Exploring the Contribution of Disruptive Technologies to Innovation in University Education: A Prevalence Study in Pre- and Post-Pandemic Contexts

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Abstract. The adoption of disruptive technologies in higher education has transformed the teaching-learning process, especially since the COVID-19 pandemic. However, the real impact of these technologies on educational innovation and their variation between different contexts and areas of knowledge are not yet fully understood. It is essential to carry out studies that explore the trends and areas where these technologies have had the greatest impact, as well as to identify the less studied fields that require greater attention. By employing a quantitative approach and exploratory-descriptive scope, this study reviewed 88

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studies, extracted from the Scopus database. The results show a growing and sustained trend, especially in the post-pandemic period, in the scientific production of research on technologies such as artificial intelligence, augmented reality, big data, and gamification. Therefore, it is concluded that disruptive technologies have taken on a central role in the innovation of university education, in which gamification—a disruptive technology already consolidated as an effective tool to promote student motivation and commitment, even in pre-pandemic contexts—has proven to be key to transforming teaching-learning processes. However, significant gaps were identified in topics such as adaptive learning, the application of big data and fuzzy neural networks in higher education, which, although promising, have been scarcely explored. Future research could focus on determining the factors that influence the effective implementation of disruptive technologies in higher education as well as identifying good practices and ethical principles in the implementation of disruptive technologies in higher education.

1. Introduction
Rapid technological advancement has driven the educational field to continually evolve, relying on innovative tools that guarantee accessible and transformative instruction for students (Prats, 2023). In higher education, technology has proven to be crucial by facilitating innovation in teaching and learning, improving the interaction between teachers and students, and facilitating the transformation of pedagogical dynamics (Gallur & Montero-Lora, 2023). Thus, its incorporation into education has been key to improving learning and developing digital skills, enriching the curriculum and promoting active learning that better prepares students for the challenges of today's world (Pérez & Cevallos, 2024). The integration of learning processes with technologies represents a transformative factor in educational methodologies, necessitating consideration of the benefits and opportunities as well as the limitations that such innovations bring to teacher performance and student learning (Bravo et al., 2023). These limitations include challenges such as the need for high investment, uncertainty about the long-term effectiveness of educational technologies, and the risk of increasing the skill and digital access gaps among students (Alvarado & Macias, 2023; Martínez et al., 2023). Furthermore, challenges to the implementation of such technologies include resistance to change on the part of educators and the perception of technology as a threat to established practices; such factors can hinder both acceptance and application (Roby et al., 2024).

During the COVID-19 pandemic, the need for emergency remote education put educational systems around the world to the test, revealing that many institutions were not prepared to face this new reality (Fernández, 2021). As countries had to close their educational institutions due to the need for

confinement and physical distance between people (Palacios-Dueñas et al., 2020; Valero-Cedeño et al., 2020), educational actors were forced to quickly implement strategies to continue the teaching-learning process (Castillo, 2020). Faced with this scenario, educational institutions endeavored to ensure the continuity of learning by adopting virtual education and using various technological tools (Alanya-Beltran et al., 2021). Many of the changes driven by scientific and technological advances are considered to be disruptive, so it is important to understand what it means to be disruptive in the educational context (Aretio, 2019).

Disruptive technologies are those that generate significant transformations in processes, products or services; they usually follow a strategy of introduction, adoption and consolidation that displaces previous technologies, thus becoming a disruptive innovation (Zuñiga et al., 2021). Therefore, higher education faces the challenge of strengthening its online teaching through the use of disruptive technologies and collaborative platforms that introduce innovative content (Romero & Hornaza, 2022). In the last decade, various studies have identified emerging technologies that are expected to generate significant disruptions that will mark turning points in different fields, particularly education (Ledo et al., 2019). Among these, digitalization stands out as allowing information to be available on the web to be accessed from any interconnected smart device; also, virtual reality and augmented reality offer virtual visits to specific places, providing an almost real experience through 3D tools and artificial intelligence (Argudo & Tenecela, 2020). For teachers, disruptive technologies facilitate the creation of practices that improve their interactions with students and allow the incorporation of resources and content into the classroom that would be impossible to replicate in a traditional setting (Rivarola et al., 2023). Thus, collaborative tools and mobile devices drive educational innovation by facilitating real-time interaction during classes and encouraging more critical participation of students in debates and problem solving (Chinkes & Julien, 2019). Disruptive innovation will open the door to innovative resources and methods, such as Industry 4.0 techniques, improving learning (Pérez-Martínez et al., 2019). Consequently, it is essential that those who participate in the educational process are willing to change spaces, time and methods to facilitate disruptive transformations that expand knowledge and promote meaningful learning (Arias-Flores et al., 2019).

Based on the above, the purpose of this study is to explore and identify the areas with the highest prevalence in terms of research on the influence of disruptive technologies on university educational innovation, as well as the gaps, in both the pre- and post-pandemic periods. For this purpose, the bibliometric review method has been selected. A total of 183 scientific documents have been obtained from the Scopus database for review. This database was selected for its broad coverage and rigor in the dissemination of high-impact academic research. The study adopts a quantitative approach with an exploratory-descriptive scope, which is relevant to identify patterns of scientific production and highlight the areas of knowledge that require a deeper analysis. In so doing,

this study aims to contribute to the existing body of knowledge by offering a solid base that serves as a guide for future research and strategies for the implementation of these technologies in different areas of knowledge. In accordance with the above, the research questions (RQ) for this study are:

- RQ1: What is the trend in scientific production on the contribution of disruptive technologies to the innovation of higher education in the contexts between pre- and post-pandemic?
- RQ2: What are the most influential studies on the contribution of disruptive technologies to innovation in higher education in the pre- and post-pandemic contexts?
- RQ3: What are the most addressed areas of knowledge and which are still in development in relation to the contribution of disruptive technologies to innovation in higher education in the pre- and post-pandemic contexts?

2. Methodology

2.1 Research approach

As it focuses on the collection and analysis of bibliometric data to identify patterns, trends and relationships within the scientific production on disruptive technologies in higher education during the pre- and post-pandemic contexts, this study adopts a quantitative approach. Under this approach, it will be possible to objectively and systematically evaluate the data obtained, facilitating the identification of the prevalence of topics and the identification of research areas that require further attention. This approach is distinguished by its ability to make predictions based on the interpretation of observed facts, which makes its direction predictable (Faneite, 2023).

2.2 Scope of the investigation

Because it seeks to investigate little-studied areas of knowledge and describe the main characteristics of scientific production around disruptive technologies in higher education, the scope of the study is exploratory-descriptive. This scope is pertinent because, although studies on disruptive technologies exist, it is necessary to further explore how these technologies have impacted educational innovation, particularly in the time frame between the pre- and post-pandemic contexts. Exploratory studies are used when knowledge on a topic is limited and the problems remain imprecise. This is complemented by descriptive studies that, based on statistics, allow us to identify the prevalences and detail the characteristics of a particular phenomenon in a field of study (Corona-Martínez & Fonseca-Hernández, 2023).

2.3 Inclusion and exclusion criteria

Inclusion and exclusion criteria are essential to ensure that the study focuses on relevant and high quality publications, avoiding studies that are not coherent or consistent with the scope of the study. These criteria contribute to reducing possible biases in the selection of publications that do not represent significant contributions to the study. Therefore, the criteria presented in Table 1 seek to guarantee accurate bibliometric results regarding the contribution of disruptive technology in higher education, in the pre- and post-pandemic contexts. Furthermore, the inclusion and exclusion criteria allow the study to be delimited

and its rigor to be established; in many cases, the types of manuscripts, the publication period, access to the manuscript, and the language in which it was published are specified (Castro-Palomino & Coras, 2024).

Table 1. Inclusion and exclusion criteria

Item	Inclusion criteria	Exclusion criteria
1	Studies that address the application of disruptive technologies in university education.	Studies that address the application of disruptive technologies in the fields of early childhood, primary or secondary education.
2	Scientific articles published in journals indexed in the Scopus database.	Conference papers, letters to the editor, books, book chapters, theses, or review articles.
3	Scientific articles published between 2016 and 2024.	Scientific articles published prior to 2016.
4	Open access scientific articles.	Scientific articles for which payment is required to obtain the full content of the study.

2.4 Data extraction source

Due to its wide coverage of publications on disruptive technologies in higher education, Scopus was selected as the data source for the extraction of scientific manuscripts. Through its rigorous indexing and peer review process, Scopus guarantees the inclusion of high-quality studies, thereby ensuring the relevance and methodological rigor of scientific articles in this field of study. Additionally, it should be noted that the Scopus database brings together scientific production worldwide in various disciplines of knowledge; its widespread visibility therefore makes it an essential source for analyzing the behavior and trends of scientific and research activity globally (Quindemil et al., 2023).

2.5 Data extraction process

The data extraction process for this study was carried out in three well-defined dimensions, each relevant to ensure the rigor and relevance of the bibliometric analysis of disruptive technologies in innovation in higher education. As shown in Figure 1, the three dimensions are described in detail below. In the first dimension, the central theme of the study was defined; this was to explore the contribution of disruptive technologies to innovation in higher education in the contexts between the pre-pandemic and post-pandemic periods. To this end, the Scopus database was chosen as the source of information, defining the search field (title of the article, abstract and keywords), the time period (2016-2024) and the type of document (scientific articles). The identification was carried out using a specific search equation, based on keywords and Boolean connectors, covering terms related to disruptive technologies and higher education. As a result of this initial search carried out on September 6, 2024, 183 potentially relevant scientific publications were identified. The second dimension consisted of screening and filtering the records obtained in the first dimension. Each scientific publication was examined on the basis of the established inclusion and

exclusion criteria. This allowed the number of publications to be reduced to 96 scientific articles, thereby eliminating those that did not meet the quality criteria or were not aligned with the study topic. Finally, the third dimension involved a detailed review of the 96 previously selected articles. In this process, a more in-depth analysis was carried out to verify the adequacy of the studies according to the objectives of the bibliometric analysis. As a result, a further eight articles were eliminated due to their lack of direct relevance to the study topic, leaving a total of 88 articles finally included for the bibliometric review process.
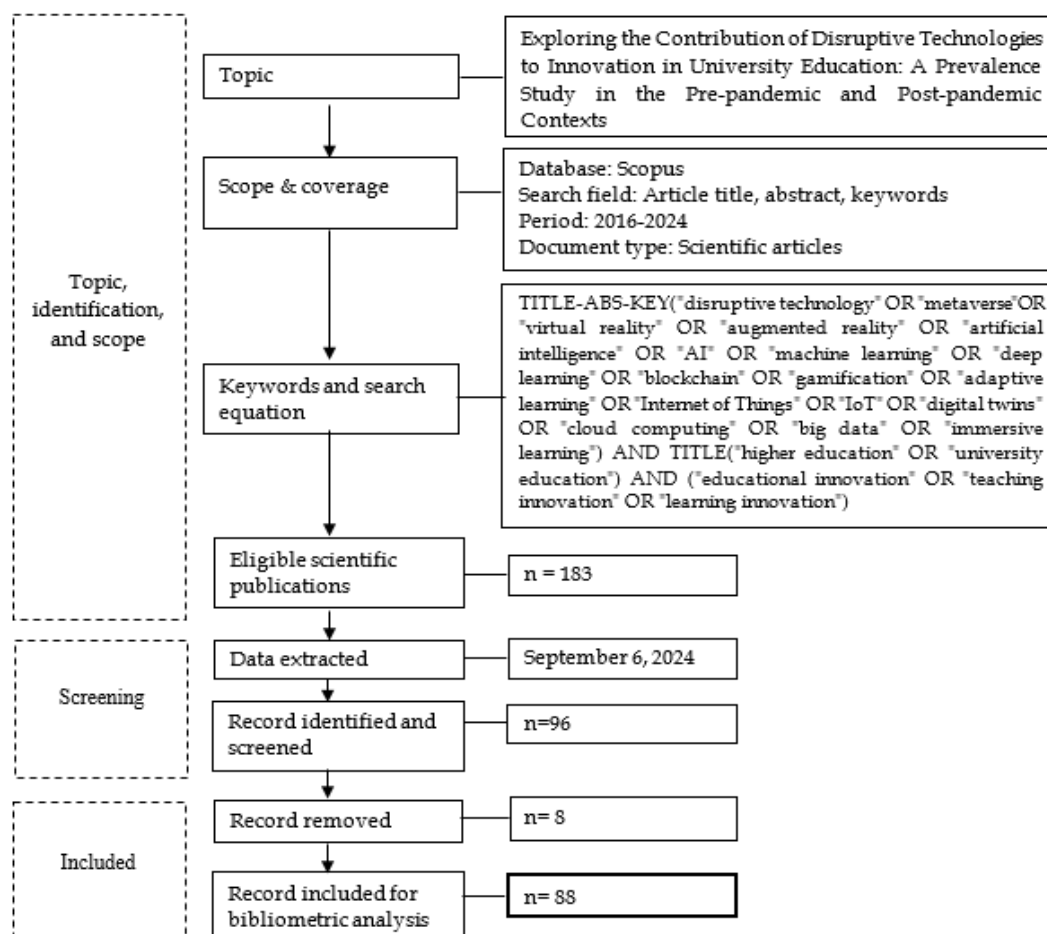

Figure 1. Process of extraction and selection of scientific articles on disruptive technologies in university education

3. Results and discussion
3.1 What is the trend in scientific production on the contribution of disruptive technologies to the innovation of higher education in the pre- and post-pandemic contexts?

Of the 88 scientific articles included in the bibliometric review, it was identified that in the pre-pandemic period the number of publications on the contribution of disruptive technologies to innovation in higher education was lower compared to the pandemic and post-pandemic contexts. Specifically, in 2016 only two scientific articles were identified, while in 2018 and 2019, five and one scientific article were identified, respectively. In other words, the number of articles published in the pre-pandemic context represents 9.09% of the total

publications included in this review study. Similarly, when analyzing the pandemic context between 2020 and 2022, a notable growing trend in the number of publications was identified. Five articles were published in 2020 while, in 2021 and 2022, 13 and 19 scientific articles were published, respectively; this represents 42.05% of the total publications included in this review study. Subsequently, in the post-pandemic context, the trend in the publication of scientific articles on the contribution of disruptive technologies to innovation in higher education has continued to rise. Thus, it was identified that in 2023 and 2024, 15 and 28 scientific articles were published, respectively. The percentage of publications in this current context represents 48.86%. Notably, this boom in scientific production reflects that disruptive technologies have been consolidated as a central axis of innovation in university education, highlighting their potential to transform educational practices in a sustainable way beyond the context of the recent health emergency. Figure 2 shows the trend of scientific articles published between the pre- and post-pandemic periods.
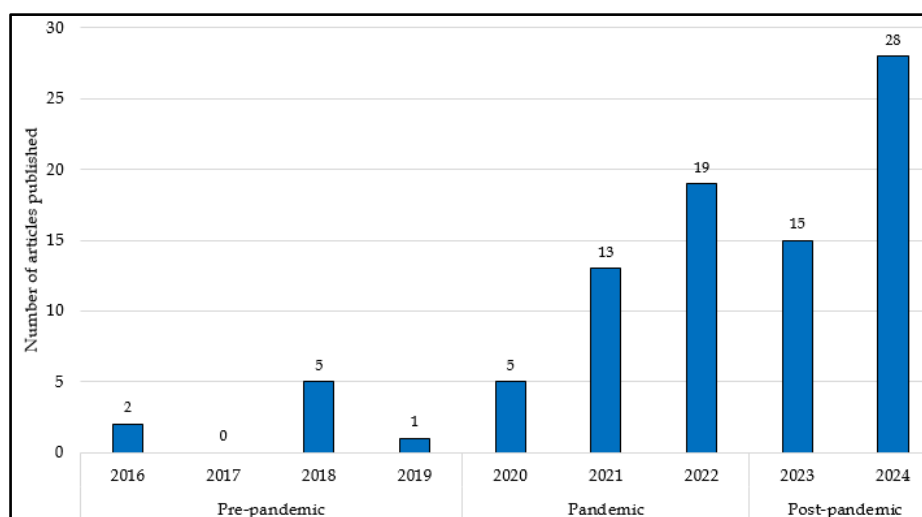

Figure 2. Trend of scientific articles published between the pre- and post-pandemic periods

The data suggest that the pandemic not only acted as a temporary catalyst, but also created a prolonged push towards the integration of advanced technologies in the field of higher education. Such a push could be motivated by the growing understanding that, regardless of health circumstances, the adoption of technologies such as artificial intelligence, augmented reality, virtual reality, data mining and IoT offers significant benefits in terms of accessibility. These findings align with those of García (2017), who pointed out that not only have distance education and digital learning consolidated and generated important disruptions, but that these technological advances will continue to encourage educational innovation on an ongoing basis. In this context, for example, the adoption of technologies such as the metaverse in higher education institutions emerges as a disruptive trend that can mark a radical change in the terms of the ways in which education is delivered and accessed. In this regard, De La O-Miranda and Cortés-Campos (2023) point out that the metaverse allows students to attend classes, interact with teachers and classmates, and access educational

resources from anywhere, eliminating geographical barriers and democratizing access to knowledge. However, as Sánchez et al. (2021) highlight, while these technological adaptations to educational innovation are crucial, successful learning does not depend solely on disruptive technologies; it is also influenced by emotional and personal factors, such as motivation and study habits. Therefore, in order to maximize the impact of disruptive technologies in higher education, it is essential to address both technological and human aspects, seeking a more comprehensive and effective approach.

3.2 What are the most influential studies on the contribution of disruptive technologies to innovation in higher education in the pre- and post-pandemic contexts?

From the analysis of the 88 scientific articles selected for the review study, 12 studies were identified as being the most influential due to their total number of citations being greater than or equal to 50. This group of scientific publications represents those works that have had a significant impact in the field of research on disruptive technologies in higher education, thereby being cited more frequently by other researchers. In addition, 20 studies were identified as having total numbers of citations ranging from 10 to 49. Although less frequently cited than the top 12, these works have nevertheless demonstrated their relevance in the discussion on educational innovation through disruptive technologies. On the other hand, 29 studies were identified as having been cited at least once, indicating a low level of recognition. Finally, 27 studies had not received any citations to date, comprising a lower percentage than the number of studies that had been cited at least once.

It is important to highlight that the most cited study was that carried out by Rasul et al. (2023) with a total of 118 citations; this presents an average of 59 total citations (TC) per year and a normalized TC of six. This reflects that the article has a significantly higher number of citations than the average in its area and evaluation period. By addressing the role of the ChatGPT artificial intelligence model in higher education, this article explores both the benefits and challenges arising from it and proposes future research directions. The second most cited study is that of Michel-Villarreal et al. (2023), with a total of 107 citations. On average it has received a total of 53.50 citations, with a normalized TC of 5.44. Similar to the first study, this work also focuses on the use of generative artificial intelligence in higher education, providing a critical perspective on the opportunities and challenges that these technologies present. Finally, in third place is the study carried out by Huda et al. (2016), with a total of 80 citations. In contrast to the two previous studies, which focused on artificial intelligence, this work focuses on the use of big data in innovative teaching in higher education. The unique perspective of this study regarding the use of big data to improve learning has captured the attention of many researchers, especially in a context wherein personalization and efficiency are increasingly valued.

Table 2. Most influential scientific articles with a total number of citations greater than 50

Author	Title of the scientific article	Total citations	TC per Year	Normalized TC
(Rasul et al., 2023)	The role of ChatGPT in higher education: Benefits, challenges, and future research directions	118	59.00	6.00
(Michel-Villarreal et al., 2023)	Challenges and Opportunities of Generative AI for Higher Education as Explained by ChatGPT	107	53.50	5.44
(Huda et al., 2016)	Innovative teaching in higher education: The big data approach	80	8.89	1.03
(Geitz et al., 2016)	Changing learning behavior: Self-efficacy and goal orientation in PBL groups in higher education	76	8.44	0.97
(Ferriz-Valero et al., 2020)	Gamification in Physical Education: Evaluation of Impact on Motivation and Academic Performance within Higher Education	74	14.80	2.78
(Chans & Castro, 2021)	Gamification as a Strategy to Increase Motivation and Engagement in Higher Education Chemistry Students	66	16.50	2.18
(Rahman et al., 2018)	The effectiveness of gamification technique for higher education students engagement in polytechnic Muadzam Shah Pahang, Malaysia	63	9.00	1.84
(Rojas-López et al., 2019)	Engagement in the course of programming in higher education through the use of gamification	63	10.50	1.00
(Ralston, 2021)	Higher Education's Microcredentialing Craze: a Postdigital-Deweyan Critique	58	14.50	1.92
(Salmerón-Manzano & Manzano-Agugliaro, 2018)	The Higher Education Sustainability through Virtual Laboratories: The Spanish University as Case of Study	54	7.71	1.58
(Collado-Valero et	Flipped Classroom: Active	50	12.50	1.65

al., 2021)	Methodology for Sustainable Learning in Higher Education during Social Distancing Due to COVID-19			
(Rincon-Flores & Santos-Guevara, 2021)	Gamification during Covid-19: Promoting active learning and motivation in higher education	50	12.50	1.65

Analysis of the most influential studies on the contribution of disruptive technologies to innovation in higher education reveals that, in addition to artificial intelligence and big data, gamification has been a widely used and frequently discussed technology in academic literature, both in pre-pandemic contexts and during the pandemic. Some of the most cited studies, such as those by Ferriz-Valero et al. (2020) and Chans and Castro (2021), highlight the implementation of gamification strategies to increase student motivation and engagement in different areas, such as physical education and chemistry. However, gamification is not a recent approach; in the pre-pandemic period, studies including those by Geitz et al. (2016) and Rahman et al. (2018) explored its effectiveness in changing learning behavior and improving student engagement in higher education. During the pandemic and the remote teaching scenario, the trend towards the use of gamification intensified, as institutions sought effective methods to maintain student participation and motivation. This trend aligns with the findings of Zúñiga et al. (2021) and Hualpa-Molina & Solís-Mazón (2024), who state that technology and disruptive innovation—such as gamification, virtual reality, artificial intelligence, augmented reality, interactive touch boards and data analysis—are rapidly being integrated into higher education, resulting in significant changes in the teaching-learning processes.

3.3 What are the most addressed areas of knowledge and which are those that are still in development in relation to the contribution of disruptive technologies to innovation in higher education in the contexts between pre- and post-pandemic?

In order to identify the most addressed areas of knowledge and those that are in the development phase with respect to the topic under study, a co-occurrence analysis was carried out based on the frequency of the keywords contained in the 88 scientific articles reviewed. Through this co-occurrence network, this study sought to identify the linking forces between the keywords to understand how they relate to each other and which areas emerge with greater centrality and influence in the field of disruptive technologies applied to higher education. The results of the co-occurrence network reveal a class structure of interconnections between the most relevant terms. "Higher education" is the most central term and has the greatest linking force, connecting significantly with other terms such as "students", "teaching", "learning", "education computing" and "education innovation". Thus, these connections reflect that disruptive technologies are seen as key tools with which to reconfigure teaching-

learning processes, especially in the university context. Furthermore, the strong presence of terms such as "education computing" and "educational innovation" highlights the growing interest in the ways in which these technologies can foster more innovative and adaptive pedagogical practices, transforming the educational experience as a whole. Figure 4 shows the network of co-occurrences between keywords obtained from the VOSviewer software.
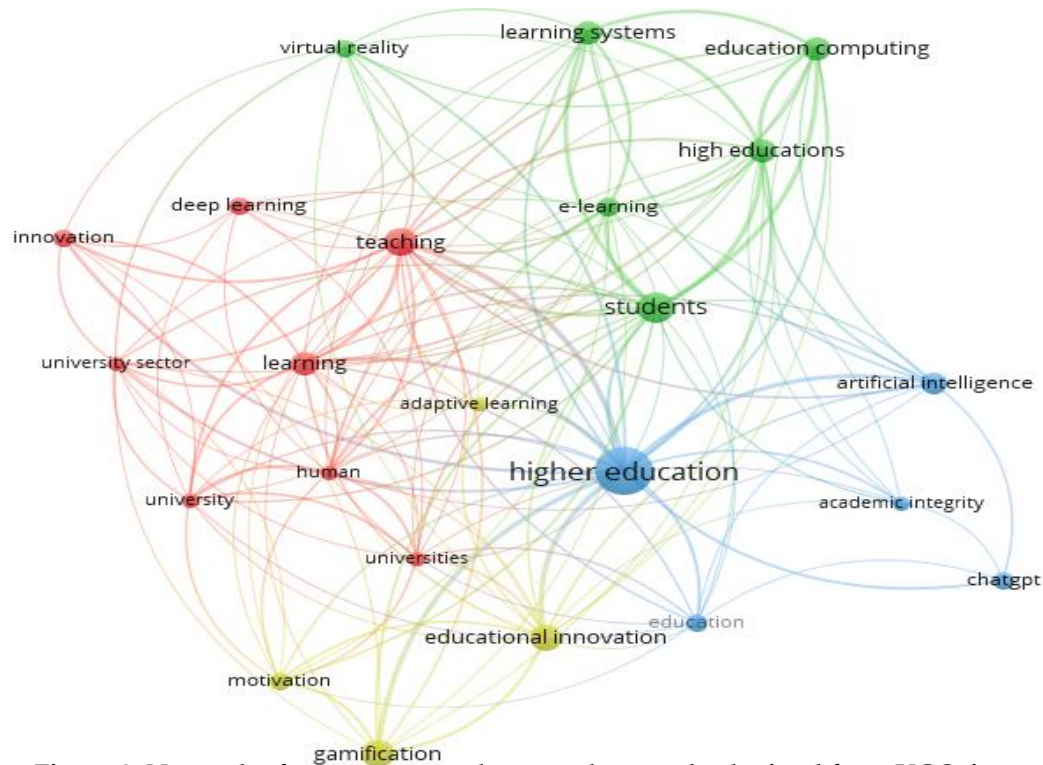

Figure 3. Network of co-occurrences between keywords obtained from VOSviewer

A subsequent analysis led to obtaining the thematic map using Bibliometrix software, which reflects the evolution and development of the areas of knowledge linked to the contribution of disruptive technologies to innovation in higher education. Structured into four quadrants, the thematic map allows us to identify the relevance and degree of development of various key themes in the field of study. In the upper right quadrant, corresponding to the Motor Themes, are the most developed and central themes, such as "teaching", "learning" and "human". The results reveal that these concepts are fundamental in the integration of disruptive technologies in higher education, highlighting that innovation in teaching and learning methods continues to be a cornerstone of educational transformations. Meanwhile, the upper left quadrant, which represents the Niche Themes, includes topics such as "adaptive learning", "educational technology" and "systematic review". Although they are highly developed topics, they have less connection with other central topics, which suggests their specialization in specific areas of higher education. This quadrant highlights that innovations in adaptive learning and educational technologies, although specialized, can offer innovative approaches to personalized learning,

thereby improving educational results. On the other hand, the lower left quadrant represents Emerging or Declining Themes; these include terms such as "big data", "higher education institutions", and "fuzzy neural networks". A limited level of development and connection is identified in these topics, indicating areas that are emerging in the context of the adoption of disruptive technologies for the management of massive data and advanced analysis in higher education, but which still need to be consolidated in the educational field. Finally, the lower right quadrant represents the Basic Themes, comprising of terms such as "higher education", "innovation", "university sector", "deep learning", "decision making" and "learning algorithms". These themes stand out as being highly relevant, although with less development density. Although these concepts are essential to understanding the core of innovation in higher education, they nevertheless require further exploration to strengthen their integration with other disruptive technologies. Figure 4 presents the thematic map on the contribution of disruptive technologies to innovation in higher education.
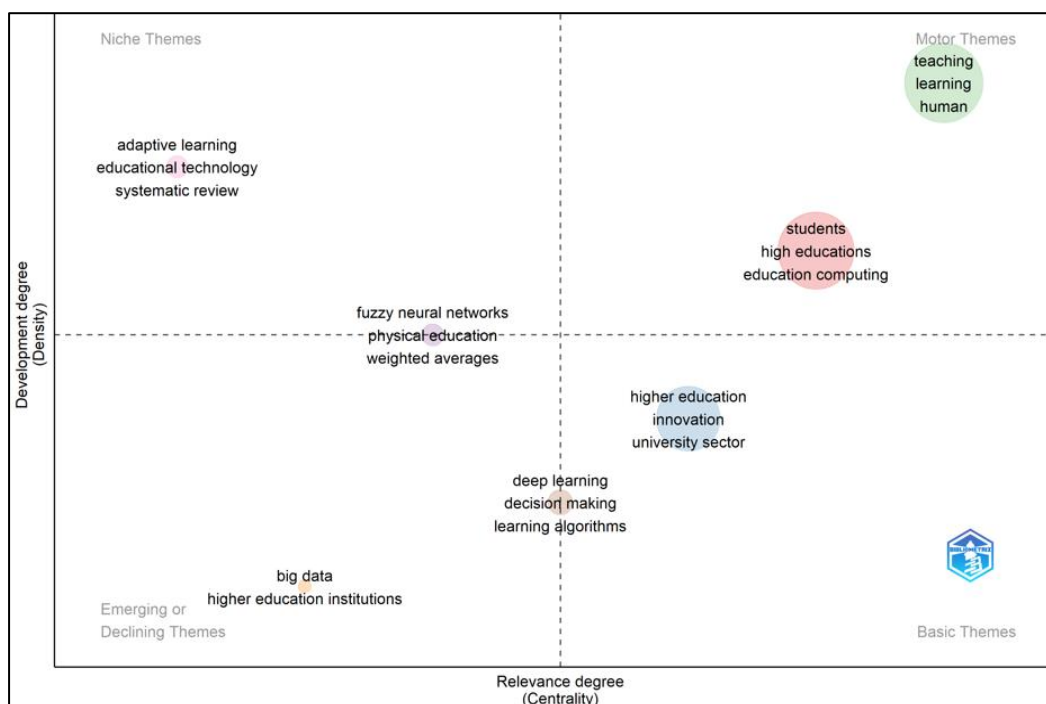

Figure 4. Thematic map on the contribution of disruptive technologies to innovation in higher education

These results establish that the most widely addressed areas of knowledge in relation to disruptive technologies in higher education are those related to teaching, learning and the study of human behavior. At the same time, emerging topics such as big data and fuzzy neural networks are gaining ground and may represent future areas of opportunity. However, adaptive learning still requires further attention in order to be consolidated as an integral component in higher education. In this vein, Castro et al. (2021) identified that disruptive technologies—such as machine learning, artificial intelligence, data mining, the Internet of Things, virtual reality and augmented reality—have significantly

improved educational practices, proving to be essential during the pandemic in maintaining educational continuity. Portillo et al. (2020) also highlighted the importance of these technologies as fundamental tools for both teachers and students in crisis contexts. Similarly, Mohamad et al. (2023) noted the innovative role of augmented reality in higher education, demonstrating that the implementation of lessons based on this technology enriches learning experiences and improves educational practices. This reinforces the idea that disruptive technologies, such as augmented reality, are essential components for educational transformation. On the other hand, Singh et al. (2023) focused on the challenges of adopting Education 4.0, including the need for solid digital infrastructures, continuous teacher training, and a culture of change to overcome barriers and maximize the benefits of disruptive technologies focused on educational innovation.

4. Conclusion

The results of this study show a sustained trend in scientific production related to the use of disruptive technologies in higher education innovation, especially driven by the educational crisis resulting from the COVID-19 pandemic. Over time, research has focused its efforts on exploring technologies such as artificial intelligence, augmented reality, big data, and gamification, each of which has a unique potential to transform educational practices, from teaching and learning to institutional management. Furthermore, the analysis of the most cited studies reveals that, in addition to the recent prominence of artificial intelligence and big data, gamification as a disruptive methodology has had a considerable impact on student motivation and engagement, even in the pre-pandemic context; thus, this demonstrates its relevance as an educational strategy that can improve active participation and academic results. The areas most addressed in research are related to teaching, learning and educational computing, which have managed to consolidate themselves as nuclei of educational innovation, while other emerging topics—such as big data and adaptive learning—although still in development, present a high potential to redefine the personalization of learning and data-informed decision-making in university environments. Therefore, it is concluded that disruptive technologies have taken on a central role in the innovation of university education, as revealed by the sustained trend in scientific production, especially in the post-pandemic period. Artificial intelligence, augmented reality and gamification are the most researched areas, with the latter being already firmly established as an effective tool with which to promote student motivation and engagement, even in pre-pandemic contexts. Additionally, artificial intelligence and augmented reality have proven to be key in transforming teaching processes. However, significant gaps have been identified in the research on topics such as adaptive learning, big data and fuzzy neural networks which, although promising, have yet been scarcely explored.

5. Future research

In order to better understand the contribution of disruptive technologies to innovation in higher education, future research could focus on addressing the implications and challenges of applying disruptive technologies in specific fields of education and identifying the factors that influence the successful

implementation of disruptive technologies in higher education. Finally, it would be useful to identify good practices and ethical principles regarding the implementation of disruptive technologies in higher education; this would contribute to understanding how different educational institutions have established standards and guidelines to ensure their efficient use in different areas of education such as medicine, engineering and social sciences.

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