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# DECISION-MAKING PROCESS IN HIGHER EDUCATION AND DIGITAL TRANSFORMATION: A BIBLIOMETRIC ANALYSIS

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**Abstract**
*The present study provides a bibliometric analysis of scientific publications addressing the relationship between managerial decision-making processes in universities and digital transformation, using data extracted from the Web of Science Core Collection. A total of 905 articles published between 2010 and 2025 were analyzed to identify productivity trends, key contributors, thematic clusters, and emergent research areas. The results show a significant increase in publication volume after 2020, reflecting the growing academic interest in digital governance in higher education, as well as the challenges and opportunities associated with the implementation of digital technologies in decision-making processes. "Digital transformation", "higher education", and "artificial intelligence" are among the most recurrent terms, highlighting the multidimensional nature of the digital shift in university management. The study concludes with recommendations for future research and university policy in the context of institutional digitalization.*
**Keywords:** *Management decision-making process, digital transformation, bibliometric analysis, higher education, academic governance*
**JEL Classification**: I23; O33.

## 1. INTRODUCTION

University management plays a crucial role in creating a learning environment that supports both the academic development and the personal well-being of students and staff (González, Abad, 2020). Educational leaders significantly influence both institutional and student success, exerting a direct impact on the quality and effectiveness of educational processes. By implementing effective management practices, educational institutions can ensure the alignment of resources with strategic objectives and foster a climate conducive to learning.

In the context of new technologies, the management of higher education institutions is a dynamic and constantly evolving field. Digital technologies have brought fundamental changes to the way universities coordinate and manage academic and administrative activities (Onan, 2024), while also creating new opportunities for enhancing the educational process (Zizikova *et al.,* 2023). Emerging technologies, including online learning platforms, learning management systems, and artificial intelligence-based solutions, exert a profound impact on university management strategies and practices (Bit *et al.,* 2024). In this context, higher education institutions must address emerging challenges and develop adaptive strategies in order to fully harness the potential of digital technologies.

Digital transformation represents one of the most significant and impactful directions of development for contemporary economies and societies. Consequently, it is generating profound changes within all organizations, both in the private and public sectors, including universities (Nugraha *et al.*, 2018). In an era marked by globalization, internationalization, and heightened competitiveness, digitalization is becoming not merely an option but a strategic necessity (Al Nuaimi *et al.*, 2022) for strengthening the decision-making and managerial capacities of higher education institutions. Digital solutions, ranging from academic management platforms to data analytics tools, enable the optimization of operational processes, increased efficiency and transparency, as well as the development of robust forecasting and planning mechanisms (Badhe, *et al.,* 2020).

The specialized literature frequently refers to this phenomenon as the Fourth Industrial Revolution (Berawi, 2018), a shift driven by the critical role of digitalization and emerging technologies. Digital development has significant implications for the Sustainable Development Goals (SDGs) set out in the United Nations' 2030 Agenda: countries, institutions, and organizations must commit to narrowing the digital divide to avoid the negative impacts of digital exclusion (Kulkarni and Ghosh, 2021).

The digitalization of education constitutes not only a step toward modernizing educational processes, but also a fundamental transformation of the educational paradigm. Ugur *et al.* (2024) emphasize that the digital

transformation of education opens new opportunities for higher education yet requires a substantial shift in managerial and organizational mindsets within universities. Furthermore, studies indicate that the integration of educational technologies enables significant improvements in accessibility and flexibility of learning, addressing the diverse needs of students from various regions across the globe.

An essential aspect of digitalization concerns the digital competencies of teaching staff – a topic explored by Momdjian *et al.* (2024), who argue that preparing educators with digital skills is vital for the successful integration of technologies into education. In this context, digital education becomes a continuous process, where teacher training plays a pivotal role in ensuring the effectiveness of new educational methods.

Another important argument for the transition to digital tools lies in the growing complexity of the university environment, which necessitates the adoption of digital management models tailored to the knowledge economy. University decision-making is increasingly dependent on rapid and efficient access to relevant information, the integration of data sources from multiple departments, and the use of advanced analytical and simulation tools (Carayannis and Morawska-Jancelewicz, 2022). This dynamic fundamentally transforms the role of university leadership, requiring more rapid and efficient responses to challenges, effective management of uncertainty, and the ability to capitalize on opportunities offered by new digital technologies.

At the European Union level, university digitalization is anchored in both European and national priorities concerning sustainable development, competitiveness, and inclusion (Bradley, 2007). Through the European programme "Digital Decade 2030," the importance of digital public services, digital competencies, and secure infrastructures is highlighted, with concrete objectives for the digitalization of education and university administration. Within this framework, one of the central goals is the development of digital skills among the population and workforce, with the ambition that at least 80% of the EU population will possess basic digital skills and 75% of enterprises within the European Union will employ advanced technologies such as cloud computing, artificial intelligence, and Big Data by 2030. Successfully implementing these policies requires not only investment in technology but also a paradigm shift in the management of decision-making processes, emphasizing the role of data, artificial intelligence, and evidence-based management.

Scientific research conducted in the pre-pandemic period, between 2015 and 2019, focused on the initial adoption of educational technologies and their benefits in education (Daniel, 2014). Studies from this period demonstrated that the onset of digitalization in higher education was facilitated by the availability of accessible educational platforms, as well as the desire to improve students' academic performance through distance learning and hybrid learning models

(Glowatz, Bofin, 2014). Bilynska *et al.* (2024) emphasize that digitalization in education has enabled universities to meet modern learning requirements by developing interactive and accessible educational content.

Since 2020, the COVID-19 pandemic has had a significant impact on research in this field, with studies focusing on the challenges related to the rapid transition to online learning. Pan *et al.* (2024) argue that the COVID-19 pandemic forced higher education to adopt digital technologies at an accelerated pace, permanently changing the way courses and assessments are designed.

As digitalization continues to become a fundamental element in higher education (Hannan, 2023), future research will focus on the integration of emerging technologies and the personalization of learning (Maulana *et al.*, 2023). Komljenovic *et al.* (2024) highlight that the future of digital education will involve not only advanced technologies such as artificial intelligence and augmented reality but also a redefinition of the relationship between teachers and students in digital environments (Ahmed, 2010). In this regard, studies will emphasize the sustainability of digital education and its long-term impact on educational quality and academic performance (Guevara-Reyes *et al*., 2025).

In conclusion, university management and institutional digitalization cannot be viewed separately, but rather as two interdependent components of a profound transformation process aimed at enhancing performance, transparency, and sustainability in higher education. This context justifies the need for a detailed analysis of how digitalization shapes university decision-making processes and its impact on long-term institutional development strategies.

The aim of this article is to identify and analyze global trends in scientific research concerning decision-making processes in the context of digital technology use in higher education, through a bibliometric analysis of articles published between 2010 and 2025 in the Web of Science database. To conduct this quantitative research, a bibliometric analysis was employed, which is a useful tool for identifying development trends, research priorities, and key references within a topic, based on geographic location and research networks (Wang, 2016). These techniques enable researchers to examine a research field through the distribution, analysis, and frequency of keywords. Additionally, they provide scholars with various instruments to evaluate academic productivity, its impact, and relative influence, to define the research topic structure and its evolution, as well as to identify different subthemes and their conceptual frameworks.

The objectives of this study can be summarized in several research questions (Table 1): questions 1 to 5 were addressed through a productivity analysis, while questions 6 and 7 were examined using a bibliometric mapping approach with the VOSviewer software. The results are presented as visual networks derived from the analysis of common keywords.

**Table 1. Research Objectives and Questions**

| *Objective* | *Research Questions* | *Bibliometric Method* | *Analysis* |
|---|---|---|---|
| *(1) Assessing academic impact and relative influence* | ***Q1** Historical evolution of the literature* | *Productivity measurement* | *Historical evolution of publications* |
| | ***Q2** Most productive journals* | | *Distribution of articles by journals* |
| | ***Q3** Most productive authors* | | *Distribution of articles by authors* |
| | ***Q4** Most influential articles* | | *Distribution of articles by institutions and countries* |
| | ***Q5** Most important institutions and countries* | | |
| *(2) Determining the evolution of research themes* | ***Q6** Main themes addressed in articles* | *Impact measurement Co-occurrence analysis* | *Keyword co-occurrence analysis* |
| *(3) Identifying significant themes* | ***Q7** Evolution of main research topics addressed in articles* | | *Keyword analysis* |
| *(4) Identifying research trends* | | | |

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## 2. ANALYSIS METHODS USED

Bibliometric analysis is a scientific field that applies mathematical and statistical methods to scientific literature for the study and analysis of scientific activity. The term "bibliometrics" as a scientific domain was officially introduced in 1969 by Alan Pritchard in his documentary note entitled "Statistical Bibliography or Bibliometrics?" However, the concept and early concerns related to the quantitative measurement of literature date back to the early 20th century, when E. Wyndham Hulme used the term "statistical bibliography" in May 1922 while delivering two lectures at the University of Cambridge. In the last century, classical literary databases predominated, serving as the primary resource for researchers conducting literature reviews. Yet, with the advent of digitalization of literature and online databases, researchers gained the ability to analyze the body of literature more easily and efficiently (AlRyalat, Malkawi, Momani, 2019). This type of analysis is known as bibliometric analysis.

Bibliometric methods are frequently used to evaluate the evolution of a research field by analyzing bibliographic data through two main approaches: performance analysis and scientific mapping (Cobo *et al.*, 2011). The advantages of bibliometric methods include: (i) providing an overview of the scientific literature; (ii) generating a more objective synthesis of selected scientific works

compared to traditional techniques (e.g., literature reviews); and (iii) attracting increased attention from the scientific community (Corsini *et al.*, 2019).

To select the papers included in the bibliometric analysis and to avoid subjectivity in data collection, a systematic literature search was conducted in the Web of Science database, in accordance with the standard practices commonly employed in this type of analysis in the literature. The choice of this database is justified by its extensive coverage of scientific publications and by the fact that journals indexed in this database are selected based on strict quality criteria and are subject to a peer-review process (Birkle *et al.,* 2020).

The search was structured using Boolean logical connectors to ensure broad coverage of the investigated topic. The following keywords were included: "decision making," "digital technolog*," and "higher education," searched within the title, abstract, and keyword fields. The use of the asterisk (*) allowed the inclusion of all word forms derived from the specified root (e.g., "technology" and "technologies"), thereby contributing to the inclusion of as many relevant articles as possible. Only scientific articles (both open access and restricted access) were included, as these are the only documents subjected to peer review, thus guaranteeing scientific accuracy. The final sample, obtained from the search conducted in May 2025, consisted of a total of 905 articles.

The methodology developed throughout this article aims to investigate the structure and dynamics of scientific communities involved in the topic area. To this end, we analyzed collaboration relationships among authors, institutions, and countries, as well as the organization, analysis, and presentation of scientific materials based on central themes recurrent in the domain's publications. Using this approach, we identified, grouped, and analyzed the main ideas and concepts found in the specialized literature (Abad-Segura *et al.*, 2020).

In the first stage of the research, Web of Science statistics were used to conduct an analysis of productivity by examining the historical evolution of publications, the most relevant journals in which articles were published, the institutions producing the highest number of articles, and the most productive authors. Additionally, the analysis allowed for the extraction of productivity and impact statistics, and the data were processed to analyze the evolution of research in the field.

In the second stage of the research, keyword analysis was performed using VOSviewer software, developed by Van Eck and Waltman. This analysis provides insight into the main research themes and trends by studying the most frequent keywords. Visual maps of keyword networks and their co-occurrences were created, aiding in the identification of central themes and the visualization of relationships between different research areas. The generated maps offered a clear representation of keyword clusters and their evolution over time.

## 3. RESULTS AND DISCUSSION

### 3.1. Scientific Production and Thematic Areas

Figure 1 illustrates the evolution of the 905 articles identified on the topic of decision-making in the context of digital transformation (DT) in higher education (HE) during the period 2010–2025. The data highlight an exponential increase in publications, particularly in recent years. Notably, 693 articles – representing 75.32% of the total – were published in the last five years (2021–2025), reflecting heightened academic interest and increasing relevance of this topic. In comparison, only nine articles were published in 2010, the first year analyzed, while in 2024, the last complete year studied, the volume reached 201 articles. Between 2010 and 2018, interest in the topic of digitalization in higher education and management was still limited. After 2020, coinciding with the COVID-19 pandemic, there was an exponential rise in the number of publications. The urgent need for universities to adapt to online methods (Hasanov, Hashimov, 2025). stimulated research in the field of digital transformation and institutional change management. The period 2023–2024 witnessed a publication peak, demonstrating that digitalization is not a temporary phenomenon but one with lasting structural effects on the higher education system.

This growth trajectory mirrors global trends identified in recent literature describing the digital transformation of higher education institutions (HEIs) as a strategic imperative driven not only by emergent technologies but also by shifting educational paradigms and management approaches. The pandemic acted as a catalyst accelerating digital adoption, compelling HEIs to rapidly redesign academic delivery and administrative operations. Beyond crisis response, current research emphasizes the ongoing integration of advanced technologies such as artificial intelligence (Kalniņa *et al.*, 2024), learning analytics, big data, and blockchain to enhance personalized learning (Onyebuchi *et al*, 2024), institutional efficiency, and governance transparency (Aguado-García *et al.*, 2025). Moreover, scholars note increasing attention to comprehensive maturity models that guide universities in assessing and optimizing their digital capabilities, ensuring sustainable and innovation-driven transformation processes. These findings suggest that research in this domain is evolving from descriptive analyses to strategic frameworks aimed at long-term institutional resilience and competitiveness in a global knowledge economy.

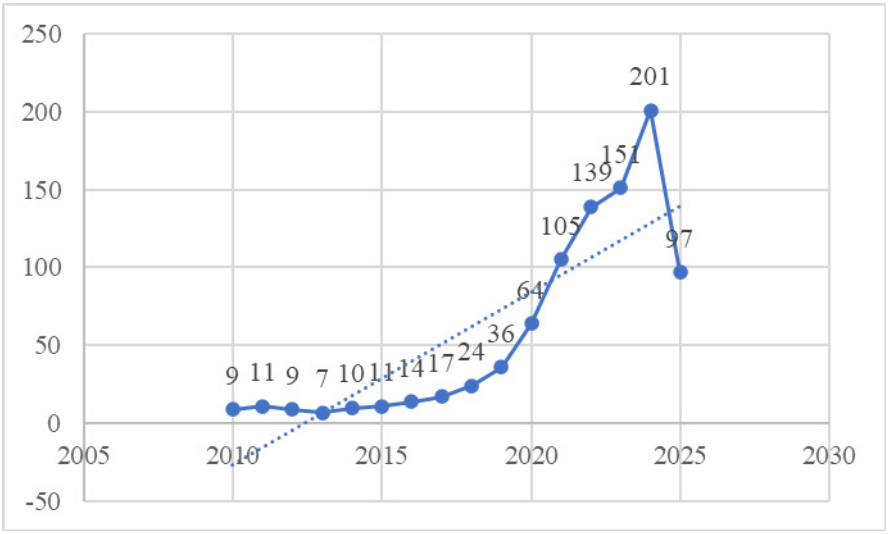


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**Figure 1. Evolution of the number of articles on decision-making in the context of digital technology use in higher education (2010–2025)**

The vast majority of these articles are written in English (95.8%), as is customary in searches within the Web of Science database. Additionally, articles have been published in other languages such as Spanish (1.99%), Russian (0.88%), and Portuguese (0.55%). Over the analyzed period, 2010–2025, the trend line indicates that the number of articles on the studied topic is increasing at an accelerating rate.

Throughout the analyzed timeframe, 2010–2025, works related to decision-making in the context of digital technology use in higher education were identified across various fields of knowledge. According to the Web of Science database, most of the 905 articles analyzed are classified into 25 thematic areas. It is important to note that the same article can be categorized into multiple fields depending on the interests of the author and the publisher.

Figure 2 shows how the thematic classification of articles on this research topic evolved. The Education Sciences category stands out consistently throughout the studied period, accounting for 20% of the articles published on digital transformation (DT) in higher education (HE). This is followed by the Engineering Sciences category with 8.5%. Computer Science (7.95%), Environmental Science (6.63%), Management (5.08%), and Sustainability (4.86%) are the next significant categories in order of importance. Together, these six main categories represent 53.02% of the articles published in this research field between 2010 and 2025.

This disciplinary distribution underscores a multidisciplinary approach to understanding digital transformation in higher education, highlighting the converging interests of pedagogical innovation, technological development, managerial strategy, and sustainable practices. The prominence of Education Sciences reflects the prioritization of instructional design, learner engagement, and educational policy reforms catalyzed by digital tools Parkin *et al.* (2011). Meanwhile, the strong presence of Engineering and Computer Science emphasizes the technical foundations and infrastructure necessary to support these educational innovations. Environmental Science and Sustainability's inclusion signal an emerging recognition of the ecological dimensions of digital technology deployment, encouraging sustainable digital practices within academia. Moreover, the Management category points to strategic decision-making processes driving organizational change, reinforcing the role of leadership in effective digital transformation. This thematic interplay signifies the complexity and integrative nature of research addressing digitalization in higher education, demanding collaborative approaches to bridge technical, pedagogical, and organizational domains.

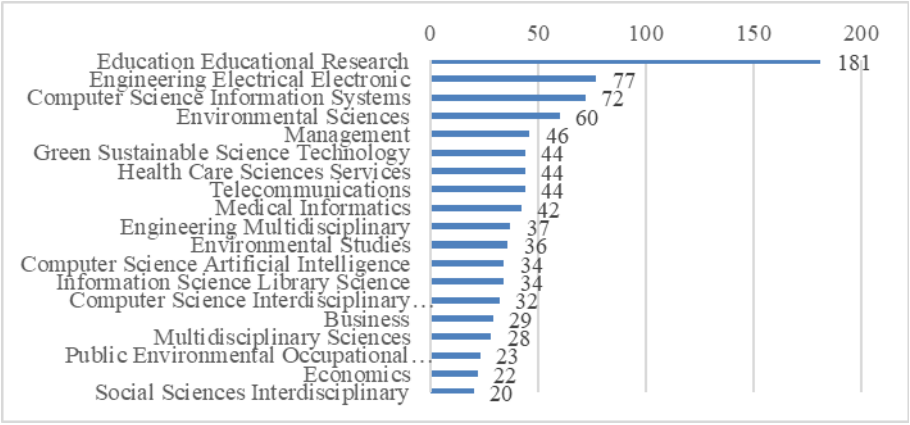


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**Figure 2. Main thematic areas regarding decision-making in the context of digital technology use in higher education (2010–2025)**

The distribution of articles by Web of Science categories highlights the interdisciplinary perspective of research dedicated to managerial decision-making and digital transformation in universities. The "Education Educational Research" category holds a significant proportion (20%) of the total 905 articles analyzed. This value underscores that digital transformation in higher education is primarily addressed from the perspective of educational practices, the efficiency of the teaching-learning process, and new technology-assisted

pedagogical models. Categories such as Engineering Electrical Electronic (8.5%), Computer Science Information Systems (8%), Computer Science Artificial Intelligence (3.75%), and Computer Science Interdisciplinary Applications (3.5%) suggest that studies on university digitalization frequently include technical dimensions, such as digital infrastructure, intelligent educational platforms, and the integration of artificial intelligence in academic administration. The fields of Management (5.1%), Operations Research Management Science (1.8%), and Economics (2.4%) demonstrate a consistent concern for decision-making efficiency, digital strategies, and the economic impact of transformations in universities.

### 3.2. Publications by Authors, Institutions, and Countries

Regarding authors, the analysis results indicate an uneven distribution of productivity. The most productive authors were Hwang GJ, who distinguished himself by publishing 10 articles, while Li X and Yu H contributed 7 and 5 papers, respectively. The remaining authors included in the analysis (Abad-Segura E, Gonzalez-Zamar MD, Niyato D, Wang J, Zhang C, Zhang J, Bazzi CL, Chen Y, De Souza EG, Ferraz GAES, Gintciak AM) each published between 3 and 4 articles, reflecting a more limited involvement in the specialized literature on this topic. This distribution highlights the existence of a small core of prolific authors who contribute significantly to the specialized literature. This phenomenon is also known as Lotka's law (Lotka, A. J., 1926), one of the fundamental laws of bibliometrics. It describes the unequal distribution of author productivity in a scientific field, emphasizing the presence of a group of prolific authors who contribute disproportionately to the specialized literature.

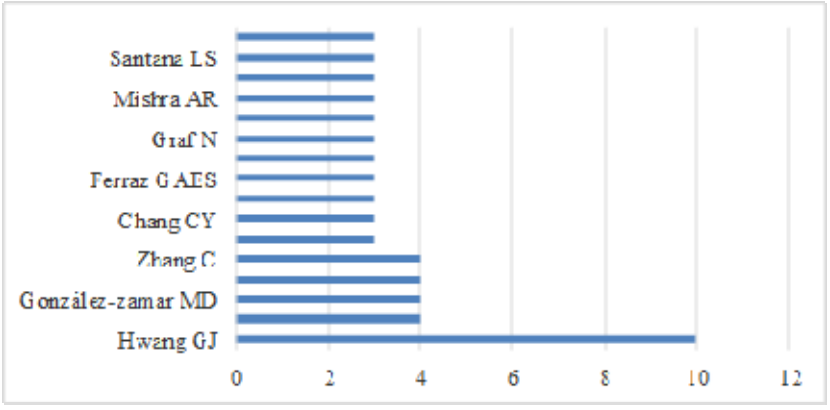


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**Figure 3. Authors with the highest number of articles on decision-making in the context of digital technology use in higher education (2010–2025)**

Figure 4 provides a clear overview of the academic institutions with the highest number of publications in the field of digital transformation in higher education, based on the affiliations of the most productive authors. National Taiwan University of Science and Technology leads the ranking with 10 articles, confirming a strong commitment to digital educational research, particularly through its Graduate Institute of Digital Learning and Education. Nanyang Technological University (Singapore), represented by the College of Engineering, follows with 7 articles, suggesting an interdisciplinary interest spanning engineering and digital education. Zhejiang University School of Medicine, with 5 articles, indicates involvement from medical universities in adopting digital technologies for management and education. Many of the institutions listed (Columbia Medical Center, Imperial College London Faculty of Medicine, University of Florida Health) belong to the medical field, suggesting that medical universities are among the most active in digitalizing administrative and teaching processes.

From a geographical distribution perspective, institutions in Asia (Taiwan, Singapore, China) are prominently represented at the top, reflecting an advanced regional strategy for the digitalization of education. Australia is represented by the University of Melbourne and Deakin University, both focused on health-related fields. Europe appears through Imperial College London and the University of Oslo, both prestigious, confirming the European commitment to transforming the educational system through digitalization.

Furthermore, this institutional landscape reveals a pattern where technologically advanced and research-intensive universities serve as pioneers in shaping digital education practices. The prominence of Asian institutions signifies substantial investment in educational technology and research infrastructure, aligned with broader governmental digital transformation policies. Meanwhile, the presence of established Western universities highlights a continued leadership role in integrating innovation with academic governance and pedagogical improvements. The collaboration and competition among these institutions drive knowledge exchange and the development of best practices, fostering a fertile environment for the diffusion of digital transformation strategies worldwide. This institutional diversity also points to evolving research priorities, encompassing not only technological innovation but also organizational change management, digital equity, and lifelong learning frameworks, which are crucial for sustaining progressive digital education ecosystems.

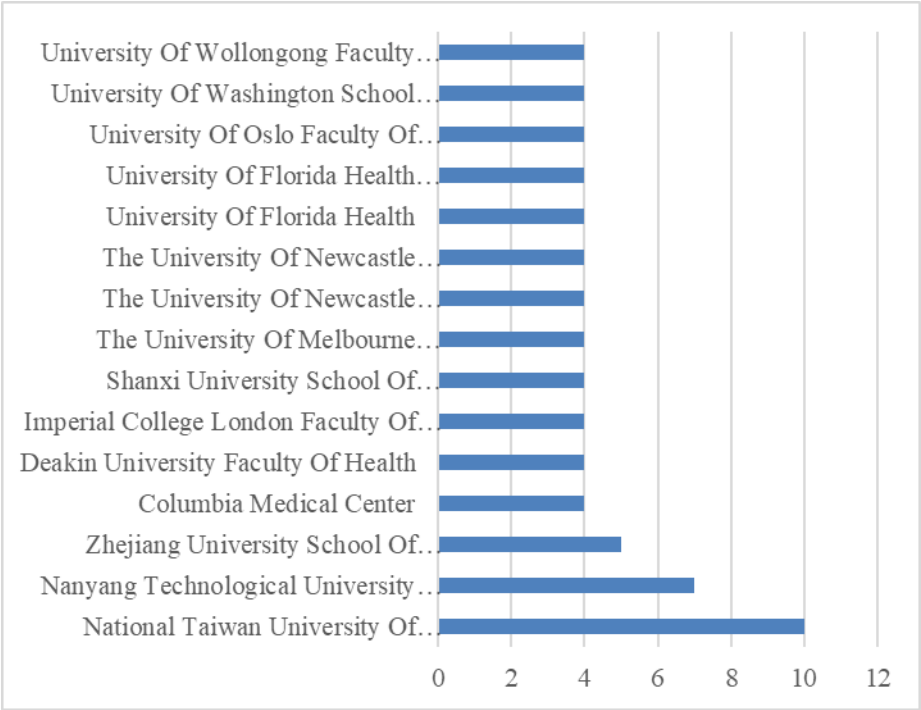


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**Figure 4. Affiliations of the most productive authors (2010–2025)**

All 905 articles included in the analysis were authored in a total of 127 countries. China leads scientific production in the field by a significant margin, contributing 213 articles (23.5%), followed by the United States with 137 articles (15.1%), the United Kingdom with 72 articles (7.9%), Russia with 60 articles (6.6%), and Spain with 60 articles (6.6%). European countries such as Germany, Spain, and Italy also show consistent contributions. In Asia, besides China, countries like India, Taiwan, Japan, and South Korea stand out as academic centers investing heavily in educational digitalization.

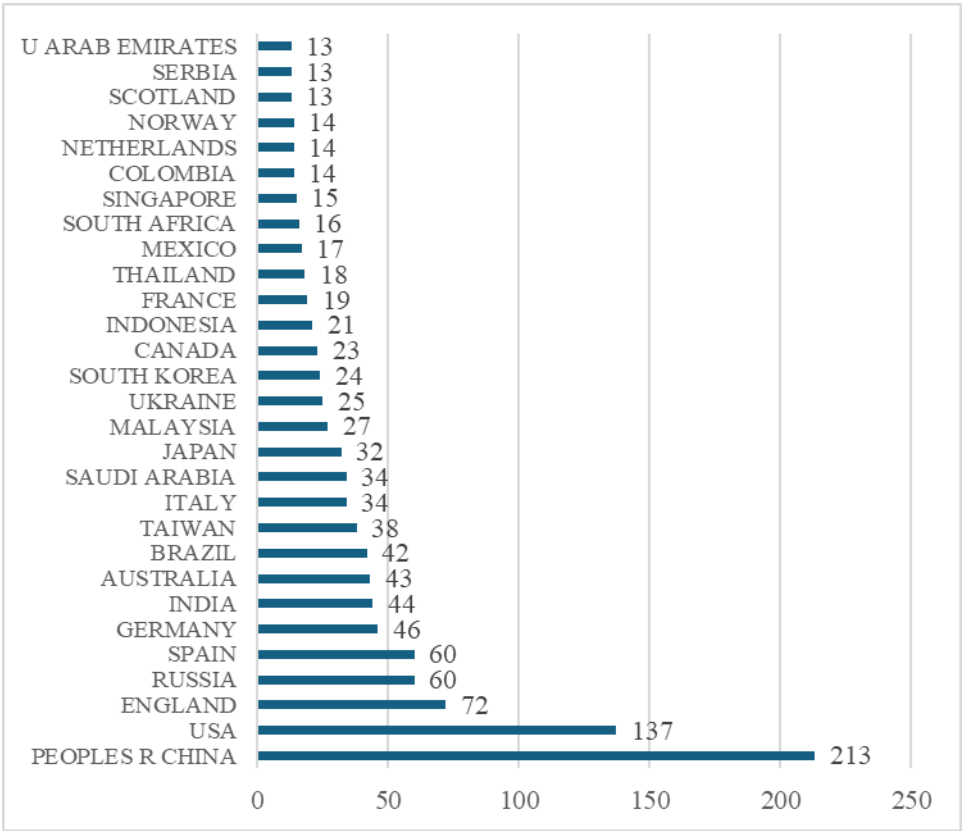


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**Figure 5. Distribution of articles by country (2010–2025)**

Figure 5 reflects a global concentration of research in a few academic power centers, particularly in East Asia (China, Taiwan, Japan), Western Europe (United Kingdom, Germany, Spain, Italy), and North America (United States, Canada). This concentration indicates both the research capacity and the strategic interest in the digitalization of higher education as a tool for managerial reform and academic competitiveness.

Figure 6 presents the collaboration network among the main countries based on co-authorship of their authors over the past 15 years. Distinct colours represent different clusters formed by groups of countries, while the size of each circle varies according to the number of articles contributed by each country. Thus, the larger the circle of a country, the higher the number of articles it represents through authorship. The contributions of countries in this research field regarding decision-making in the context of digital technology use in higher education have been grouped into three clusters.

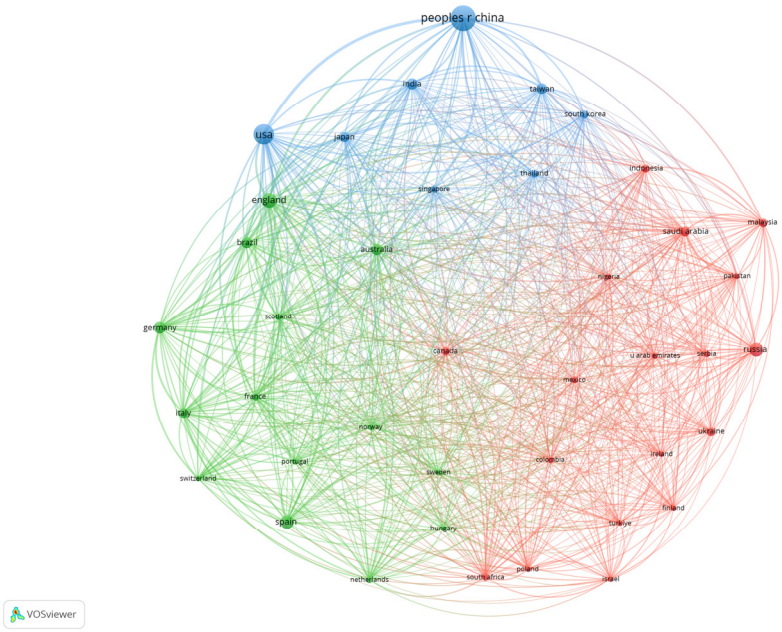


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**Figure 6. Collaboration network between countries based on co-authorship**

Thus, the blue cluster, although including the smallest number of countries (8 countries), comprises the largest number of articles, led by China with strong connections to Asia and the United States. The green cluster is led by the United Kingdom and primarily collaborates with France, Germany, and Italy. The red cluster is led by Russia and collaborates in article production in the research field with emerging countries (Serbia, Saudi Arabia, Malaysia) and also maintains internal links with Asia.

Based on these clusters, it is observed that digitalization in higher education is a theme of international cooperation, and managerial decisions are addressed within transnational research networks. China not only produces many articles but is also highly internationally connected, especially with the United States, India, Japan, and ASEAN countries. Europe (England, Germany, Italy) functions as a cooperation hub within the European Research Area.

### 3.3. Keyword Analysis

Figure 7 presents the keyword network regarding decision-making in the context of digital technology use in higher education, based on co-occurrence. Keyword analysis, through which scientific documents are classified, represents one of the main contributions of bibliometric analysis (Patel, R., 2019, He *et. al*, 2019). The primary keywords used in articles within this research domain are:

"digital transformation," "artificial intelligence," "higher education," "decision making," "education," "machine learning," "digital technologies," and "big data." Additionally, major groups of keywords were identified through the co-occurrence analysis of articles published on this topic. Each cluster consists of numerous interdependent and correlated terms.

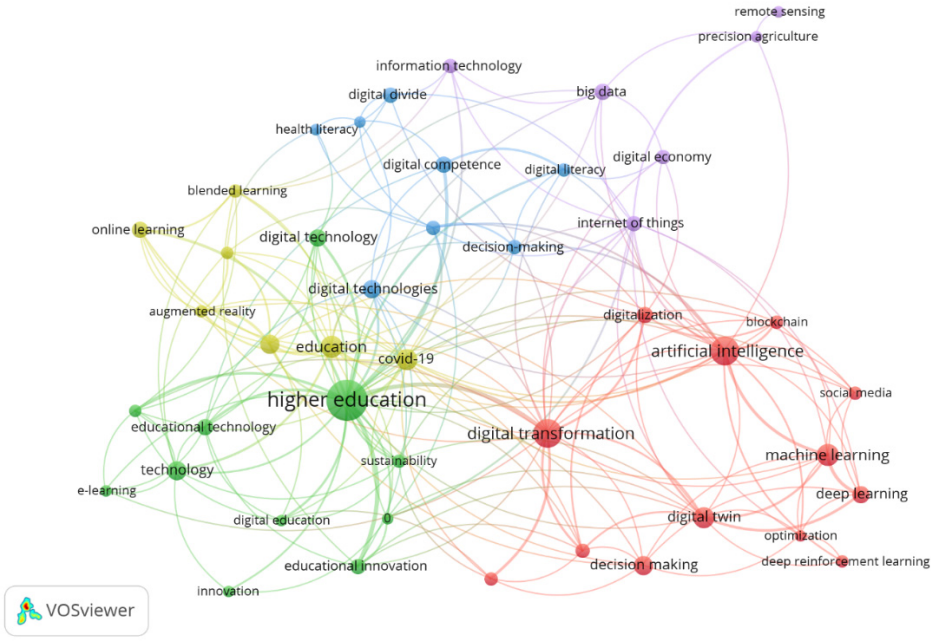


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**Figure 7. Keyword network based on co-occurrence**

Figure 7 presents a keyword co-occurrence network generated with VOSviewer, based on a minimum threshold of 7 occurrences for each keyword (out of a total of 3,602 terms, 45 met this criterion). This visualization highlights the main themes and relationships among key concepts in the literature on digital transformation and higher education.

From a general interpretative perspective, the nodes represent keywords, with their size reflecting the frequency of occurrence in the analyzed corpus. The lines between nodes indicate co-occurrences of terms within the same articles, highlighting thematic connections, while colors represent thematic clusters – groups of terms that frequently appear together and define subfields of the research.

Within this map, five clusters marked with different colors are identified, whose analysis is detailed below.

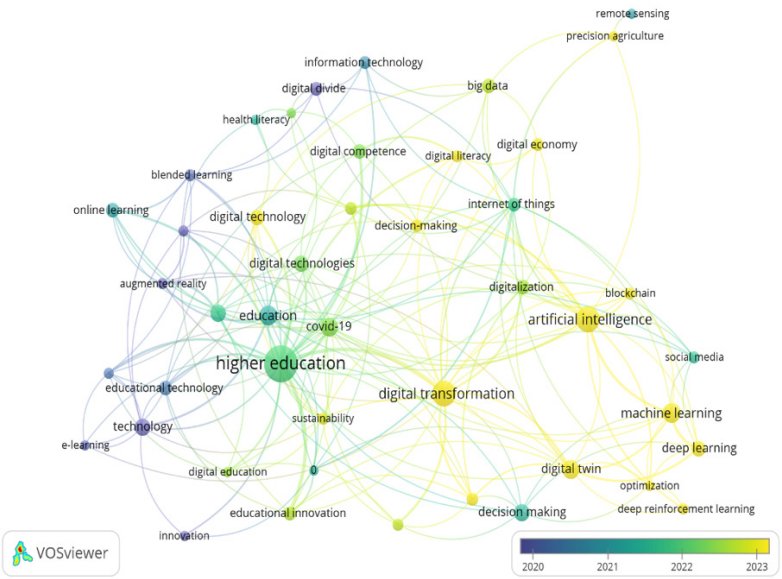
1. ***Green Cluster*** *– Higher Education and Digital Education. The largest node is "higher education," located at the network's center, indicating the primary theme of the corpus. Associated terms include "education," "digital technology," "digital technologies," "educational technology," "digital education," "innovation," "sustainability," and "COVID-19." This cluster reflects concerns about the impact of digital technologies on teaching, learning, and university management processes, emphasizing innovation and sustainability. Concepts such as "educational technology," "digital education," and "e-learning" highlight the integration of digital platforms and innovative tools in the academic environment. Terms like "blended learning," "online learning," and "augmented reality" underscore diversified teaching methods, highlighting flexible learning and the use of immersive technologies. "COVID-19" emerges as a catalyst accelerating digitalization in university education.*
2. ***Red Cluster*** *– Digital Transformation and Artificial Intelligence. This cluster concerns advanced technologies and digital transformation in higher education, focusing on innovation, automation, and artificial intelligence. It includes terms such as "digital transformation," "artificial intelligence," "machine learning," "deep learning," "blockchain," "digitalization," "digital twin," "optimization," "social media," and "decision making." "Digital transformation" and "digitalization" are central nodes, reflecting the processes by which universities adopt and integrate digital technologies on a large scale. "Artificial intelligence," "machine learning," and "deep learning" highlight the focus on technologies revolutionizing not only administrative processes but also teaching, assessment, and personalized learning. Literature emphasizes the opportunities (personalization, efficiency, innovation) and challenges (adoption, infrastructure, training, ethics) associated with these technologies. Universities must develop coherent strategies for integrating AI, ML, and other digital tools (Kasneci et al., 2023) to maximize benefits for students and meet future labor market demands.*
3. ***Yellow Cluster*** *– Online Learning, Blended Learning, and Augmented Reality. This cluster highlights research focusing on digital methods and technologies transforming higher education, emphasizing online learning, blended learning, and the use of technologies like augmented reality. Online and distance learning have become essential for ensuring educational continuity, especially following the COVID-19 pandemic,*

*which accelerated their adoption (Treve, M., 2021). These methods facilitate flexible access to resources, personalized pacing, and expanded educational opportunities for diverse student populations. Furthermore, educational innovation driven by these digital technologies contributes to reducing access inequalities and enhancing equity by providing flexible and accessible learning solutions (Sova, Rusov, Cotos, 2018). Innovation is viewed as a deliberate process aiming to improve learning outcomes and participant satisfaction.*

4. ***Blue Cluster*** *– Digital Competencies and Decision-Making in the Context of Digital Transformation of Education. The blue cluster in the keyword co-occurrence map reflects themes related to digital competencies, digital literacy, and decision-making within the context of digital transformation in education. These concepts are essential for understanding how individuals and institutions adapt to and leverage new technologies in the educational environment. The main terms comprising this cluster are: "digital competence," "digital literacy," "decision-making," "health literacy," and "digital divide." Digital competencies and literacy are fundamental for active and effective participation in contemporary digital society. Research (Pangrazio, Godhe, Ledesma, 2020) emphasizes the need to develop these competencies among both students and teaching staff to ensure equitable access to digital educational resources and facilitate the learning process.*
5. ***Purple Cluster*** *– Advanced Digital Technologies and the Digital Economy: Impact on Education and Related Sectors. The purple cluster in the keyword co-occurrence map represents themes related to advanced technologies and the digital economy, highlighting the broad impact of digitalization on education and other connected sectors. Key terms in this cluster include "information technology," "big data," "internet of things (IoT)," "digital economy," "precision agriculture," and "remote sensing." Terms like "information technology," "big data," and "internet of things" indicate a strong focus on integrating sophisticated digital technologies across various domains, including education. These technologies enable the collection, analysis, and use of large volumes of data to optimize educational processes, personalize learning, and support evidence-based decision-making. The terms "precision agriculture" and "remote sensing" reflect the extension of digitalization into specialized fields such as smart agriculture, where digital technologies enable efficient monitoring and management of natural resources (Nicolescu, O., Popa, I., Dumitrașcu, D., 2020). Such applications can be integrated into educational programs to develop*

*technical and interdisciplinary competences, preparing students for future challenges. Thus, the purple cluster serves as a bridge between the educational/technological area (green cluster) and the digital transformation/AI area (red cluster). It highlights the link between digital competency development, information technology use, and their impact on society and the economy. It also underscores the importance of equitable access to technology and digital literacy to fully exploit the potential of digital transformation.*

This bibliometric analysis suggests that digital transformation is not a unidimensional process, but rather an orchestrated convergence of multiple dimensions: the technological dimension, represented by the red and purple clusters; the educational dimension, represented by the green and yellow clusters; and the social dimension, represented by the blue cluster.




Source: own processing

**Figure 8. Evolution of the keyword co-occurrence network**

Detailed temporal analysis of the co-occurrence network during 2020–2023 reveals a clear and structured evolution of scientific interest in digitalizing education over the past four years. This evolution can be segmented into four distinct stages, each marking a significant transition in the approach to and integration of digital technologies in the educational process.

*The first stage,* the crisis response phase (2020), was triggered by the COVID-19 pandemic. Educational institutions faced the urgent need to ensure

continuity of learning by rapidly transitioning to online teaching (Dhawan, 2020). This period highlighted systemic vulnerabilities such as lack of equipment, connectivity, and basic digital competencies of some teachers (Sibug *et. al*, 2024) and students, but it also fostered national and European cooperation to manage the situation. The terms "e-learning" and "online learning" emphasize the shift to virtual environments, while "blended learning" suggests the initial integration of digital elements into traditional education.

*The second stage*, consolidation and adaptation (2021), focused on strengthening digital infrastructure and developing digital skills. At the European level, initiatives like the Digital Education Action Plan 2021–2027 were launched, highlighting the importance of a high-performance digital ecosystem (Szanter *et al.,* 2024) and digital skill development. This phase laid the foundation for legislative frameworks, curriculum updates, and continuous teacher training, emphasizing digital literacy and online safety. The terms "digital competence" and "digital literacy" underline the need for student and teacher training in technology use, while "health literacy" appears in the context of online health concerns.

*The third stage,* strategic development and innovation (2022), marked the maturation of education digitalization. Terms such as "digital transformation" and "innovation" denote strategic change and the integration of emerging technologies in education. "Big data," "blockchain," and "IoT" indicate the expansion of digitalization into other fields, such as the economy and industry (Bravo-Jaico *et al.*, 2025) During this stage, pilot projects for integrating artificial intelligence and learning analytics were launched, and institutions developed their own digitalization strategies (Perwej *et al.*, 2024). Efforts intensified to develop digital educational resources and to certify digital competencies nationally and internationally.

*The fourth stage,* specialization and expansion (2023 and beyond), reflects a focus on advanced technologies such as artificial intelligence, blockchain, digital twin, big data, and sectoral applications. The emphasis is on personalized learning, automation of administrative and teaching processes (Akinwalere, Ivanov, 2022), and the extension of digitalization beyond education into sectors such as the economy, agriculture, and health. In this latest stage, the terms reflect specialization and application of digitalization in specific domains. "Digital twin," "precision agriculture," and "remote sensing" highlight the use of digital technologies in agriculture, monitoring, and other sectors. "Emerging technologies" and "data analytics" suggest ongoing innovation and advanced data analysis. "Specialization" and "sectoral applications" indicate the expansion of digitalization into new fields and adaptation to the specific needs of the economy and society.

## 4. CONCLUSIONS

This study examined the main global research trends concerning decision-making within the context of digital technology use in higher education over the period 2010–2025, employing a bibliometric analysis of 905 articles from the Web of Science database. Dominant thematic areas, as well as the most productive authors, institutions, and countries in the field, were identified.

A significant annual increase in publications was observed, particularly in the last five years, accounting for over 75% of the total contributions. The most prominent thematic categories included Education Sciences, Engineering Sciences, Computer Science, Environmental Science, and Sustainability. This reflects a multidimensional approach whereby digitalization is understood not merely as a technology but as an institutional strategy for supporting educational sustainability and excellence.

Keywords such as "digital transformation" and "artificial intelligence" highlight universities as adaptive ecosystems integrating advanced technologies into decision-making processes. The geographical diversity of authors underscores a pronounced globalization of interest in innovation in higher education, though substantial disparities remain between developed and emerging countries in implementation capabilities.

The most prolific institutions include National Taiwan University of Science and Technology, Nanyang Technological University (Singapore), Zhejiang University School of Medicine, and Columbia Medical Center, while countries such as China, the United States, the United Kingdom, Russia, Spain, and Germany dominate scientific output. International collaboration appears to be driven more by institutional alliances and scientific globalization dynamics than by cultural or political factors.

Keyword analysis revealed five major clusters structuring the thematic research, featuring frequently co-occurring terms such as "digital transformation," "artificial intelligence," "higher education," "decision making," "education," "machine learning," "digital technologies," and "big data." Their temporal evolution indicates progress toward integrating digital technologies to enhance the quality of educational and decision-making processes at the university level.

The co-occurrence network highlights that successful digital transformation depends on a balanced integration of technological innovation, adaptive education, and digital inclusion, which together form the foundation of a sustainable digital society. Consequently, digitalized education emerges as a cornerstone for guiding society through the complexities of the contemporary world.

Temporal analysis of the keyword network reveals a clear progression from reactive responses to the COVID-19 crisis toward strategic, interdisciplinary, and innovative approaches in digital education. This rapid transformation

reflects the maturation of educational systems adopting emerging technologies to accelerate innovation and social inclusion.

The main limitations of this study stem from the bibliometric methodology itself, which, as a quantitative method, could be complemented by qualitative or mixed-method approaches in future research. Extending the analysis timeline could also provide a broader perspective on evolving trends in the field.

It is also important to emphasize that the increasing interest of authors, institutions, and countries, as demonstrated by the significant rise in publications in recent years, reflects strong support from the international scientific community for the study of various thematic directions related to digital transformation (DT) in the higher education (HE) sector.

Future research lines in this field should consider, among other aspects, the development of integrated institutional digitalization strategies that combine technological infrastructure with continuous training of management personnel to enhance digital decision-making processes. Promoting multidisciplinary and international research is essential, given the global nature of digital transformation. Encouraging international collaborations (e.g., with universities from Asia or Western Europe) can bring direct benefits in know-how and institutional innovation. Furthermore, clarifying the future of higher education within the context of Industry 4.0 remains a critical priority.

Finally, it is noteworthy that university digitalization has become a mature research domain, experiencing exponential growth in publications over the last five years. University management is increasingly analyzed through the lens of digital transformation, with a focus on emerging technologies and adaptive decision-making models (Akmad, 2025). Research in this field is predominantly international but is dominated by contributions from Asia and North America, particularly China and the United States. Keywords and prolific authors identified in this study can guide future research directions, especially concerning artificial intelligence, educational data analytics, and digital university governance.

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