, the blue cluster can be named as the “AI content-related cluster”.

Density visualizations are another visualization option that enable insights into the main areas in a bibliometric network. The intensity of colour assigned to each term in a density map corresponds to the density of elements in a network. The density visualization of the analysed terms in shown in the Figure 3. As can be seen from the density map, same three cluster have been found by the density visualization.

Figure 3: Fig. 3. Co-occurrence density map of title and abstract phrases within analysed publications



VOSviewer, 2023; own analysis.

CONCLUSION

This research server as an initial point of a wider research of the use of AI in the higher education. The main purpose of the study was to implement the co-occurrence analysis and identify the clusters that reveal the current research trends in the tackled area. To achieve this, presented paper first offers the initial critical literature review of the papers published in the AI in higher education research. Next, the bibliometrics has been introduced. A special focus has been given to the co-occurrence analysis as a special form of the co-word analysis that can be used to reveal and understand the patterns of terms in the analysed data and reveal correlations among individual terms.

By performing co-occurrence analysis, three clusters have been found. The biggest cluster (AI organizational research cluster) refers to the research focusing on the organizational performance and business-related perspectives. The second biggest cluster (AI technology research cluster) focuses on papers that are more technically oriented and approach AI from an information technology development perspective. The third cluster (AI content-related cluster) include papers that approach AI in higher education from a content-related perspective (e.g. use of AI in different environments, for different purposes and within different educational levels and fields. Identified clusters have been analysed and briefly described.

The area of AI use in higher education is developing rapidly and the time will reveal, what will happen in the future. Nevertheless, AI has the huge potential to improve teaching and learning process. It is expected that the sophistication and precision of AI apps for learning will increase, while these apps will effectively analyse data to provide a personalized experience for students. In addition, AI-based virtual reality games and software are expected to gain prominence in the classroom. Virtual reality can provide students with a hands-on experience and make learning more interactive and effective. Moreover, such technology can be used to conduct science experiments, creating a safer and more engaging environment for learners. Eventually (University of the People, 2023). The use of AI in teaching and assessment may cause universities to rethink their pedagogical strategies and AI can provide students with tailored learning experiences. This could lead to higher student engagement and academic performance (Cardoso, 2023).

The presented research is facing some limitations that can also be used as a starting point for the future research. Thus, the search string for extracting the relevant publications from the Web of Science could be modified. Also, the time span of analysed publications could be expanded. Next, the Web of Science consists of specific databases. Hence, future research could include some other relevant scientific databases, such as Scopus, Elsevier abstract and citation database. Finally, in addition to co-occurrence analysis, also other bibliometrics should be performed and the results compared.

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REFERENCES

Ahmad, S. F., Alam, M. M., Rahmat, M., Mubarik, M. S., & Hyder, S. I. (2022). Academic and administrative role of artificial intelligence in education. *Sustainability*, *14*(3), 1101.

Aluthman, E. S. (2016). The effect of using automated essay evaluation on ESL undergraduate students' writing skill. *International Journal of English Linguistics*, *6*(5), 54-67.

Aoun, J. E. (2017). *Robot-proof: higher education in the age of artificial intelligence*. MIT press.

Ballester, O. (2021, June). An artificial intelligence definition and classification framework for public sector applications. In *DG. O2021: The 22nd Annual International Conference on Digital Government Research* (pp. 67-75).

Börner, K., Chen, C., & Boyack, K. W. (2003). Visualizing knowledge domains. *Annual review of information science and technology*, 37(1), 179-255.

Cardoso, E. (2023). AI in Higher Education: Leveraging the Benefits for Universities. *LinkedIn*. Retrieved April 20th, 2023, https://www.linkedin.com/pulse/ai-higher-education-leveraging-benefits-universities-cardoso/

Chassignol, M., Khoroshavin, A., Klimova, A., & Bilyatdinova, A. (2018). Artificial Intelligence trends in education: a narrative overview. *Procedia Computer Science*, *136*, 16-24.

Deng, S., & Xia, S. (2020). Mapping the interdisciplinarity in information behavior research: A quantitative study using diversity measure and co-occurrence analysis. *Scientometrics*, *124*, 489-513.

Ellis, G. W., Silva, K. L., Epstein, T., & Giammaria, N. C. (2009). Artificial intelligence in pre-college education: learning within a philosophy of the mind framework. *The International journal of engineering education*, *25*(3), 511-522.

Ghosh, A., Chakraborty, D., & Law, A. (2018). Artificial intelligence in Internet of things. *CAAI Transactions on Intelligence Technology*, *3*(4), 208-218.

Glanzel, W. (2003). *Bibliometrics as a research field a course on theory and application of bibliometric indicators*.

Glanzel, W., & Thijs, B. (2011). Using 'core documents' for the representation of clusters and topics. *Scientometrics*, 88(1), 297-309.

Haenlein, M., & Kaplan, A. (2019). A brief history of artificial intelligence: On the past, present, and future of artificial intelligence. *California management review*, *61*(4), 5-14.

Hooda, M., Rana, C., Dahiya, O., Rizwan, A., & Hossain, M. S. (2022). Artificial intelligence for assessment and feedback to enhance student success in higher education. *Mathematical Problems in Engineering*, *2022*.

Isaias, P. (2018). Model for the enhancement of learning in higher education through the deployment of emerging technologies. *Journal of Information, Communication and Ethics in Society*, *16*(4), 401-412.

King, L. J., & Wu, W. (2014, November 14). *Artificial Intelligence and eLearning 4.0: A New Paradigm in Higher Education.* Franklin University. Retrieved March 2, 2023, from https://fuse.franklin.edu/cgi/viewcontent.cgi?article=1032&context=ss2014

Kok, J. N., Boers, E. J., Kosters, W. A., Van der Putten, P., & Poel, M. (2009). Artificial intelligence: definition, trends, techniques, and cases. *Artificial intelligence*, *1*, 270-299.

Kranch, D. A. (1992). Teaching artificial intelligence and expert systems: concepts in library curricula. *Journal of education for library and information science, 33*(1),18-34.

Lynch, M. (2019). 26 ways that artificial intelligence (AI) is transforming education for the better. *The edvocate.* Retrieved April 20, 2023, from https://www.theedadvocate.org/26-ways-that-artificial-intelligence-ai-is-transforming-education-for-the-better/

McCardle, J. R. (2002). The challenge of integrating ai & smart technology in design education. *International Journal of Technology and Design Education*, *12*, 59-76.

Moreno-Marcos, P. M., Muñoz-Merino, P. J., Alario-Hoyos, C., Estévez-Ayres, I., & Delgado Kloos, C. (2018). Analysing the predictive power for anticipating assignment grades in a massive open online course. *Behaviour & Information Technology*, *37*(10-11), 1021-1036.

Newton, D. (2021). From admissions to teaching to grading, AI is infiltrating higher education. *The Hechinger Report*. Retrieved April 19, 2023, from https://hechingerreport.org/from-admissions-to-teaching-to-grading-ai-is-infiltrating-higher-education/

Ocaña-Fernández, Y., Valenzuela-Fernández, L. A., & Garro-Aburto, L. L. (2019). Artificial Intelligence and Its Implications in Higher Education. *Journal of Educational Psychology-Propositos y Representaciones*, *7*(2), 553-568.

Oke, S. A. (2008). A literature review on artificial intelligence. *International journal of information and management sciences*, *19*(4), 535-570.

Ouyang, F., Zheng, L., & Jiao, P. (2022). Artificial intelligence in online higher education: A systematic review of empirical research from 2011 to 2020. *Education and Information Technologies*, *27*(6), 7893-7925.

Perez, S., Massey-Allard, J., Butler, D., Ives, J., Bonn, D., Yee, N., & Roll, I. (2017). Identifying productive inquiry in virtual labs using sequence mining. In *Artificial Intelligence in Education: 18th International Conference, AIED 2017, Wuhan, China, June 28–July 1, 2017, Proceedings 18* (pp. 287-298). Springer International Publishing.

Rapanta, C., & Walton, D. (2016). The use of argument maps as an assessment tool in higher education. *International Journal of Educational Research*, *79*, 211-221.

Sekeroglu, B., Dimililer, K., & Tuncal, K. (2019). Artificial Intelligence in Education: application in student performance evaluation. *Dilemas Contemporáneos: Educación, Política y Valores*, *7*(1).

Simmons, A. B., & Chappell, S. G. (1988). Artificial intelligence-definition and practice. *IEEE journal of oceanic engineering*, *13*(2), 14-42.

Stratil, M., Hayball,C, & Jarratt, P. (1989). Artificial Intelligence in Higher Education and CBT Technology, *Educational and Training Technology International, 26*(3), 215-225.

Toorajipour, R., Sohrabpour, V., Nazarpour, A., Oghazi, P., & Fischl, M. (2021). Artificial intelligence in supply chain management: A systematic literature review. *Journal of Business Research*, *122*, 502-517.

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence□informed management knowledge by means of systematic review. *British journal of management*, *14*(3), 207-222.

University of the People (2023). *AI in Education: Where Is It Now and What Is the Future*. Retrieved April 20, 2023, from https://www.uopeople.edu/blog/ai-in-education-where-is-it-now-and-what-is-the-future/

Williams, N. (1992). *The artificial intelligence applications to learning programme,* paper presented at the CAL '91 Symposium, 101-107, Pergamon,

Xu, Z., & Yu, D. (2019). A Bibliometrics analysis on big data research (2009–2018). *Journal of Data, Information and Management*, *1*, 3-15.

Yinxiang, Z. (2017). Multimedia teaching of ideological and political education based on artificial intelligence. *Agro Food Industry Hi-Tech*, *28*(1), 683-687.

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education–where are the educators? *International Journal of Educational Technology in Higher Education*, *16*(1), 1-27.

Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. *Organizational research methods*, *18*(3), 429-472.