Innovation and Adaptation in Higher Education in Colombia: Post-Pandemic Methodological Transformations

Innovación y adaptación en la educación superior en Colombia: Transformaciones metodológicas postpandemia

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ABSTRACT: The COVID-19 pandemic caused significant changes in Colombia's higher education system, promoting the use of digital technology and active learning methodologies. The objectives of this research were to analyse these methodological and technological changes, identify challenges and opportunities, and explore innovative approaches applied in different disciplines. To this end, a descriptive and exploratory qualitative approach was used, based on a systematic review of 55 academic articles from the Scopus scientific database and Colombian university theses. The information was analysed using the VOSviewer and Bibliometrix softwares, which allowed for the visualisation of collaboration networks, thematic clusters, and the evolution of trends. The studies showed an increase in the use of hybrid models and learning methodologies such as flipped classrooms and challenge-based learning, as well as technologies such as artificial intelligence, virtual reality and virtual laboratories, especially in engineering, health and education programmes. However, challenges remain in the areas of infrastructure, teacher training and digital equity. Therefore, it can be concluded that the consolidation of a global and resilient educational model requires sustainable investments, innovative policies, and strategies that support adaptable, student-centred pedagogy.

Keywords: Active learning, digitalisation, higher education, educational innovation, pandemic.

RESUMEN: La pandemia del COVID-19 provocó cambios significativos en el sistema de educación superior de Colombia, impulsando el uso de la tecnología digital y de las metodologías de aprendizaje activo. El objetivo de esta investigación fue analizar dichos cambios metodológicos y tecnológicos, identificar los desafíos y las oportunidades, y explorar los enfoques innovadores aplicados en distintas disciplinas. Para ello, se empleó un enfoque cualitativo de tipo descriptivo y exploratorio, basado en una revisión sistemática de 55 artículos académicos de la base de datos científica Scopus y tesis universitarias colombianas. El análisis de la información se llevó a cabo con los programas VOSviewer y Bibliometrix, que permitieron visualizar de las redes de colaboración, los clústeres temáticos y la evolución de las tendencias. Los estudios mostraron un aumento en el uso de modelos híbridos y de metodologías de aprendizaje como las aulas invertidas y el aprendizaje basado en retos, así como de tecnologías como la inteligencia artificial, la realidad virtual y los laboratorios virtuales, especialmente en programas de ingeniería, salud y educación. No obstante, siguen existiendo desafíos en las áreas de infraestructura, formación pedagógica y equidad digital. Por lo tanto, se puede concluir que la consolidación de un modelo educativo global y resiliente requiere inversiones sostenibles, políticas innovadoras y estrategias que apoyen una pedagogía adaptable y centrada en el estudiante.

Palabras clave: Aprendizaje activo, digitalización, educación superior, innovación educativa, pandemia.

1. INTRODUCTION

The global pandemic caused by COVID-19 resulted in an unprecedented transformation in education systems, driving forward digitisation projects that had previously been planned for the long term. Higher education institutions (HEIs) had to reconfigure their conventional teaching methods to adapt to virtual and hybrid environments, leading to a structural transformation in the way knowledge is imparted, acquired and administered [1], [2].

Transition highlighted inequalities in access to technological and institutional infrastructure, causing difficulties for teachers and students, especially in countries with wider digital gaps [3]. However, this process has also made possible the incorporation of active methodologies and innovative technologies that promote autonomous and collaborative learning, such as challenge-based learning, gamification, virtual reality, artificial intelligence, and virtual laboratories, whose effectiveness has been demonstrated in recent experiences in higher education [4].

This article sought to identify methodological and technological changes implemented in Colombian university education during the post-pandemic period. Special emphasis was placed on identifying trends, proposing innovative solutions, and analysing cutting-edge approaches that contribute to the country's educational transformation.

The analysis of the articles reviewed shows that hybrid models are becoming increasingly important, as they combine face-to-face and virtual resources. This converges with research highlighting their role in educational digitisation [5]. The use of digital platforms and tools such as Arena, Flexsim, Anylogic, Power BI, Python, Simio, SQL, R Studio, Solidworks, SketchUp, Odoo, Minitab, Bizagi Modeler, Microsoft Project, MATLAB, Simulink, Virtual Plant, AutoCAD, Labster, Smart Sparrow, and ChatGPT was also identified. These technologies facilitate simulation and artificial intelligence-supported learning [6], [7]. Finally, the importance of student-centred methods, such as the flipped classroom, adaptive learning and international collaboration, which improve global and sustainable skills in higher education, was identified [8].

The lessons learned during this transition process offer the possibility of creating a more resilient and equitable educational paradigm that is adapted to the demands of the digital and knowledge society. The aim of this research is to contribute to the development of inclusive and sustainable educational strategies that prioritise innovation in teaching and respond to the emerging challenges of the Colombian higher education system.

2. MATERIALS AND METHODS

This study was conducted using a qualitative approach, with the aim of understanding the methodological and technological changes that have taken place in Colombian higher education during and after the COVID-19 pandemic. This approach seeks to interpret complex phenomena and, to this end, examines institutional and academic experience, prioritising a contextualised analysis of the strategies implemented by higher education institutions (HEIs).

The study is descriptive, as it allows the characterisation of active methodologies, digital resources, and technologies used in diverse educational programmes. At the same time, it has an exploratory nature, as it investigates new trends and approaches that have emerged or been strengthened in response to the health crisis in a constantly changing context.

The selection of the documentary corpus was carried out through a systematic search in the Scopus scientific database, using a Boolean equation designed to identify literature on higher education, innovative methodologies, and technologies applied to the teaching-learning process: (TITLE-ABS-KEY("higher education") OR TITLE-ABS-KEY("university education") AND TITLE-ABS-KEY("teaching methodologies") OR TITLE-ABS-KEY("innovative education") OR TITLE-ABS-KEY("active learning") OR TITLE-ABS-KEY("project-based learning") OR TITLE-ABS-KEY("problem-based learning") OR TITLE-ABS-KEY("flipped classroom") OR TITLE-ABS-KEY("challenge-based learning") OR TITLE-ABS-KEY("experiential learning") AND TITLE-ABS-KEY("educational technologies") OR TITLE-ABS-KEY("digital tools") OR TITLE-ABS-KEY("simulation software") OR TITLE-ABS-KEY("virtual laboratories") OR TITLE-ABS-KEY("MATLAB") OR TITLE-ABS-KEY("AutoCAD") OR TITLE-ABS-KEY("ANSYS") OR TITLE-ABS-KEY("Labster") OR TITLE-ABS-KEY("virtual reality") OR TITLE-ABS-KEY("augmented reality") OR TITLE-ABS-KEY("AI in education") OR TITLE-ABS-KEY("learning analytics") OR TITLE-ABS-KEY("blockchain in education")) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO(DOCTYPE, "ar")) AND (LIMIT-TO(SUBJAREA, "ENGI")).

The search was limited to document type (academic articles), subject area (engineering and education), language (English and Spanish), and publication period (2015–2025). As a result of the analysis, 55 documents were selected that met the criteria for inclusion and academic rigour.

The information was processed using the bibliometric analysis tools VOSviewer and Bibliometrix, which facilitated the study of the structure and relationships of knowledge present in the collected documents. The analysis was carried out on two main levels. First, a co-authorship study was conducted to identify collaboration networks between authors, academic institutions, and countries, as well as to determine the density and dispersion of scientific production on the topic in question. Second, a term co-occurrence analysis was performed, resulting in the creation of visualisations that organised the basic concepts into thematic groups. This made it possible to identify emerging topics, predominant pedagogical methodologies, and recurring educational technologies.

The analyses were performed using files exported from Scopus in a format compatible with VOSviewer (RIS), after cleaning and normalising the metadata. The data was then processed to create visualisations of networks between authors, keywords and publications. The methodology not only quantified scientific output, but also made it possible to examine the links between concepts and actors, and to identify existing connections between active methodologies and technologies in higher education. This process made possible the organisation of a study based on the proposed objectives in order to understand new methodological and technological strategies in higher education in Colombia.

3.   RESULTS

With the aim of delving deeper into the prevailing trends in educational innovation and technologies applied to higher education in the post-pandemic period, the results of the qualitative analysis carried out with the VOSviewer and Bibliometrix software programmes are presented. These tools allowed the identification of relevant authors, keyword co-occurrence maps, thematic patterns, research trends over time, scientific production by country, and collaboration networks, which has facilitated the interpretation of research dynamics and the detection of emerging approaches in this field.

The analysis in Figure 1 allows us to identify the academic collaboration networks among the authors who have researched this topic the most. Sixteen nodes were detected that are interrelated by a large volume of academic output, with [4], [8]-[9] standing out as they account for a significant proportion of the most relevant publications on the latest methodologies, active learning and the use of technologies in higher education. The

analysis therefore reveals the existence of strong, collaborative academic communities that are leading current scientific discussions in the field of education and educational innovation.
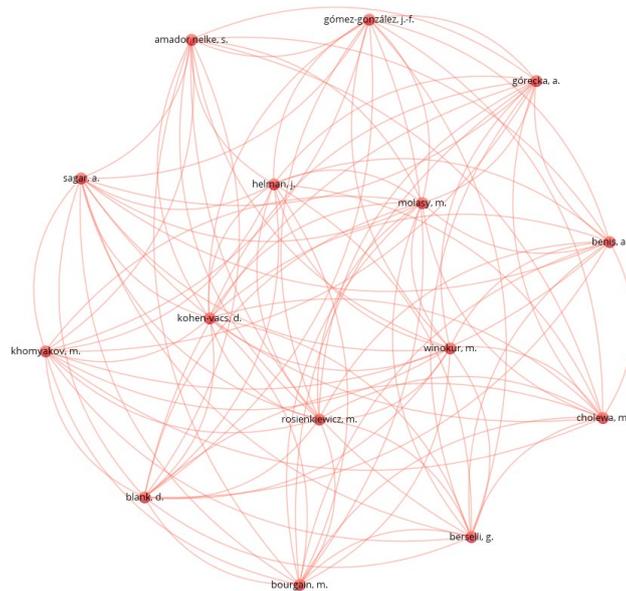
Figure 1. Visualisation of co-authorship in research on educational methodologies and technologies in higher education (VOSviewer).
Source: own elaboration.

In their publications, the most relevant authors indicated that educational transformation is based on the integration of active methodologies and emerging technologies. In [4] emphasis was placed on blended learning supported by learning management systems (LMS), massive open online courses (MOOCs) and learning analytics; [8] presented the COIL model, understood as an international online collaboration scheme that connects classrooms in different countries and is complemented by challenge-based learning and the use of Zoom, Padlet, Kahoot and digital badges [10] addressed adaptive learning with Industry 4.0 and 5.0 tools, such as virtual reality, augmented reality, artificial intelligence, and blockchain; and [9] emphasised the implementation of hybrid classrooms with interactive whiteboards, videoconferencing, and teacher training. Overall, these experiences show that the convergence of innovative pedagogical models and advanced technologies promotes more inclusive, personalised and global learning.

The co-occurrence analysis of key terms, represented in Figures 2 and 3 using the VOSviewer software, allowed us to visualise the most frequent concepts and their relationships within the corpus of the 55 articles analysed. The process generated a network of 22 clusters based on the highlighted topics, which contain terms that share a high frequency of co-occurrence. Thus, each cluster reveals the structure of knowledge about educational innovation and its role in the transformation of university teaching.

The terms with the highest frequency and centrality were: higher education, engineering education, active learning, project-based learning, virtual reality, AI in education, flipped classroom, educational technologies, and digital tools. These terms had the strongest links to other concepts, demonstrating their importance in recent literature. It should be noted that the densest cluster was that corresponding to higher education, which was related to methodologies such as active learning, blended learning, flipped classroom, and challenge-based learning. This group shows an interest in rethinking the usual teaching models in universities and integrating student-centred strategies that encourage collaboration and the practical application of what has been learned. These practices have been shown to improve student engagement and motivation in hybrid settings, provided they are supported by robust digital platforms [9], [11].

Figure 2. Visualisation of the co-occurrence of key terms in publications on higher education and innovative methodologies. Source: own elaboration using the VOSviewer software.

It is important to mention the engineering education cluster, which groups together terms related to MATLAB, AutoCAD, simulation software and virtual laboratories. This grouping highlights the importance of digitisation in the implementation of engineering programmes and in the use of techniques and laboratories. This has been a response to the limitations of face-to-face activities and the need to adopt virtual schemes. In this regard, it has been proven that simulators allow complex processes to be recreated and critical skills to be developed without the need for costly physical infrastructure [12]. In addition, digital

Figure 3. Map of co-occurrence networks centred on main thematic nodes: higher education, engineering education and active learning. Source: own elaboration.

resources in engineering have been valued as strategies that enhance creativity, critical thinking, and autonomous learning [13].

The cluster formed by virtual reality, augmented reality, and Labster is a growing trend in the implementation of immersion-based technologies in the teaching of medical disciplines, applied sciences, and engineering. Although these are more recent terms, they show strong links to other concepts, such as experiential learning, which reinforces their role in supporting active methodologies that seek to replicate practical experience in virtual environments. In fact, the literature confirms that VR and AR have promoted more meaningful learning by improving the understanding of abstract content and increasing student motivation [7], [14]. The incorporation of 5G technology has expanded these possibilities by reducing latency and enabling more realistic immersive experiences [15].

Topics related to AI in education and learning analytics, which are linked to personalised learning and adaptive learning, are of interest. These links demonstrate the shift towards more automated and personalised teaching approaches. Recent research confirms that the integration of 4.0 technologies in higher education, such as artificial intelligence and virtual laboratories, has favoured the adaptation of learning to professional skills [16]. Similarly, gamification-based flipped classroom models have been shown to increase motivation and facilitate adaptive processes [17]. Furthermore, the use of learning analytics makes it possible to anticipate difficulties and offer immediate feedback, consolidating its role as one of the most promising lines of research in university education [11], [18].

Finally, terms grouped around project-based learning and problem-based learning were associated with words such as collaborative learning, engineering education, digital assessment, and skill development. These words allow the conceptualisation of a competency-based pedagogical approach, aligned with the changing needs of the labour market and comprehensive professional training. Recent evidence confirms that the integration of interdisciplinary projects and digital assessment strengthens professional preparation and enhances the creativity and innovation of engineering students [12], [19].

The analysis with Overlay Visualisation in Figure 4 allowed us to observe how key concepts in academic literature on higher education and new methodologies have changed over time. On the map, the colours indicate the average year of appearance of each term, showing a gradual transition towards emerging technologies from 2021 onwards. The concepts of augmented reality, blockchain in education, adaptive learning, and AI in education are highlighted in yellow, indicating their recent inclusion in scientific publications. This transition shows that advanced digital tools enhance learning by enabling greater personalisation and feedback through data mining and micro-skills [20], the use of active methodologies such as challenge-based learning that integrate 4.0 technologies into engineering environments [16], and the incorporation of simulators and immersive environments that reproduce complex processes and improve practical understanding in safe spaces [21]. In addition, experiences such as peer tutoring and the use of digital platforms show that these innovations help to retain knowledge and apply what has been learned in universities [22]. This supports a digital and hybrid educational model that combines face-to-face and automated teaching.
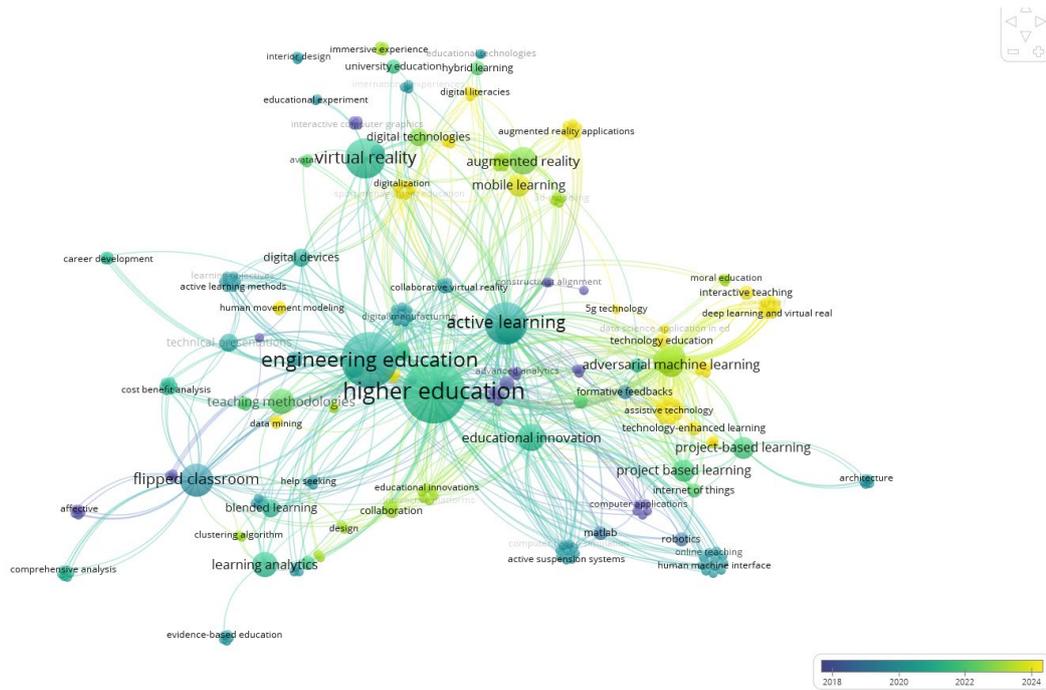
Figure 4. Overlay Visualisation of keywords in research on higher education and innovative methodologies.
Source: own elaboration.

The analysis of scientific output by country (Figure 5 and Table 1) shows that Spain leads the list with 24 publications on innovative methodologies and technologies applied to higher education, followed by China and Mexico (11 each), the United States (9), India (7) and Israel (6). Portugal (4) also stands out, along with Australia, Colombia and Indonesia, with three contributions each. Even though the participation of Colombia is still in its infancy, there is growing interest in strengthening digital and methodological transformation in higher education in the post-pandemic context.
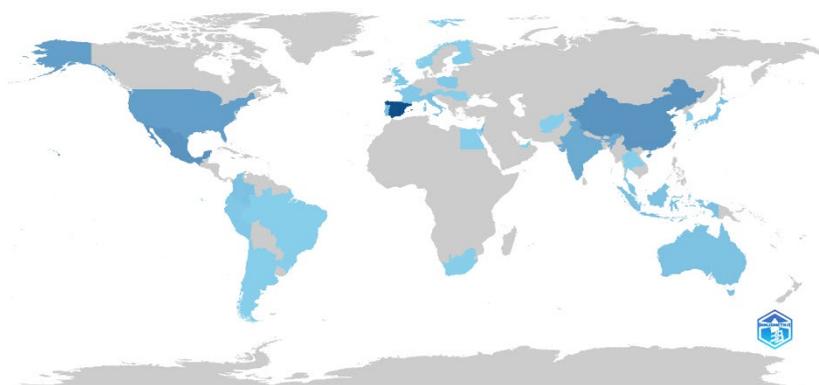

Figure 5. Scientific production by country in research on higher education and innovative methodologies. Source: own elaboration.

Table 1. Frequency of publications by country in the area of higher education and innovative methodologies (2015–2025). Source: own elaboration based on data exported from the Scopus database and analysed using Bibliometrix software (2025).

Country	Frequency
Spain	24
China	11
Mexico	11
USA	9
India	7
Israel	6
Portugal	4
Australia	3
Colombia	3
Indonesia	3

According to the Country Collaboration Map (Figure 6 and Table 2), produced using the Bibliometrix software, an international scientific cooperation network linking authors and institutions from different regions can be observed. China stands out as a coordinating hub, establishing joint publications with India and other Asian countries such as Malaysia, Singapore and Hong Kong, demonstrating regional leadership in academic production. In Europe, France appears as a relevant node, consolidating ties with Finland and Poland, while in Latin America, Argentina is identified as a country with connection capacity, particularly in its relationship with Finland. Although the number of collaborations is still small, the way in which these links are being established shows the emergence of strategic alliances that support knowledge networks focused on educational innovation, the use of new technologies and the application of active methods in higher education.

Country Collaboration Map
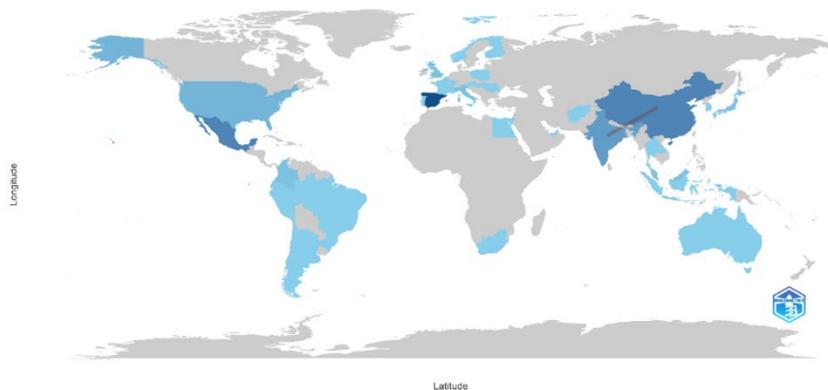
Figure 6. Map of international scientific collaboration between countries in research on higher education and methodological innovation. Source: own elaboration.

Figure 7 shows a co-occurrence map in which students and teaching appear as the largest and most central nodes. This indicates that the literature on higher education continues to focus on the student as the centre of the teaching process and on the teaching methodologies that mediate the learning experience. The links connecting these nodes with learning systems, higher education, and educational technology show that recent research integrates pedagogical analysis with the use of digital platforms and learning management systems [23], [24]. This finding coincides with studies indicating that methodologies such as project-based learning and flipped classrooms are positioned as predominant approaches in engineering and applied sciences, due to their ability to combine autonomous work with technology-mediated collaborative environments [25].

Table 2. Frequency of scientific collaboration between countries according to co-authorship in documents indexed in Scopus. Source: own elaboration with data exported from the Scopus database (2024) and processed using Bibliometrix in RStudio.

From	to	Frequency
Argentina	Finland	1
China	Hong Kong	1
China	India	2
China	Malaysia	1
China	Singapore	1
France	Argentina	1
France	Finland	1
France	Poland	1
Hong Kong	Malaysia	1
Hong Kong	Singapore	1

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On the periphery of the map, terms associated with emerging technologies such as virtual reality, augmented reality, blockchain, and the Internet of Things can be observed. Their lower centrality does not imply irrelevance, but rather that these are consolidating fields that expand the possibilities for teaching and practice in university environments [24], [26]. For example, virtual reality and digital laboratories can replace face-to-face practices and improve the visualisation of complex phenomena in engineering [27], while digital twins and the Internet of Things (IoT) allow the creation of simulated scenarios for designing prototypes, managing infrastructure and experimenting at a reduced cost [26]. The cluster structure in the figure, where concepts are grouped by affinity, reflects that post-pandemic academic discourse is oriented towards three main areas: active student-centred methodologies, integration of immersive technologies, and incorporation of artificial intelligence and data analytics to personalise learning [28].

The Thematic Map (Figure 8), generated with the Bibliometrix software, classifies key terms in the literature according to two levels: centrality, which measures the connection with other topics, and density, which indicates the degree of development. The upper right quadrant shows the driving, consolidated and strategic topics, including active learning, educational technology, project-based learning and the internet of things. The aforementioned reflects technology-supported active learning, in which project-based learning is applied to engineering to solve problems through prototypes and simulations [23], while the internet of things is linked to smart city projects and the integration of sensors in areas such as civil, mechanical and environmental engineering [26]. The lower right quadrant contains basic topics, such as engineering education and teaching, which are cross-cutting but have less specific development [24]. The upper left quadrant groups together topics that have been studied but are less connected to each other, such as MATLAB, robotics, and human-machine systems, which are applied in technical training in programming, control, and simulation [28]. Finally, the lower left quadrant contains emerging or declining topics, such as mobile learning, virtual learning environments, and innovative education. These topics have proven useful for continuing education and

promoting independent learning through the use of mobile devices and collaborative virtual environments [25], [29].
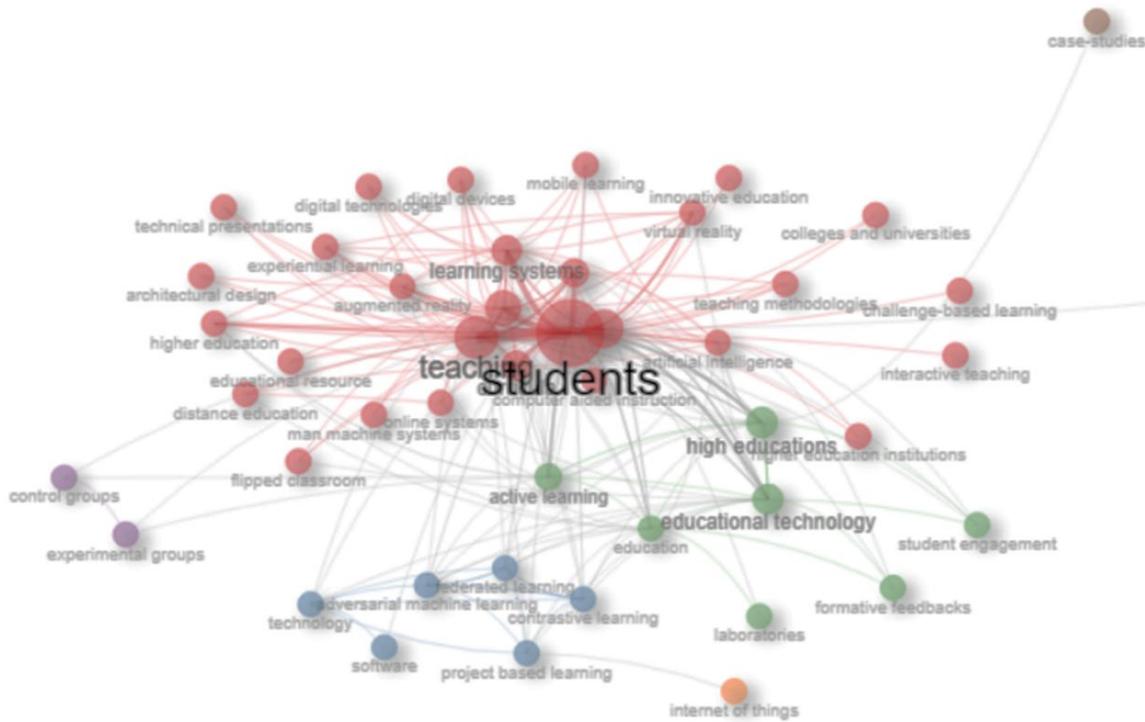
Figure 7. Map of keyword co-occurrence in scientific literature on post-pandemic higher education. Source: own elaboration.
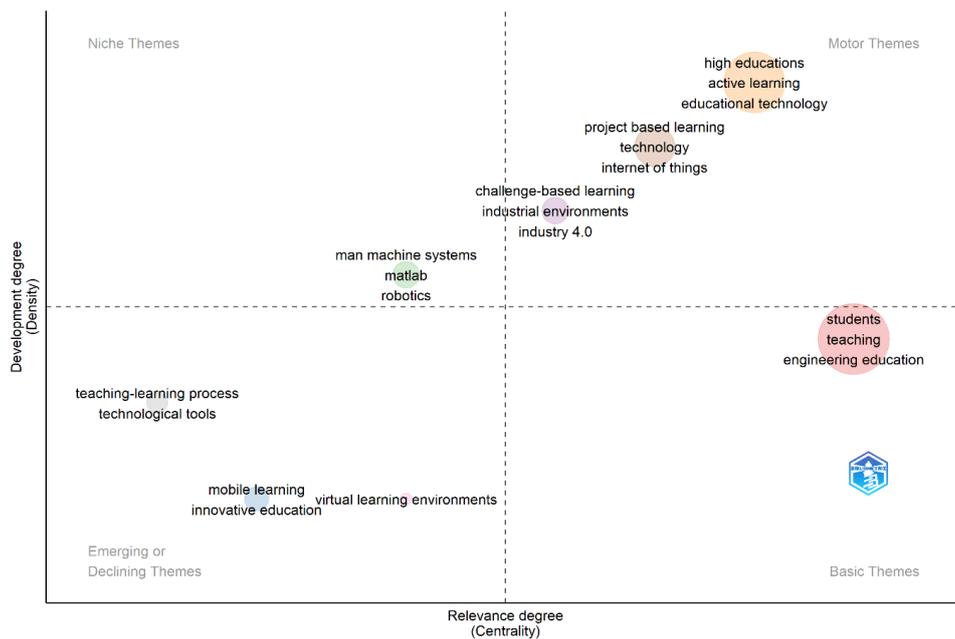
Figure 8. Thematic map of the literature on methodological and technological innovation in higher education according to centrality and density. Source: own elaboration.

Global trends in literature have an impact on Colombia, where digital innovation in higher education has stood out for combining active methodologies and new technologies, which has transformed the way of teaching. Platforms such as Moodle, Blackboard and Google Classroom have been widely used to support teaching and learning processes, encouraging the transition to hybrid and distance learning models. However, inequalities

in terms of internet accessibility, access and teacher training have also become apparent, especially in rural areas [4], [30].

Collaboration-focused methodologies, such as the Global Shared Learning Classroom (GSLC), based on the Collaborative Online International Learning (COIL) model, have enabled students from diverse cultures and disciplines to work together synchronously on global challenges, thereby fostering intercultural and sustainable skills. The use of platforms such as Zoom, Microsoft Teams, and Padlet has been fundamental to the strategy [8].

Among the most notable active methodologies are problem-based learning, the flipped classroom, and gamification. Tools such as Kahoot!, Classcraft, and Quizizz have been used to increase student motivation and encourage active participation, with positive results in knowledge retention, although their adoption remains limited due to a lack of teacher training [7], [31], [32].

The use of emerging technologies such as AI and dynamic adaptive learning has become increasingly important in the university setting. Portals and websites such as Smart Sparrow, ChatGPT and Watson Tutor make it possible to identify difficulties in real time and generate new learning paths tailored to the needs of each student. These solutions have also been applied to predictive performance analysis and the automation of teaching tasks [6], [10].

In the healthcare field, Body Interact clinical simulators and other virtual environments (Labster) have improved the training of medical and nursing students. These resources allow complex clinical scenarios to be replicated, facilitating decision-making and the application of medical protocols without putting real patients at risk [9], [10].

Engineering education has evolved with the integration of computer programmes such as MATLAB, AutoCAD, ANSYS, Solidworks, Inventor, Flexsim, Arena, Simio, Anylogic, Power BI, Python, R Studio, Minitab, SQL, and Tinkercad. These tools enable modelling, design, simulation, data analysis, automation, business management, and other cross-cutting applications in industrial engineering. These technologies are essential for maintaining technical practices without the need for physical laboratories [33], [34].

In the social sciences and humanities, the use of software such as NVivo and Atlas.ti has been strengthened, as well as platforms focused on collaboration such as Miro. These tools have made it possible to continue qualitative research, document analysis, and the construction of conceptual maps from virtual and rigorous environments [14], [35].

The Microsoft Teams, Google Meet, and Moodle platforms allow for collaborative work, especially in the disciplines of architecture and design. Students have developed group projects and virtual prototypes in real time, fostering digital creativity and interaction [10].

The bibliometric analysis carried out with the VOSviewer and Bibliometrix softwares based on 55 articles from Scopus revealed a series of thematic clusters focused on higher education, active learning, and engineering education. These themes function as structuring conceptual axes, connected to the methodologies of flipped classroom, challenge-based learning, virtual laboratories, and AI in education.

Overlay Visualisation showed the growing emergence, from 2021 onwards, of augmented reality, blockchain in education and adaptive learning technologies, highlighting the trend towards advanced digitalisation and personalisation of learning. These topics are consolidated as emerging in the thematic maps generated with Bibliometrix [7].

In the context of Education 4.0 and 5.0, virtual and augmented reality have been used to create immersive environments that simulate laboratories, clinics, and collaborative workspaces. Tools such as EduAssistant enable gamified experiences with 3D environments, which improve the understanding of abstract concepts [6], [7].

The development of educators' digital skills has been essential to implementing these technologies. However, research indicates that structural barriers, such as insufficient connectivity, lack of institutional investment, and absence of continuing education, hinder the incorporation of digital tools into university academic programmes [4], [36].

In summary, the use of educational technologies has increased, but policies need to be established in institutions to promote sustainability, equity, and relevance. This includes incorporating technologies such as blockchain into academic certification processes and data analytics to continuously improve learning [14].

4. DISCUSSION

Research has shown that the COVID-19 pandemic accelerated the digitisation of higher education in Colombia and structurally transformed teaching methodologies. The incorporation of digital platforms increased accessibility and flexibility, but also highlighted limitations such as the digital divide and the need to strengthen teacher training [37]. This pattern is similar to what has happened in other countries, where the transition to hybrid models was more successful in institutions with sufficient resources. In places with less infrastructure, the impact was limited [38], [39].

Bibliometric analysis identified the concepts of higher education, engineering education, active learning, and project-based learning. These results add to the evidence of increased use of new tools such as augmented reality, adaptive learning, and, to a lesser extent, blockchain in education. This confirms the trend towards more immersive and personalised experiences [16], [40].

The thematic maps created with Bibliometrix show that active methodologies, such as the flipped classroom and project-based learning, are combined with applied technologies to strengthen important topics such as virtual laboratories, educational artificial intelligence, and learning analytics. In engineering, there is a particular emphasis on the use of simulators and specialised software such as MATLAB and AutoCAD, which strengthen practical teaching in design, modelling and calculation subjects [16], [37]. These results coincide with those of other studies that highlight the effectiveness of computer simulation and virtual reality in improving motivation and knowledge retention [21].

In engineering education, programmes such as SolidWorks for 3D design, Revit and Civil 3D for construction and urban planning, Ansys and Comsol Multiphysics for the simulation of physical phenomena, and management tools such as Microsoft Project and Excel for data organisation and analysis have also become established. Currently, these programmes are complemented by platforms such as Coursera, which facilitate access to specialised courses in software engineering. They are also complemented by learning management systems such as Moodle and Blackboard, which facilitate course administration, traceability, and student assessment [16], [37], [39], [40].

The use of simulation technologies is also present in disciplines such as medicine, where platforms such as Body Interact have become essential resources for clinical training in controlled, low-risk environments. At the same time, the use of collaborative environments and interactive web platforms has increased in the social and economic sciences, demonstrating the importance of digitisation in education [22].

From the students' perspective, the results reveal an improvement in general skills and critical thinking; however, problems related to the decrease in face-to-face interaction and the increase in independent work persist [41]. This contrast shows that, although digital modernisation increases autonomy and adaptability, it needs to be complemented by strategies that encourage social interaction and motivation [22].

Co-authorship analysis in collaborative networks shows international interactions in countries such as Spain, China, Mexico, the United States, and India. On the other hand, Colombia is gradually improving, although its integration is still partial [16], [39]. This confirms the growing interest in consolidating educational research, although limitations persist in positioning itself in networks with greater impact.

The adoption of new technologies has been fundamental in engineering, medicine, and architecture, where practical learning is increasingly supported by digital environments and simulations. However, barriers remain related to the lack of specialised teacher training and the scarcity of institutional resources to implement these tools [28]. In this regard, recent experiences emphasise the need for sustainable policies aimed at continuous training in digital skills and the strengthening of infrastructure [22], [39].

The diversification of digital resources in virtual classrooms includes management platforms such as Moodle and Blackboard, collaborative tools such as Microsoft Teams and Google Classroom, and educational simulators such as Labster and Smart Sparrow. These environments have been important in ensuring academic continuity and enhancing the flexibility of hybrid models [40]. At the same time, bibliometric data show a direct correlation between the expansion of these technologies and the emergence of concepts such as interactive teaching, digital skills, and curriculum adaptation, confirming a shift towards competency-based models.

The findings also show an increase in interest in applying artificial intelligence to personalise learning, closely related to adaptive learning and student engagement approaches [22]. This approach is due both to Industry 4.0, which emphasises automation and connectivity, and to the ideas of Industry 5.0, which focus on more human and sustainable learning, centred on the interaction between people and machines [16], [37].

In summary, the literature review confirms that the pandemic not only generated temporary solutions, but also accelerated innovative processes that were already underway. The use of simulators, virtual laboratories, engineering software, and active teaching methods has brought about a lasting change in Colombian university education, adapting training to the challenges of the transition to Industry 4.0 and 5.0.

5. CONCLUSIONS

The results of this research highlight a remarkable transformation in higher education in Colombia, brought about by the pandemic, which encouraged the gradual adoption of digital technologies and active methodologies. Through a bibliometric analysis, entrenched trends were identified, such as the adoption of active learning, project-based learning, and flipped classroom education as essential pedagogical strategies in post-pandemic university environments. These methodologies have fostered a more participatory, student-centred pedagogy geared towards solving real-world problems.

In addition, the incorporation of emerging technologies such as virtual reality, augmented reality, artificial intelligence, learning analytics, and specialised simulation software such as MATLAB, Flexsim, Virtual Plant, Solidworks, Arena, AutoCAD, Body Interact, and Labster has been fundamental to modernising academic curricula, especially in disciplines such as engineering, health, and social sciences. These tools have improved the educational experience by promoting practical training and the development of technical skills in digital environments.

However, the implementation of these methodologies and tools faces structural limitations. This occurs especially in university institutions with limited technological infrastructure. The digital divide, also known as the digital gap, refers to inequalities in the digital context. Lack of connectivity and poor teacher training remain fundamental challenges that hinder the implementation of educational projects.

The research also highlights that emerging technologies such as artificial intelligence and adaptive learning offer new opportunities for educational personalisation and attention to diverse learning rhythms and styles. However, their incorporation is still in its early stages and requires greater investment in research, development and institutional implementation.

In summary, the pandemic not only prompted a reconsideration of conventional educational models, but also provided an opportunity to reconfigure university pedagogy based on pedagogical and technological innovation. To consolidate these advances, it is essential that higher education institutions strengthen their teacher training policies, invest in sustainable digital infrastructure, and promote inclusive strategies that guarantee equity in access to and use of digital technologies. The future of education in Colombia will depend on the university system's ability to adapt and lead transformation processes in an increasingly digitalised global context.

6. ABOUT THE ARTICLE

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Author contributions:

David Bermeo: study design, literature search, bibliometric analysis, development of the theoretical framework, interpretation of results, and manuscript writing.

Johanna Mildred Méndez Sayago: study design, literature search, bibliometric analysis, development of the theoretical framework, interpretation of results, and manuscript writing.

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