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ORIGINAL RESEARCH

Artificial Intelligence and Digital Ecosystems in Education: A Review

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Abstract
Digital ecosystems are a set of interconnected elements that enable an integrated and seamless digital experience. In education, the use of Artificial Intelligence (AI) has great potential to improve teaching and learning. However, for the expectations placed on the educational use of AI to be met, it is necessary to develop adequate digital ecosystems that allow its effective implementation. Therefore, it is of great importance to deepen the understanding of these ecosystems and their key elements for such implementation. For this purpose, a systematic review of the literature on this subject was conducted, which included the analysis of 76 articles published in peer-reviewed journals. The main results of the review highlight the current focus of research in that matter, which relates digital ecosystems and artificial intelligence around the personalization of learning. Also, some aspects related to this relationship are analyzed from four categories: networks, applications, services, and users.

Keywords Digital ecosystems · Educational technology · Educational innovation · Artificial intelligence

1 Introduction

Information and Communication Technologies (ICT) are essential for the development of the knowledge society (Pedraja Rejas, 2012; Pérez-delHoyo & Mora, 2019; Phillips et al., 2017), as they serve as means of communication, sources of information, and learning scenarios for students, allowing the construction of knowledge and articulation of elements of science, technology, and culture (Ibrahim et al., 2020). In this way, ICTs are increasingly

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friendly, accessible, adaptable, and used in schools as innovative tools to motivate pedagogical changes toward more active and participatory learning (Rajarapollu & Bhagwatkar, 2017). This motivates the promotion of ICTs to develop abilities and skills in students so that they not only search for information, but also discriminate, build, and verify hypotheses based on said information (Nzomo et al., 2021).

Some examples of the use of innovative tools to motivate pedagogical changes that allow us to understand the impact on the educational context are (a) Dynamic assessment applications such as Kahoot! o Quizizz, through which surveys, questionnaires, or other evaluation mechanisms are applied, provides instant feedback, identifies areas for improvement, and keeps students engaged (Nicol & Macfarlane-Dick, 2006). (b) Videoconferencing Platforms for Synchronous Classes, such as Zoom or MSTeams, which are used to guide online classes, discussions, and question and answer sessions, facilitating real-time interaction and allowing students to actively participate from any location (Means et al., 2009), C) Use of simulators and Virtual Laboratories for scientific and technical disciplines, for example in physics, chemistry or virtual programming environments, which provide practical, safe and accessible experiences, improving the understanding of complex concepts (Smetana & Bell, 2012).

Since the 2000s, the production of digital technologies has led to the emergence of digital ecosystems, where software, hardware, and digital services complement each other in synergistic ways (Anwar et al., 2018; Wu, 2020). The concept of ecosystem, proposed by British biologist Arthur George Tansley in 1935, refers to a biological system consisting of living beings and their environment. This sense of ecosystem has evolved to encompass all aspects of society and its organizations, linked with survival, reproduction, evolution, and economic and social interconnection (Golov & Myl'nik, 2022).

An AI-enabled digital educational ecosystem refers to complex and dynamic environments composed of diverse interconnected elements that collaborate to facilitate digitized educational experiences, leveraging AI capabilities. According to Giró-Gracia and Sancho-Gil (2022), this implies the effective articulation of a set of technologies (main technologies of the fourth industrial revolution), learning management platforms, data, intelligent devices, applications, content, infrastructure, and users, to foster social interaction, collaboration and communication among students, teachers and learning communities.

Digital ecosystems play a critical role in facilitating knowledge sharing within organizations, acting as platforms for cooperation, exchange, and access to knowledge (Gupta et al., 2019). In education, digital ecosystems have gained more consistency since the early 2000s, particularly through the implementation of Learning/Content Management Systems (LMS/CMS) and open digital educational content sharing through collaborative or social spaces (Setiana et al., 2022). Thus, the media and telecommunications industry has had a significant impact on this evolution in the last 20 years, with products such as the Internet, personal devices, communication services, social networks, search engines, and intercommunication becoming increasingly refined and with greater range and coverage (Prashantham, 2020).

Digital ecosystems have not received the research attention they deserve despite their growing significance in education. While research on this topic has grown in the last decade, the number of articles published per year has remained less than 20 on average, with a maximum of 25 in a single year. This trend is surprising considering the potential impact of digital ecosystems on education. In this regard, Fig. 1 shows a steady increase in research

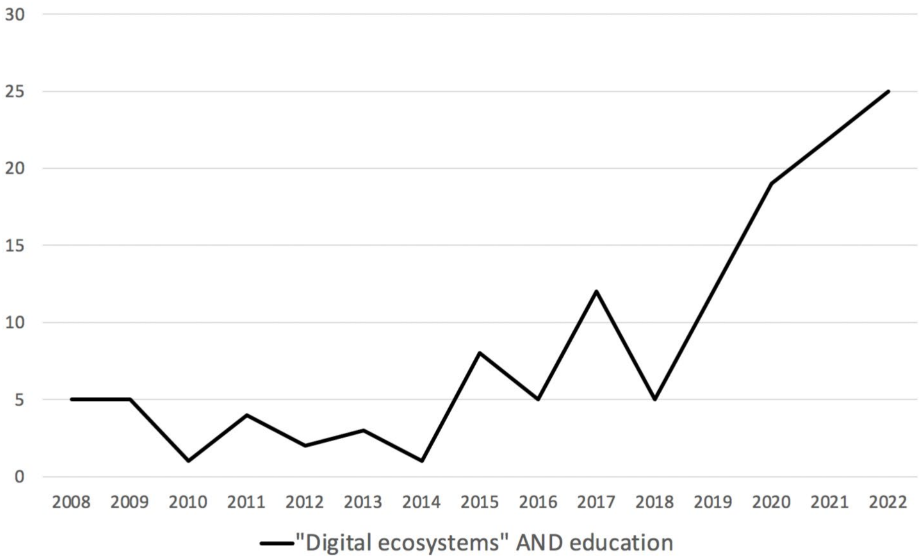

Fig. 1 Research on digital ecosystems and Education published in Scopus-indexed journals. *Source* Own elaboration based on Scopus data

interest in digital ecosystems, yet there is still a need for further investigation into the topic to better understand its implications for the field of education.

Among the cases mentioned in some of the studies worth highlighting is Siriborvornratanakul (2022), who involves image-based learning models, where it can be inferred that, despite the growing demand for AutoML (Automated Machine Learning) seeking to be more accessible For users without programming or machine learning experience, it is possible to create accurate and efficient models without having to go through the process of manually selecting algorithms. The above is still far from becoming a conventional solution for learning professionals and researchers, due to the high consumption of computational resources.

On the other hand, Niyogisubizo et al. (2022) provide a proposal to support the resolution of student attrition, using big data technology to analyze student performance records through a two-layer stacking ensemble based on a hybrid of RF, XGBoost, GB, and FNN to improve overall classification performance, which helps estimate students at risk of dropping out of an academic course.

Furthermore, Lamb et al. (2022) examine the utility of using neurocognitive data to develop student response prediction on a science content test, the results of which provide evidence supporting the use of neurocognitive data for the adaptation of digitally presented content and how it is They can use machine learning and artificial intelligence approaches to classify student data in real-time. The results also illustrate good precision and capture of moment-to-moment cognitive fluctuations in real-time. These findings can help the development of tutors with artificial intelligence and improve the analysis of learning based on data generated by students.

Incorporating ICTs has been a key effort in improving the educational system, as noted by Sholichah et al. (2022), which has motivated teachers to build adequate mediations and innovative ICT-based teaching and learning processes. In this concern, Suárez Guerrero et al. (2021) highlight the importance of how contemporary students learn, communicate, and relate in the community how technology mediates these interactions in digital ecosystems, and the important role ICT plays, in the form of digital ecosystems, in the creation of new educational scenarios and transforming the traditional roles of teachers and students. In this sense, Belessova et al. (2023) emphasize that rapid changes in digital technologies require rethinking literacy processes, with a focus on developing digital skills for both students and teachers.

As a result, Morris and Rohs (2021) emphasize that students are increasingly engaging in self-directed learning processes, leading to a need to involve their context in educational processes mediated by digital ecosystems. So, developing intercultural skills in students is also essential for their proper development in multicultural work contexts, such as those generated through digital ecosystems (Sukovataia et al., 2020). Regarding this, Artificial intelligence (AI) is considered one of the most promising trends in education, with great potential to personalize learning and provide a wide range of benefits to students of all ages and levels.

To make this possible, AI should be able to analyze large volumes of data related to students learning to adapt both teaching materials and learning strategies to meet the individual needs of each student. This means that students can learn at their own pace and in their style, which according to Vuk et al. (2022), can significantly improve their academic performance and motivation.

According to Vera (2023), several benefits of artificial intelligence (AI) have been identified that support its use in higher education. These benefits include improving student participation and engagement in the classroom, providing instant and personalized feedback, increasing the accessibility of content for students with disabilities, as well as encouraging student creativity and critical thinking. However, when integrating AI into the educational curriculum, one of the main challenges facing higher education is ensuring equitable access for all.

Although it is recognized that AI has the potential to democratize access to education by offering online learning opportunities to large numbers of students, there is a latent risk that only those with access to adequate technology and resources can fully benefit from it. This situation could further aggravate educational inequalities among students.

On the other hand, according to Cornejo-Plaza and Cippitani (2023), AI in Higher Education addresses other ethical challenges, among which are the transparency and explainability of decision-making processes, equity, non-discrimination, privacy, and protection. of data, responsibility, and trust in technology.

Moreover, as pointed out by Rensfeldt and Rahm (2023), the integration of AI in education provides a wide range of benefits, including the ability to personalize learning and automate low-level tasks such as homework correction or grading, enabling teachers to focus on refining their teaching strategies and developing critical thinking and problem-solving skills in students. However, to effectively use AI in education, adequate digital ecosystems are necessary. Digital ecosystems provide the necessary infrastructure to collect large amounts of data, making personalization of learning possible (Jacobsen et al., 2022). In this regard, it is crucial that student data is used securely and that AI algorithms are transparent and understandable to both educators and students, which emphasizes the importance of the responsible and ethical management of the collected data (Fang & Tse, 2022).

According to the above, it can be inferred that without adequate development of digital ecosystems, the expectations that have been placed on the educational use of AI would not be met, and in this sense, it becomes imperative to deepen as much in their understanding as well as in the elements of these ecosystems that are key for an adequate educational implementation of AI (Haji & Azmani, 2020).

To take the first steps towards achieving the above, it has been considered pertinent to carry out a systematic review of the literature on this subject. In this regard, a systematic review of the literature will allow the rigorous collection and analysis of relevant information on digital ecosystems in education and their relationship with the use of AI. This review could identify the key elements of digital ecosystems that are necessary for the effective implementation of AI in education, as well as the best practices for its development and use.

On the other hand, a systematic literature review would also make it possible to critically assess the quality of existing research on the topic, identify gaps in knowledge, and propose areas for future research. This would be especially important given that the educational use of AI is a relatively new and constantly evolving field.

2 Method

The methodological structure of this review followed the recommendations of Sánchez-Martín et al. (2022) and Vidal Ledo et al. (2015), who, based on specific needs, have adjusted the different steps or processes of the literature review. For its application in this review, three main processes have been considered: (1) Review planning, (2) information extraction, and (3) analysis and interpretation, which are shown in detail in Fig. 2.

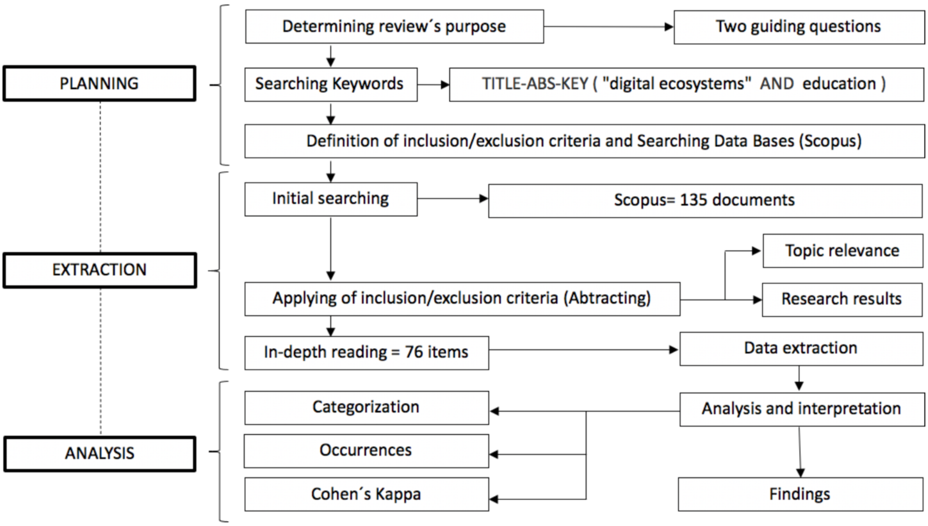

Fig. 2 Review phases. *Source* Own elaboration

2.1 Review Planning

2.1.1 Determining the Review´s Purpose

As Visic (2022) indicates, the initial step in documentary research processes is to establish the purpose of the review, which is crucial as it sets the direction for the search, reading, information extraction, and subsequent analysis. By clarifying the purpose, the interpretation and rigor of the method can be strengthened. In this first process, the general objective of the literature review was established, which was expressed through two guiding questions: 1) How has the concept of the Digital Ecosystem evolved over the recent decades? and 2), what are the key components of a Digital Ecosystem from which the educational use of artificial intelligence can be approached?

These questions not only served as the basis for making decisions about the subsequent processes but also for organizing the presentation of the results of the review.

2.1.2 Searching Keywords

After having defined the guiding questions, the next step was to identify the search keywords that were applied in the Scopus Database.

To establish a broad search framework but at the same time narrow it down enough to focus the results consistently, a search string was defined with the following terms: TITLE-ABS-KEY ("digital ecosystems" AND education), from which 135 result items were obtained. With the said amount and with the time frame in which they were located (2008–2023), it was not found relevant to apply other filters such as "subject area", "year" or "document type".

2.1.3 Definition of Inclusion/Exclusion Criteria

To select only the pertinent documents for a subsequent in-depth reading process, the inclusion/exclusion criteria were defined so that only articles that addressed the search topic not exclusively from a technical perspective but from an educational point of view were selected. A second criterion allowed selection only of those articles that presented research results.

As part of the inclusion and exclusion criteria, it was decided to use Scopus as the main search source for the articles. This decision was because it is one of the most complete and up-to-date bibliographic databases currently available, containing more than 80 million publication records, including journals, books, and conference proceedings, and fairly broad temporal coverage. In addition, Scopus also offers advanced search tools and filtering features to help researchers quickly find the most relevant articles that meet predefined selection criteria.

2.2 Data Extraction

This phase began with the application of the keywords in the Scopus search field. The 135 documents that resulted from this initial search were subjected to a purification and selection process that began with the ordering of the results by order of citation. Then, all documents were subjected to an abstracting process, through which both the title and abstract of each article were reviewed to identify the relevance of the document and compliance with the previously defined exclusion criteria. As a result of this process, 59 documents were eliminated due to non-compliance with said criteria, leaving a final set of 76 articles, which followed the following process: in-depth reading. In this next process, relevant information was identified to find possible answers to the guiding questions of the review. The data extracted from the articles was recorded in a documentation matrix that included the bibliographic information of each article analyzed and the information related to the research questions.

2.3 Analysis and Interpretation

The information registered in the documentation matrix was analyzed from two perspectives, the first of a quantitative order, through an analysis of frequencies or occurrences, in which the elements that appeared commonly in more than one article were identified. These elements were listed and ordered from highest to lowest according to the number of times they appeared in the total corpus of texts analyzed. For this, these data were treated from a process of term homologation.

The other analysis process, of a qualitative nature, was conducted by way of categorization or grouping by similarities or elements in common, from which the main categories of analysis and ordering of the results were identified.

As a way to reduce bias in the review process, a two-observer mechanism of consistency verification was applied through a measure of Kohen´s kappa coefficient (k = 0,7478). As pointed out by Losada and Arnau (2000) this result corresponds to an adequate consistency of the two reviewer´s observations.

3 Results

3.1 Bibliometric Results

The 135 articles were published in 71 journals or proceedings, which shows a fairly homogeneous distribution of them, with a maximum concentration of 5 articles in 3 journals. The quality of the sources consulted is expressed in their impact factor and their location in the SJR ranking. In this regard, the top 10 distribution of the articles analyzed are shown in Table 1.

3.2 Results Regarding Question 1

How has the concept of the Digital Ecosystem evolved over the recent decades?

Even though over the years, elements such as collaboration, interaction, and the implementation of platforms have continued to be associated in the literature with digital ecosystems in education, we have been able to identify certain periods where different issues have specifically emerged as interesting for educational researchers.

Table 1 Top 10 peer-reviewed journals with analyzed articles

Name	# articles	impact factor	SJR quartile
ACM International Conference Proceeding Series	5	0.232	Q4
Communications in Computer and Information Science	5	0.209	Q3
Lecture Notes in Computer Science	5	0.407	Q2
CEUR Workshop Proceedings	4	0.228	Q4
Advances in Intelligent Systems and Computing	2	0.215	Q3
JMIR Research Protocols	2	0.441	Q2
Lecture Notes in Information Systems and Organisation	2	0.197	Q3
Revista Iberoamericana de Tecnologías del Aprendizaje	2	0.480	Q2
Springer Series on Cultural Computing	2	N/A	Q4
British Journal of Educational Technology	1	1.870	Q1

Source Own elaboration based on Scopus data

3.2.1 2008–2010: Challenges and Opportunities

These years the central focus of the research was mainly on digital technologies and their use in education particularly in e-learning, platforms, and virtual worlds. Researchers also refer to the challenges and opportunities presented by the use of technology in education, such as curriculum relevance, skilled workers, and the need for governance frameworks. Additionally, many of the key issues related to innovation and collaboration, either between stakeholders in the education process, such as academics and students, or between different components of digital ecosystems, such as agents and service-oriented platforms. Examples of the above are found in Kum et al. (2008), Biuk-Aghai et al. (2008), Dreher et al. (2009), Reiners (2010), and Chang and Uden (2008).

3.2.2 2011–2013: Knowledge in Motion, Focus on Content, Introducing Social Networks

In the context of digital learning ecosystems and social networks, the common theme among the main issues presented in the articles is the idea of interconnectedness and interdependence as the basics of knowledge flow. They present the complex interactions and relationships between different entities within a system, such as students, teachers, content, technology, and other stakeholders, and a shift towards the use of digital platforms and tools in educational processes, such as online learning and open digital resources.

As in the years before, these issues also imply the need for collaboration, communication, and cooperation among these entities to achieve shared goals and objectives. Also, they suggest that the success of digital learning ecosystems and social networks depends on the quality of relationships and interactions among their various components. Examples of the above are found in Naghshineh and Zardary (2011), Stale and Majors (2012), Goldstein et al. (2013), and Reyna (2011).

3.2.3 2014–2017: Welcome to Openness and hyper-connections, Introducing AI

The main issues of this period are related to the concept of accessibility and the use of technology to provide access to information, education, and opportunities. They are also related to the idea of openness and the potential for artificial intelligence, big data, and other advanced technologies to bridge gaps and create hyper-connections between people and communities around the world. Specifically, these ideas highlight the importance of universal access to information and education, the need for effective knowledge management and data sharing, and the potential of technologies like mobile devices, learning analytics, big data, augmented reality, natural interaction technologies, and semantic technologies to promote accessibility and innovation as key elements of digital learning ecosystems. Examples of the above are found in Dodero et al. (2015), Johnson (2015), and Rothe and Steier (2017).

3.2.4 2018–2023: In Pursuit of Personalized Learning, IA at the Front line

In the context of pursuing personalized learning through the use of digital ecosystems and artificial intelligence, there are several key areas of focus. One of these areas is the use of mobile devices which can provide access to a wealth of educational resources, as well as support for personalized learning paths that can be tailored to the specific needs and interests of individual learners. In addition, mobile technology can enable participation and inclusion for learners with special needs or disabilities, allowing them to access learning opportunities that may not be available in a traditional classroom setting.

Another area of focus is the integration of digital systems and other technologies like the Internet of Things to support personalized learning. This includes the use of learning analytics to monitor and track student progress, as well as the integration of gamification and MOOCs to make learning more engaging and interactive. Also, Blockchain technology can be used to provide secure and transparent tracking of learning progress and achievements.

Examples of the above are found in Burbano and Soler (2020), Nunez and Padilla (2020), Kay (2022), Wolff et al. (2021), Jha (2023) and Ilic (2022).

3.3 Results Regarding Question 2

What are the key components of a Digital Ecosystem from which the educational use of artificial intelligence can be approached?

In general, although applicable to the field of education, Kim et al. (2010) establish four necessary components for the formation of a digital ecosystem, which are: networks, services, applications, and users. For purposes of organizing the results of this review based on this second guiding question, we have used these four components as the base categories of analysis and interpretation.

This set of basic categories summarizes elements proposed by various authors such as Cárdenas Peña (2021) - (model of infrastructure - service - applications - users), Islas Torres (2019) - (model of applications - devices - content exposure - users), Chang (2008)- (model of technological infrastructure - actions - transactions - information flow), Islas and Carranza (2017) - (model of context - users - content - devices - applications - forms of communication).

The categories of networks, applications, services, and users are fundamentally interrelated within the framework of digital ecosystems and artificial intelligence (AI), as follows: Users use applications to access services over digital networks. In that sense, AI can be incorporated into all these stages to improve the user experience, personalize services, optimize processes, and provide insights based on data. User feedback through apps and services can feed artificial intelligence algorithms to improve efficiency and personalization. In this context, network security is essential to protect the privacy and integrity of user data, especially when it comes to services that use artificial intelligence. Furthermore, the connection and interaction of these systems are essential to improve the quality of the service and facilitate management, creating opportunities for the emergence of interconnection frameworks, which, in turn, allows the development of digital ecosystems (Bazán et al., 2023).

From these 4 base categories, 10 key elements have been grouped, which are shown in Fig. 3, and which we will detail below based on the perspective of educational use of artificial intelligence.

3.3.1 Networks

"Coverage" appeared 36 times, corresponding to 47.4% of the total elements extracted from the reviewed articles.

AI, network infrastructure, and education are interrelated. AI can improve education by providing personalized learning experiences. However, this requires robust network infrastructure to support data transmission and AI algorithms. Strong network infrastructure is also needed for the development and deployment of AI technologies and can be used to support educational initiatives such as online learning platforms. Also, AI can recognize patterns in student performance and highlight areas where educational coverage may be lacking, which can help to improve educational programs and infrastructure to better serve students. Examples of the above are found in Sivetc and Wijermars (2021) and Oughton et al. (2019).

3.3.2 Services

"Informal learning" appeared 34 times, corresponding to 44.7% of the total elements extracted from the reviewed articles. AI can enhance educational services by providing personalized learning experiences which can be achieved through the use of AI-powered educational tools and platforms, such as chatbots and virtual assistants, which can analyze vast amounts of data to identify patterns in student performance, recommend personalized learning paths, provide real-time support to students, answering their questions and providing

Fig. 3 Categories of analysis. *Source* Own elaboration

effective feedback by tailoring the learning experience to each individual's needs. Examples of the above are found in Martinez et al. (2012) and Gordienko et al. (2015).

"Tutoring" appeared 23 times, corresponding to 30.3% of the total elements extracted from the reviewed articles. AI can be used to support tutoring by providing real-time feedback and guidance to tutors, allowing them to tailor their instruction to the needs of each student. Moreover, AI-powered tutoring systems can provide personalized instruction to students in real-time, allowing them to work at their own pace and receive immediate feedback on their progress. This can be particularly beneficial for students who require additional support in specific areas, such as math or language skills, or to students in remote or underserved areas, where access to traditional tutoring services may be limited. Examples of the above are found in Setiana et al. (2022) and Ilic (2022).

"Data analysis" appeared 17 times, corresponding to 22.4% of the total elements extracted from the reviewed articles. Data analysis can be used to identify patterns in student performance and learning outcomes, allowing educators to tailor instruction to the needs of individual students. For example, data analysis can be used to identify students who are struggling with specific concepts or skills, allowing educators to provide additional support or resources as needed. Data analysis can also be used to evaluate the effectiveness of different instructional approaches, identifying areas where changes or improvements may be needed using machine learning algorithms and predictive models. Examples of the above are found in Fu (2006) and Katsadouros et al. (2022).

3.3.3 Applications

"Videogames" appeared 10 times corresponding to 13.2% of the total elements extracted from the reviewed articles. AI can enhance educational video games by providing more intelligent and responsive game mechanics, personalized learning experiences, and more engaging and immersive game worlds. This can help to improve the overall educational experience and make learning more enjoyable and effective. Moreover, AI-powered applications can support educational video games by providing tools and resources for game development, including AI-powered game engines, character creation tools, and machine learning algorithms for adaptive learning. Examples of the above are found in Walter-Linne (2020) and Torres-Toukoumidis et al. (2021).

"Digital footprints" appeared 22 times, corresponding to 28.9% of the total elements extracted from the reviewed articles. AI can be used to analyze and interpret digital footprints created by educational applications, which can provide valuable insights into student learning behavior and performance. This information can be used to improve educational applications, personalize learning experiences, and provide more effective educational services. For example, AI-powered educational applications can analyze students' digital footprints to identify patterns in their learning behavior, such as the topics they struggle with or the areas where they excel. Examples of the above are found in Yegina et al. (2020) and Gabor and Brooks (2017).

"Social media" appeared 14 times corresponding to 18.4% of the total elements extracted from the reviewed articles. AI can be used to enhance the educational experience provided by social media platforms or to develop educational applications that incorporate social media elements. For example, AI-powered educational applications can be integrated with social media platforms to provide a more immersive and engaging learning experience.

Thus, students can use these applications to collaborate with their peers, share resources, and receive feedback from their instructors. Examples of the above are found in Mohammed et al. (2022) and Dossena and Mochi (2020).

3.3.4 Users

"Digital skills" appeared 23 times, corresponding to 30.3% of the total elements extracted from the reviewed articles. Artificial intelligence (AI) can play a significant role in enhancing the digital skills of both students and teachers. For the first ones, AI can provide individualized feedback and support, helping them to develop digital skills in a way that is tailored to their learning style and pace. AI-powered educational applications can also provide real-time analytics that track student progress and performance, enabling students to identify areas where they need improvement. For teachers, AI can assist in developing and delivering more effective instructional materials. AI can be used to analyze student data and identify patterns in their learning behavior, which can inform the design of instructional materials. AI can also be used to automate administrative tasks, such as grading and record-keeping, freeing up time for teachers to focus on instruction. Examples of the above are found in Guzmán-Mendoza et al. (2015) and Denys and Klimczuk (2022).

"Emotional experiences" appeared 5 times, corresponding to 6.6% of the total elements extracted from the reviewed articles. Artificial intelligence (AI) can play a role in enhancing emotional experiences for both students and teachers in the educational setting. For students, AI can provide emotional support by analyzing their responses to various stimuli and identifying patterns in their behavior. This analysis can help to detect signs of distress, such as anxiety or depression, and provide targeted support to help students manage these emotions. Additionally, AI-powered tools can provide personalized recommendations for self-care and wellness activities, which can help students maintain a positive emotional state. For teachers, AI can assist in creating a more supportive and collaborative learning environment and develop a more empathetic and understanding approach to teaching, which can help to build stronger relationships with their students. Examples of the above are found in Xuanhui (2020).

"Open communities" appeared 18 times, corresponding to 23.7% of the total elements extracted from the reviewed articles. Artificial intelligence (AI) can play a significant role in fostering open communities within the educational setting. AI-powered tools can facilitate communication and collaboration between students, teachers, and other members of the educational community, creating a more open and inclusive learning environment. For students, AI can provide access to open educational resources and online communities where they can connect with peers and experts from around the world. AI-powered tools can also facilitate peer-to-peer learning and provide personalized feedback to help students improve their skills and knowledge. For teachers, AI can provide opportunities to collaborate and share best practices with other educators from around the world. Examples of the above are found in Tzouganatou (2022) and Witte et al. (2020).

4 Discussion

As mentioned throughout this article, it is clear that digital ecosystems have enormous potential to transform educational practices, but integrating them poses great challenges that require further research. One key challenge has to do with developing digital skills among educators and learners to effectively navigate and utilize these technologies. Also, it is important to study the impact of the lack of digital literacy that can hamper the adoption and utilization of AI-based tools in education. Additionally, privacy and security concerns are raised by the collection, storage, and use of student data, and to address these concerns properly, measures must be taken to protect student data through robust data protection and security protocols, informed consent, and compliance with data protection laws and regulations.

Besides the above, effective integration of digital ecosystems into traditional classrooms requires careful consideration and research, which results in the crucial to identify the most appropriate and effective tools and resources for specific learning objectives and to ensure that they are aligned with the curriculum and teaching goals. Moreover, the use of digital tools and resources should not be seen as a substitute for effective teaching and learning practices but as a complementary tool to enhance them.

The results of the review and the reflections that emerge in this regard suggest the relevance of advancing various lines of research towards the future, among which are: (1) Impact of Artificial Intelligence on Educational Assessment: Explore how artificial intelligence systems influence assessment methods, including the authenticity of assessments, plagiarism detection, and test adaptation, (2) Adaptability of Digital Ecosystems to Student Diversity: Identify how digital ecosystems can adapt to meet the needs of diverse students, including those with different learning styles, abilities and special needs, (3) Development of Digital Competencies in Higher Education: identify how digital ecosystems impact the development of digital competencies in students and teachers, including digital literacy, digital ethics and online collaboration skills, and (4) Ethics and Responsibility in the Use of Intelligence Artificial in Education: Analyze the ethical implications of the implementation of AI systems in educational decision-making, including aspects such as equity, privacy and transparency.

Finally, research is also needed to understand how to effectively measure the impact of AI-based digital ecosystems and machine learning algorithms on student learning outcomes, and how to use data analysis to provide personalized support, accurate assessments, and guidance to students.

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Declarations

Conflict of interests Not applicable.

References

Anwar, M. J., Gill, A. Q., & Beydoun, G. (2018). A review of information privacy laws and standards for secure digital ecosystems. In *Australasian Conference on Information Systems 2018* (pp. 1–12). Sydney: University of Technology, Sydney. https://doi.org/10.5130/acis2018.bb.

Bazán, P. A., Clara, L., Ceballos, H., Giorgetti, J. L., Ugalde, G., D. F., & Moreno, D. A. (2023). Integrabilidad y ecosistemas digitales: problemática, fundamentos y normalización. In *XXVIII Congreso Argentino de Ciencias de la Computación* (pp. 807–816). Presented at the XXVIII Congreso Argentino de Ciencias de la Computación, La Rioja: Editorial de la Universidad Nacional de La Rioja (EUDELAR). http://sedici.unlp.edu.ar/handle/10915/149433. Accessed 23 January 2024.

Belessova, D., Ibashova, A., Bosova, L., & Shaimerdenova, G. (2023). Digital Learning Ecosystem: Current state, prospects, and hurdles. *Open Education Studies*, *5*(1), 20220179. https://doi.org/10.1515/edu-2022-0179.

Biuk-Aghai, R. P., Kelen, C., & Venkatesan, H. (2008). Visualization of interactions in collaborative writing. In *2008 2nd IEEE International Conference on Digital Ecosystems and Technologies* (pp. 97–102). Presented at the 2008 2nd IEEE International Conference on Digital Ecosystems and Technologies (DEST), Phitsanuloke, Thailand: IEEE. https://doi.org/10.1109/DEST.2008.4635141.

Burbano, G., D. C., & Soler, J. A. (2020). Learning analytics in M-learning: Periodontic Education. In M. F. Mata-Rivera, R. Zagal-Flores, & C. Barria-Huidobro (Eds.), *Telematics and Computing* (Vol. 1280, pp. 128–139). Springer International Publishing. https://doi.org/10.1007/978-3-030-62554-2_10.

Cárdenas Peña, O. A. (2021). Diseño y construcción de un ecosistema digital: Estrategias para articular la información Y La formación Policial. *Revista Logos Ciencia & Tecnología*, *13*(3), 71–85. https://doi.org/10.22335/rlct.v13i3.1417.

Chang, V. (2008). An evaluation instrument for e-learning ecosystem. In *2008 6th IEEE International Conference on Industrial Informatics* (pp. 1244–1249). Presented at the 2008 6th IEEE International Conference on Industrial Informatics (INDIN), Daejeon, South Korea: IEEE. https://doi.org/10.1109/INDIN.2008.4618293.

Chang, V., & Uden, L. (2008). Governance for E-learning ecosystem. In *2008 2nd IEEE International Conference on Digital Ecosystems and Technologies* (pp. 340–345). Presented at the 2008 2nd IEEE International Conference on Digital Ecosystems and Technologies (DEST), Phitsanuloke, Thailand: IEEE. https://doi.org/10.1109/DEST.2008.4635164.

Cornejo-Plaza, I., & Cippitani, R. (2023). Consideraciones éticas y jurídicas de la Inteligencia Artificial en Educación Superior: desafíos y perspectivas. *Revista de Educación y Derecho*, (28). https://doi.org/10.1344/REYD2023.28.43935.

Denys, B., & Klimczuk, B. (2022). International Cooperation Towards Digital Transformation and Digital Ecosystems in Education. In *2022 45th Jubilee International Convention on Information, Communication and Electronic Technology (MIPRO)* (pp. 589–593). Presented at the 2022 45th Jubilee International Convention on Information, Communication and Electronic Technology (MIPRO), Opatija, Croatia: IEEE. https://doi.org/10.23919/MIPRO55190.2022.9803524.

Dodero, J. M., Palomo-Duarte, M., Ruiz-Rube, I., Traverso, I., Mota, J. M., & Balderas, A. (2015). Learning technologies and Semantic Integration of Learning resources. *IEEE Revista Iberoamericana De Tecnologias Del Aprendizaje*, *10*(1), 11–16. https://doi.org/10.1109/RITA.2015.2391312.

Dossena, C., & Mochi, F. (2020). Organizational Capabilities for Social Media Management: How Restaurant managers Approach to the Digital Ecosystem. In R. Agrifoglio, R. Lamboglia, D. Mancini, & F. Ricciardi (Eds.), *Digital Business Transformation* (Vol. 38, pp. 269–284). Springer International Publishing. https://doi.org/10.1007/978-3-030-47355-6_18.

Dreher, C., Reiners, T., Dreher, N., & Dreher, H. (2009). 3D virtual worlds as collaborative communities enriching human endeavours: Innovative applications in e-Learning. In *2009 3rd IEEE International Conference on Digital Ecosystems and Technologies* (pp. 151–156). Presented at the 2009 3rd IEEE International Conference on Digital Ecosystems and Technologies (DEST), Istanbul: IEEE. https://doi.org/10.1109/DEST.2009.5276761.

Fang, C., & Tse, A. W. C. (2022). Quasi-Experiment: Postgraduate Students' Class Engagement in Various Online Learning Contexts when Taking Privacy Issues to Incorporate with Artificial Intelligence Applications. In *Proceedings of the 14th International Conference on Education Technology and Computers* (pp. 356–361). Presented at the ICETC 2022: 2022 14th International Conference on Education Technology and Computers, Barcelona Spain: ACM. https://doi.org/10.1145/3572549.3572606.

Fu, H. (2006). Formal Concept Analysis for Digital Ecosystem. In *2006 5th International Conference on Machine Learning and Applications (ICMLA'06)* (pp. 143–148). Presented at the 2006 5th International Conference on Machine Learning and Applications (ICMLA'06), Orlando, FL, USA: IEEE. https://doi.org/10.1109/ICMLA.2006.24.

Gabor, D., & Brooks, S. (2017). The digital revolution in financial inclusion: International development in the Fintech era. *New Political Economy*, *22*(4), 423–436. https://doi.org/10.1080/13563467.2017.1259298.

Giró-Gracia, X., & Sancho-Gil, J. M. (2022). La Inteligencia Artificial en la educación: Big data, cajas negras y solucionismo tecnológico. *Revista Latinoamericana De Tecnología Educativa - RELATEC*, *21*(1), 129–145. https://doi.org/10.17398/1695-288X.21.1.129.

Goldstein, K., Briggs, M., Oleynik, V., Cullen, M., Jones, J., Newman, E., & Narva, A. (2013). Using Digital Media to promote kidney Disease Education. *Advances in Chronic Kidney Disease*, *20*(4), 364–369. https://doi.org/10.1053/j.ackd.2013.04.001.

Golov, R. S., & Myl'nik, V. V. (2022). Principles for constructing Digital ecosystems in Industry. *Russian Engineering Research*, *42*(4), 420–421. https://doi.org/10.3103/S1068798X2204013X.

Gordienko, Yu., Stirenko, S., Gatsenko, O., & Bekenov, L. (2015). Science gateway for distributed multiscale course management in e-Science and e-Learning —Use case for study and investigation of functionalized nanomaterials. In *2015 38th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)* (pp. 178–183). Presented at the 2015 38th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, Croatia:IEEE. https://doi.org/10.1109/MIPRO.2015.7160260.

Gupta, R., Mejia, C., & Kajikawa, Y. (2019). Business, innovation, and digital ecosystems landscape survey and knowledge cross sharing. *Technological Forecasting and Social Change*, *147*, 100–109. https://doi.org/10.1016/j.techfore.2019.07.004.

Guzmán-Mendoza, J. E., Muñoz-Arteaga, J., Muñoz-Zavala, Á. E., & Santaolaya-Salgado, R. (2015). An Interactive Ecosystem of Digital Literacy Services: Oriented to reduce the Digital divide. *International Journal of Information Technologies and Systems Approach*, *8*(2), 13–31. https://doi.org/10.4018/IJITSA.2015070102.

Haji, E. E., & Azmani, A. (2020). Proposal of a digital ecosystem based on big data and artificial intelligence to support educational and vocational guidance. *International Journal of Modern Education and Computer Science*, *12*(4), 1–11. https://doi.org/10.5815/ijmecs.2020.04.01.

Ibrahim, R., Norman, H., Nordin, N., & Mazin, K. A. (2020). Research trends in ICT and education: A systematic review of continuous professional development courses for online educators. *Journal of Physics: Conference Series*, *1529*(4), 042060. https://doi.org/10.1088/1742-6596/1529/4/042060.

Ilic, P. (2022). Work in progress: Reducing the Impact of Emergency Remote Teaching Through an Understanding of Personal Digital Ecosystems. In *2022 IEEE Frontiers in Education Conference (FIE)* (pp. 1–3). Presented at the 2022 IEEE Frontiers in Education Conference (FIE), Uppsala, Sweden: IEEE. https://doi.org/10.1109/FIE56618.2022.9962698.

Islas, C., & Carranza, M. R. (2017). Ecosistemas digitales y su manifestación en El Aprendizaje: Análisis De La Literatura. *Revista De Educación a Distancia (RED)*, *55*, 1–13. https://doi.org/10.6018/red/55/9.

Islas Torres, C. (2019). Los ecosistemas de aprendizaje y estudiantes universitarios: Una propuesta de abordaje sistémico. *Revista De psicología y ciencias del comportamiento de la Unidad Académica De Ciencias Jurídicas Y Sociales*, *10*(2), 172–186. https://doi.org/10.29059/rpcc.20191126-98.

Jacobsen, E. L., Solberg, A., Golovina, O., & Teizer, J. (2022). Active personalized construction safety training using run-time data collection in physical and virtual reality work environments. *Construction Innovation*, *22*(3), 531–553. https://doi.org/10.1108/CI-06-2021-0113.

Jha, S. K. (2023). The counterfeit degree certificate: Application of blockchain technology in higher education in India. *Library Hi Tech News*, *40*(2), 20–24. https://doi.org/10.1108/LHTN-02-2022-0023.

Johnson, M. J. J. (2015). Universal Access to Media and the California Community Colleges Online Education Initiative. In M. Antona, & C. Stephanidis (Eds.), *Universal Access in Human-Computer Interaction. Access to Learning, Health and Well-Being* (Vol. 9177, pp. 120–126). Springer International Publishing. https://doi.org/10.1007/978-3-319-20684-4_12.

Katsadouros, E., Kogias, D. G., Patrikakis, C. Z., Giunta, G., Dimou, A., & Daras, P. (2022). Introducing the Architecture of FASTER: A Digital Ecosystem for First Responder teams. *Information*, *13*(3), 115. https://doi.org/10.3390/info13030115.

Kay, J. (2022). Grand challenges for Pervasive Technology to transform Pervasive Education. *IEEE Pervasive Computing*, *21*(3), 32–41. https://doi.org/10.1109/MPRV.2022.3199104.

Kim, Y., Kelly, T., & Raja, S. (2010). *Building Broadband: Strategies and Policies for the developing world*. Washington D.C.: The World Bank. https://openknowledge.worldbank.org/server/api/core/bitstreams/55740d06-6984-5979-afd7-62ffbb40caf1/content.

Kum, L. C., Chang, E., & Atkinson, D. (2008). A digital ecosystem for ICT educators, ICT industry and ICT students. In *2008 2nd IEEE International Conference on Digital Ecosystems and Technologies* (pp. 660–673). Presented at the 2008 2nd IEEE International Conference on Digital Ecosystems and Technologies (DEST), Phitsanuloke, Thailand: IEEE. https://doi.org/10.1109/DEST.2008.4635225.

Lamb, R., Neumann, K., & Linder, K. A. (2022). Real-time prediction of science student learning outcomes using machine learning classification of hemodynamics during virtual reality and online learning sessions. *Computers and Education: Artificial Intelligence*, *3*, 100078. https://doi.org/10.1016/j.caeai.2022.100078.

Losada, J. L., & Arnau, J. (2000). Reliability among observers when the data are categorical. *Psicothema*, *12*(SUPPL. 2), 335–339.

Martinez, R., Slotta, J., Dillenbourg, P., Clayphan, A., Tissenbaum, M., Schwendimann, B., & Ackad, C. (2012). Digital ecosystems for collaborative learning: Embedding personal and collaborative devices to support classrooms of the future. *Presented at the 10th International Conference of the Learning Sciences: The Future of Learning ICLS 2012 - Proceedings*, *2*, 588–589.

Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2009). *Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies*. Washington D.C.: U.S. Department of Education. http://repository.alt.ac.uk/629. Accessed 23 January 2024.

Mohammed, S., Getahun, F., & Chbeir, R. (2022). Semantic event relationships identification and representation using HyperGraph in multimedia digital ecosystem. *Journal of Intelligent Information Systems*. https://doi.org/10.1007/s10844-022-00732-6.

Morris, T. H., & Rohs, M. (2021). The potential for digital technology to support self-directed learning in formal education of children: A scoping review. *Interactive Learning Environments*, 1–14. https://doi.org/10.1080/10494820.2020.1870501.

Naghshineh, N., & Zardary, S. (2011). Information ecology as a mind tool for repurposing of educational social networks. *Procedia - Social and Behavioral Sciences*, *15*, 3640–3643. https://doi.org/10.1016/j.sbspro.2011.04.348.

Nicol, D. J., & Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in Higher Education*, *31*(2), 199–218. https://doi.org/10.1080/03075070600572090.

Niyogisubizo, J., Liao, L., Nziyumva, E., Murwanashyaka, E., & Nshimyumukiza, P. C. (2022). Predicting student's dropout in university classes using two-layer ensemble machine learning approach: A novel stacked generalization. *Computers and Education: Artificial Intelligence*, *3*, 100066. https://doi.org/10.1016/j.caeai.2022.100066.

Nunez, S., & Padilla, J. M. (2020). Industry 4.0: An Integrated Distance Learning Solution. In *2020 6th International Conference on Science in Information Technology (ICSITech)* (pp. 29–34). Presented at the 2020 6th International Conference on Science in Information Technology (ICSITech), Palu, Indonesia: IEEE. https://doi.org/10.1109/ICSITech49800.2020.9392072.

Nzomo, P., McKenzie, P., Ajiferuke, I., & Vaughan, L. (2021). Towards a definition of multilingual information literacy (MLIL): An essential skill for the 21st Century. *Journal of Library Administration*, *61*(7), 897–920. https://doi.org/10.1080/01930826.2021.1972737.

Oughton, E. J., Frias, Z., van der Gaast, S., & van der Berg, R. (2019). Assessing the capacity, coverage and cost of 5G infrastructure strategies: Analysis of the Netherlands. *Telematics and Informatics*, *37*, 50–69. https://doi.org/10.1016/j.tele.2019.01.003.

Pedraja Rejas, L. (2012). Desafíos para El profesorado en la sociedad del conocimiento. *Ingeniare Revista Chilena De ingeniería*, *20*(1), 136–144. https://doi.org/10.4067/S0718-33052012000100014.

Pérez-delHoyo, R., & Mora, H. (2019). Knowledge society technologies for smart cities development. In *Smart Cities: Issues and Challenges* (pp. 185–198). Elsevier. https://doi.org/10.1016/B978-0-12-816639-0.00011-9.

Phillips, F., Yu, C. Y., Hameed, T., & El Akhdary, M. A. (2017). The knowledge society's origins and current trajectory. *International Journal of Innovation Studies*, *1*(3), 175–191. https://doi.org/10.1016/j.ijis.2017.08.001.

Prashantham, S. (2020). New ventures as value cocreators in digital ecosystems. *Industrial Management & Data Systems*, *121*(1), 111–122. https://doi.org/10.1108/IMDS-07-2020-0414.

Rajarapollu, P. R., & Bhagwatkar, S. A. (2017). ICT - An Effective Way for Active and Collaborative Learning Teaching Process in Engineering Education - A Review. In *2017 International Conference on Transforming Engineering Education (ICTEE)* (pp. 1–6). Presented at the 2017 International Conference on Transforming Engineering Education (ICTEE), Pune: IEEE. https://doi.org/10.1109/ICTEED.2017.8585697.

Reiners, T. (2010). University of Hamburg in 3D: Lesson learned (pp. 19–27). Presented at the Workshop Proceedings of the 18th International Conference on Computers in Education, ICCE 2010.

Rensfeldt, A. B., & Rahm, L. (2023). Automating teacher work? A history of the politics of automation and Artificial Intelligence in Education. *Postdigital Science and Education*, *5*(1), 25–43. https://doi.org/10.1007/s42438-022-00344-x.

Reyna, J. (2011). Digital teaching and learning ecosystem (DTLE): A theoretical approach for online learning environments (pp. 1083–1088). Presented at the ASCILITE 2011 - The Australasian Society for Computers in Learning in Tertiary Education.

Rothe, H., & Steier, F. (2017). Shaping the boundaries of a service ecosystem: The case of udacity (Vol. 2017-January, pp. 5255–5264). Presented at the Proceedings of the Annual Hawaii International Conference on System Sciences.

Sánchez-Martín, M., Navarro-Mateu, F., & Sánchez-Meca, J. (2022). Las revisiones sistemáticas Y La educación basada en evidencias. *Espiral Cuadernos Del Profesorado*, *15*(30), 108–120.

Setiana, D., Besar, N., Susanto, A. K. S., Yie, L. F., Susanto, H., & Subramanian, U. (2022). Digital Education, Learning Management Systems: Shifting Paradigm of Education Technology Within Digital Ecosystems. In P. Ordóñez de Pablos, X. Zhang, & M. N. Almunawar (Eds.), *Advances in Educational Technologies and Instructional Design* (pp. 13–30). IGI Global. https://doi.org/10.4018/978-1-6684-5914-0.ch002.

Sholichah, A. F., Gunarhadi, Musadad, A., & CONFERENCE ON FRONTIERS OF SCIENCE AND TECHNOLOGY. (2022). The use of role-playing game (RPG) media in ICT subject to improve learning motivation (p. 050014). Presented at the PROCEEDING OF INTERNATIONAL 2021, Ghaziabad, India. https://doi.org/10.1063/5.0103290.

Siriborvornratanakul, T. (2022). Human behavior in image-based Road Health Inspection systems despite the emerging AutoML. *Journal of Big Data*, *9*(1), 96. https://doi.org/10.1186/s40537-022-00646-8.

Sivetc, L., & Wijermars, M. (2021). The vulnerabilities of trusted notifier-models in Russia: The case of Netoscope. *Media and Communication*, *9*(4), 27–38. https://doi.org/10.17645/mac.v9i4.4237.

Smetana, L. K., & Bell, R. L. (2012). Computer simulations to support science instruction and learning: A critical review of the literature. *International Journal of Science Education*, *34*(9), 1337–1370. https://doi.org/10.1080/09500693.2011.605182.

Stale, G., & Majors, I. (2012). The application of em for knowledge flow analysis and the development of an educational it ecosystem (Vol. 933, pp. 95–105). Presented at the CEUR Workshop Proceedings.

Suárez Guerrero, C., Garrido, R., A., & Lizandra, J. (2021). Aproximación A La Competencia digital docente en la formación profesional. *Revista De Educación a Distancia (RED)*, *21*(67). https://doi.org/10.6018/red.431821.

Sukovataia, I. E., Cherkasova, Y. I., Dvinskikh, E. V., & Mitkovskaya, L. K. (2020). New approaches to the development of additional professional competences for the purposes of New Economy. *Journal of Siberian Federal University Humanities & Social Sciences*, *13*(11), 1781–1782. https://doi.org/10.17516/1997-1370-0684.

Torres-Toukoumidis, A., González-Moreno, S. E., & Palma-Ruiz, J. M. (2021). Gamification in MOOC Context. Documentary Analysis. In Á. Rocha, H. Adeli, G. Dzemyda, F. Moreira, & A. M. Ramalho Correia (Eds.), *Trends and Applications in Information Systems and Technologies* (Vol. 1368, pp. 267–277). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-72654-6_26.

Tzouganatou, A. (2022). Openness and privacy in born-digital archives: Reflecting the role of AI development. *AI & SOCIETY*, *37*(3), 991–999. https://doi.org/10.1007/s00146-021-01361-3.

Vera, F. (2023). Integración De La Inteligencia Artificial en la Educación superior: Desafíos Y oportunidades. *Transformar*, *4*(1), 17–34.

Vidal Ledo, M., Oramas Díaz, J., & Cruz, B., R (2015). Revisiones sistemáticas. *Educación Médica Superior*, *29*(1), 198–207.

Visic, M. (2022). Connecting puzzle pieces: Systematic literature review method in the social sciences. *Sociologija*, *64*(4), 543–562. https://doi.org/10.2298/SOC2204543V.

Vuk, J., Anders, M. E., & Rhee, S. W. (2022). Self-paced polling increases medical student engagement in recorded lectures and improves examination performance. *Advances in Physiology Education*, *46*(4), 728–734. https://doi.org/10.1152/advan.00083.2022.

Walter-Linne, J. (2020). No sos vos, es Tinder. Gamificación, consumo, gestión cotidiana y performance en aplicaciones de levante. *Convergencia Revista De Ciencias Sociales*, *27*, 1. https://doi.org/10.29101/crcs.v27i0.13365.

Witte, A. K., Zarnekow, R., & Fürstenau, D. (2020). Digital health ecosystems for sensor technology integration - A qualitative study on the paradox of data openness. Presented at the International Conference on Information Systems, ICIS 2020 - Making Digital Inclusive: Blending the Local and the Global.

Wolff, C., Reimann, C., Mikhaylova, E., Aldaghamin, A., Pampus, S., & Hermann, E. (2021). Digital Education Ecosystem (DEE) for a Virtual Master School. In *2021 IEEE International Conference on Smart Information Systems and Technologies (SIST)* (pp. 1–7). Presented at the 2021 IEEE International Conference on Smart Information Systems and Technologies (SIST), Nur-Sultan, Kazakhstan: IEEE. https://doi.org/10.1109/SIST50301.2021.9465914.

Wu, Q. (2020). Structure and Function Analysis of the Digital Ecosystem of Scientific Journals. In *Proceedings of the 3rd International Conference on Data Science and Information Technology* (pp. 165–169). Presented at the DSIT 2020: 2020 3rd International Conference on Data Science and Information Technology, Xiamen China: ACM. https://doi.org/10.1145/3414274.3414499.

Xuanhui, Z., Yuxiang, Z., Wei, L., & Qinghua, Z. (2020). An Action Research on user experience optimization of the Crowdsourcing transcription platform in Digital humanities: A Socio-Technical System Theory Perspective. *Journal of Library Science in China*, *46*(5), 94–113. https://doi.org/10.13530/j.cnki.jlis.2020042.

Yegina, N. A., Zemskova, E. S., Anikina, N. V., & Gorin, V. A. (2020). Model of consumer behavior during the Digital Transformation of the economy. *Industrial Engineering & Management Systems*, *19*(3), 576–588. https://doi.org/10.7232/iems.2020.19.3.576.