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Artificial intelligence-assisted innovation in higher education: an analysis of key trends and future directions

La innovación asistida por inteligencia artificial en la Educación Superior: un análisis de las principales tendencias y líneas futuras

MSc. Carlos Alberto Gómez Cano[1], PhD. Verenice Sánchez Castillo[2]
MSc. Elvia María Jiménez Zapata[3]

[1]***Corporación Unificada Nacional de Educación Superior – CUN.*** *Dirección Nacional de Investigaciones, Florencia, Colombia.*
[2]***Universidad de la Amazonia****, Facultad de Ingeniería, Florencia, Colombia.*
[3]***Universidad Surcolombiana,*** *Facultad de Economía y Administración, Neiva, Colombia.*

Correspondence: *carlos_gomezca@cun.edu.co*

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Abstract: The study analyzed the trends and challenges of AI-assisted educational innovation in global higher education through a bibliometric analysis of 666 Scopus documents (2020-2024). The results revealed exponential growth in scientific production, led by China (166 documents) and the US (61), with dominant thematic clusters in AI technologies, pedagogical innovation, and ethics. However, gaps in equity, interdisciplinarity, and longitudinal assessment were diagnosed. Furthermore, international collaborations showed asymmetries, while the explored sources pointed to a low integration of critical perspectives and vulnerable contexts. It is concluded that adopting intelligence in higher education requires solid ethical frameworks, inclusive approaches, and policies that prioritize innovation focused on social justice.

Keywords: Educational innovation, artificial intelligence, higher education, bibliometric analysis, educational equity.

Resumen: El estudio analizó las tendencias y desafíos de la innovación educativa asistida por inteligencia artificial en la educación superior global mediante un análisis bibliométrico de 666 documentos de Scopus (2020-2024). Los resultados revelaron un crecimiento exponencial de la producción científica, liderado por China (166 documentos) y EE.UU. (61), con clústeres temáticos dominantes en tecnologías de IA, innovación pedagógica y ética. Sin embargo, se diagnosticó la persistencia de vacíos en cuanto a equidad, a interdisciplinariedad y a evaluación longitudinal. Además, las colaboraciones internacionales mostraron asimetrías, mientras que las fuentes exploradas señalaron una baja integración de perspectivas críticas y contextos vulnerables. Se concluye que la adopción de la inteligencia en la educación superior requiere marcos éticos sólidos, enfoques inclusivos y políticas que prioricen una innovación abocada a la justicia social.

Palabras clave: innovación educativa, inteligencia artificial, educación superior, análisis bibliométrico, equidad educativa.

1. INTRODUCTION

Recent evidence indicates that higher education is undergoing an unprecedented transformation [1], [2]. This process is not only due to the disruptive impact of new educational models and the growing need for these institutions but also to preserve and transmit knowledge and promote responsible and sustainable development at different levels of society [3], [4]. This movement has also been fueled by the convergence of the rise of artificial intelligence, accelerated post-pandemic digitalization, and global demands for socio-educational innovation [5]-[7].

In this scenario, artificial intelligence is no longer a technical tool restricted to advanced fields within the applied sciences, especially computer science. In this regard, while pointing out barriers and limitations, recent studies affirm that artificial intelligence constitutes a catalyst for profound changes in how learning is designed, delivered, and assessed [8], [9]. Furthermore, its potential use transcends the substantive aspects of higher education, specifically in teaching and research, which points to its potential to revolutionize these institutions in their cultural and organizational dimensions.

As mentioned, the adoption process raises complex questions, especially in innovation processes where practical applications may have limited evidence of their benefits and threats. The elements highlighted in the literature are broad and conditioned by the process in which artificial intelligence is introduced as an innovation assistant. Thus, research indicates factors associated with ethical use [10], [11]; biases and risks of exclusion posed by algorithms [12], [13]; equity in access to emerging technologies; and the redefinition of teaching roles in virtual, hybrid, and in-person environments [14]-[17].

It is essential to highlight that while studies on artificial intelligence have a long history dating back to the first half of the 20th century, since the 2000s and more recently in 2022, the field has experienced a figuratively visible growth spiral. Additionally, its numerous applications and trends warrant a critical and multidimensional analysis.

On the one hand, technologies such as machine learning, natural language processing, and intelligent tutoring systems have consolidated their presence in educational proposals. These advances have gradually been incorporated into technological and pedagogical innovation agendas, revealing that artificial intelligence provides a dual dimension that contributes to preparing new generations of professionals and scientific advancement. Among the most notable models in which artificial intelligence has been integrated are blended and project-based learning. This trend reflects the search to adapt curricula to Industry 4.0 and 5.0 demands.

However, this accelerated increase in studies, initiatives, and theoretical and practical proposals has also highlighted the importance of understanding how human-AI interaction occurs. Concepts such as personalized learning and information literacy reflect an approach focused on addressing the personal and professional skills required to use these tools properly. In this regard, areas of interest include prompt engineering learning, ethical governance, legal regulation, socio-emotional and cognitive impact, and exacerbated dependency.

On the other hand, from a regional perspective, their implementation reveals global asymmetries regarding objectives, funding, and collaboration. While some nations prioritize post-pandemic curricular adaptations, the literature suggests that developing countries and territories must face infrastructure and access challenges that limit the equity and social impact of adoption processes and innovation [18]-[21].

Based on these ideas, a mixed-methods research project was designed to examine trends, gaps, and critical lines for developing AI-assisted innovation. To this end, a systematic bibliometric study was conducted, combined with a content analysis of relevant sources in the Scopus database, from 2020 to 2024.

This proposal aimed to map dominant trends, knowledge networks, and priority agendas in global research. This rationale, supported by the methodological contributions of studies with a similar focus, aims to produce data that contribute to the debate beyond technical efficiency indicators

and examine the ethical, social, and pedagogical challenges that could define the future of AI-assisted innovation in higher education.

2. METHODOLOGY

The design of the methodology began with selecting Scopus as the primary database and determining the mixed approach to follow. The first decision was made based on the multidisciplinary coverage offered by the database and its relevance to the social sciences, education, applied sciences, and technology. The second decision was based on achieving a proposal that combined the methodological rigor of quantitative studies with an interpretive bias that would provide depth to the analysis. Furthermore, this rationale was supported by the design of previous studies that integrated both approaches to achieve a comprehensive mapping of a field of knowledge [22]-[25].

The search strategy focused on identifying documents that included the keywords "artificial intelligence," "innovation," and "higher education" in their titles, abstracts, or keywords, restricting the period to 2020–2024 to capture recent trends (TITLE-ABS-KEY (artificial AND intelligence) AND TITLE-ABS-KEY (innovation) AND TITLE-ABS-KEY (higher AND education) AND PUBLICATION > 2019 AND PUBLICATION < 2025). A total of 666 records were obtained, which were then subjected to a refinement process to exclude non-scientific documents (editorials, errata). Additionally, thematic relevance was verified through a manual review of titles and abstracts, a procedure to ensure the source's alignment with the object of study.

The quantitative analysis was conducted using standard bibliometric techniques, beginning with calculating annual productivity indicators, analyzing collaboration between countries/regions, and investigating geographic distribution patterns. The analysis of conceptual relationships was conducted using VOSviewer, where keyword co-occurrences and the distribution of key terms within thematic clusters were studied in depth. These data, reinforced through source triangulation, made it possible to identify consolidated research cores and gaps in the literature.

A qualitative approach was integrated to interpret and strengthen the quantitative findings. Critical readings of highly cited articles were conducted, comparing data and main ideas and categorizing emerging themes. Finally, the results of this line of analysis were integrated into the bibliometric analysis, strengthening the results and their discussion. This combination of quantitative and qualitative methods made it possible to describe the structural patterns of the research and contextualize its evolution.

Throughout the research process, the authors sought to ensure methodological transparency. Measures taken included documenting the process steps and using reproducible scripts for data analysis.

3. RESULTS AND DISCUSSION

3.1. Analysis and interpretation of annual field productivity

Data on annual scientific production showed a clear upward trend. Starting with 52 documents on innovation and artificial intelligence in higher education, the field grew in size to reach 362 by 2024 (see Fig. 1). This 696% increase in five years indicated exponential growth marked by the dynamism of research projects, the growing adoption of artificial intelligence in higher education, and its establishment as a priority area on institutional agendas globally.

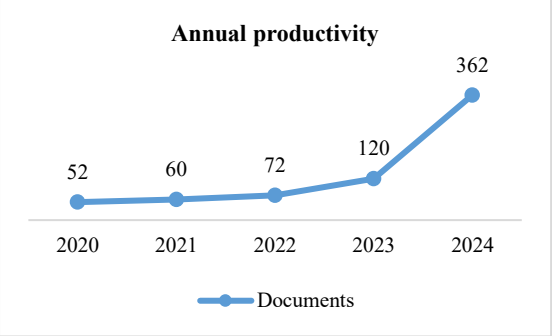

Fig. 1. *Annual field productivity by year.*
Source: *Prepared by the authors.*

Furthermore, it is worth highlighting that the most significant jump occurred between 2023 and 2024, where the increase of 242 documents represented 201%. Given this fact, constant triangulation in the literature indicated that it is necessary to question its causes since, in addition to factors such as coverage gaps or the inclusion of preprints, the data do not support the claim that this year was a turning point. This assessment makes greater sense when examining the impact of 2022 when seminal articles were published, and ChatGPT was launched [26].

On the other hand, the analysis of the impact of the COVID-19 pandemic, coupled with the aforementioned ChatGPT milestone, showed that this period was particularly productive [27], [28]. When analyzing the production figures, it was observed that since 2020, there has been a sustained acceleration with annual increases of 15% (2020-2021), 20% (2021-2022), and 67% (2022-2023). This trend confirms that this scenario acted as a catalyst for the development of the field, as it drove technological integration and digital transformation processes assisted by artificial intelligence [29]. This initial adoption was carried out to provide innovative responses to pedagogical, teaching, research, and organizational challenges [30], [31].

3.2. Analysis and interpretation of impact and citations

The analysis of citation patterns, relevance, and impact showed an even more pronounced increase than that observed in the annual production dynamics (see Fig. 2). Of the total documents collected, 391 received at least one citation. Between 2020 and 2024, the number of citations rose from 27 to 3,443, representing an increase of 12,644%. This ratio of documents to citations received confirms that the field has progressively gained relevance in academic and applied research.

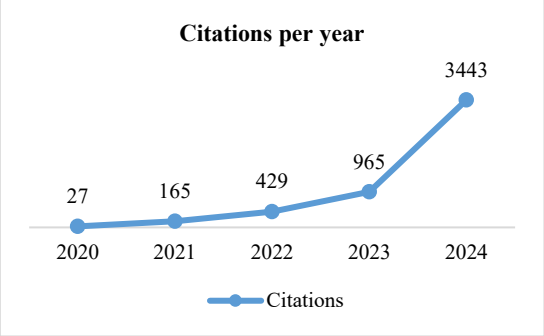

Fig. 2. *List of citations received by year.*
Source: *Prepared by the authors.*

In this regard, the h-index of 34 indicated that, despite being a relatively nascent field, a core of research has a significant impact. On the other hand, the citations per document metric (17) show a double trend, where some documents are consolidated as seminal studies while others are relegated to a marginal contribution.

According to the literature analysis, this characteristic may be conditioned by the divergence in the attention received by beautiful online articles. On the one hand, chatbots are used with a broad and relevant output [32], [33]. On the other hand, there are particularly technical or methodological contributions that target a small niche of researchers, such as [34], [35], and [36]. Furthermore, various studies confirm that the majority of production on artificial intelligence focuses on students [37]-[39]. This tendency could determine that articles on innovation related to this particular educational agent gain greater relevance.

In summary, the integrated analysis of productivity and relevance shows that the field is actively building on recent contributions. It should be noted that 66% of citations (4408) correspond to documents published between 2022 and 2024. The literature supports this finding, which establishes that the rise of AI-assisted innovation is influenced by the multiple demands that the post-pandemic places on research systems and the growing pressure on higher education institutions to ethically and responsibly adopt these tools [40]-[42].

3.3. Analysis of production by country and co-authorship networks

The analysis of the geographical distribution of documents revealed a diverse landscape marked by considerable asymmetries. In terms of leadership, China emerged as the leader in innovation during the period with 166 documents, followed by Mexico (n = 101) and the United States (n = 61) (see Fig. 3).

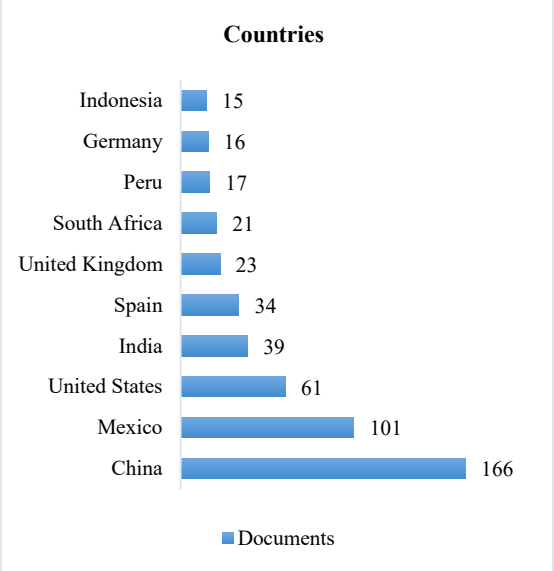

Fig. 3. *Leading countries in terms of production.*
Source: *Prepared by the authors.*

An auxiliary literature analysis confirmed that the aforementioned situation is primarily driven by the strategic investment made by institutions and the Chinese state in artificial intelligence, which is

considered a vital pillar for technological and educational development. Studies such as [43], [44], and [45] demonstrate that technological growth assisted by or oriented toward the creation of artificial intelligence systems is a phenomenon that transcends industries, social sectors, and geographic regions.

Mexico, for its part, stood out for its influence and collaboration networks, not only in the Latin American context. Additionally, it is crucial to note that, among the top ten institutions, the Tecnológico de Monterrey is by far the most productive and influential (see Fig. 4). Studies such as [46], [47], and [48] demonstrate the institution's commitment to digital transformation processes and technological development in the post-pandemic era.

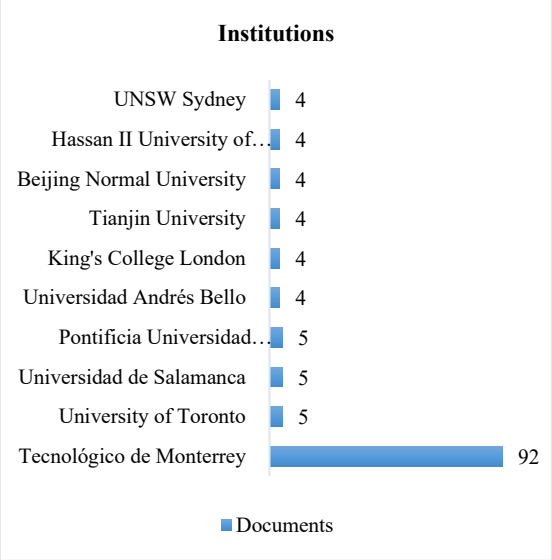

Fig. 4. *Leading institutions in terms of production.*
Source: Prepared by the authors.

Finally, although the United States had a lower relative output, it maintained a relevant role during the period. This statement should be interpreted in light of the academic infrastructure and funding allocated to interdisciplinary projects. The auxiliary search indicated that the main lines of work were critical analyses of ethics, equity, and AI governance in multiple contexts associated with higher education [49], [50], [51].

Regarding co-authorship networks, the pattern remained in the United States (46), Mexico (44), and China (24) as the countries with the most robust collaboration networks (see Fig. 5). This finding is fundamental because, although the United States was the third largest producer, its high connectivity indicates that it is a hub with global reach where national and international funding converges for the conduct of interdisciplinary research.

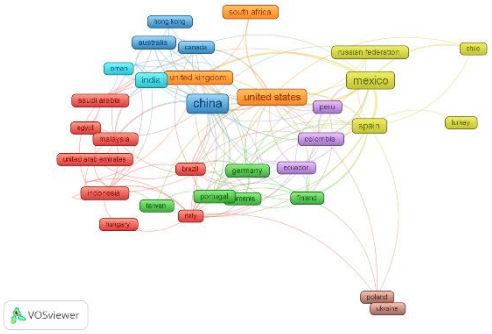

Fig. 5. *Global collaboration networks by co-authorship.*
Source: *Prepared by the authors.*

Regarding Mexico, the co-authorship network showed that, beyond its productivity, its relevance lies in a dense collaborative network. Regional alliances and the promotion of Ibero-American educational innovation projects drive this network. In the specific case of Colombia, the country positioned itself during the period as an important regional player, but also with key alliances with leading countries such as the United States, China, and Germany (see Fig. 6). The auxiliary search revealed that the indexed studies had not achieved the necessary focus on the applied phases of innovation. However, they did show a critical commitment to exploring the processes of integration, acceptance, and possible lines of specific development [52]-[54].

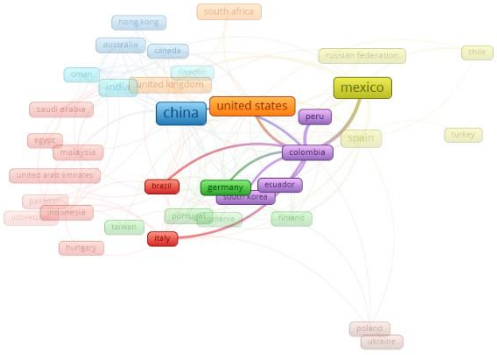

Fig. 6. Colombian collaboration networks.
Source: Prepared by the authors.

For its part, China, despite its high productivity, displayed relatively low connection strength. The analysis showed that this was influenced by the clear focus on internal collaborations and sociocultural barriers that hinder the transfer of results to other contexts.

At the regional level, it was found that Latin American countries form an emerging network whose results have not translated into impact measured by citations. This finding indicates that barriers to access to mainstream scientific journals clearly limit the visibility of Latin American production.

In Asia, the trend appears to be the opposite, with Singapore (6 documents, 56 citations) and South Korea (5 documents, 57 citations), both with low production, showing high impact. Finally, the centers of most significant impact and relevance in Europe are Spain and Germany, two countries that typically top the list of production in studies on digital transformation.

3.2. Main thematic clusters and relationships

The keyword co-occurrence analysis revealed a configuration organized into five dominant thematic clusters. The analysis of the main categories showed that the field had a clear, multidimensional structure integrating technical, pedagogical, ethical, and socioeconomic dimensions (see Fig. 7).

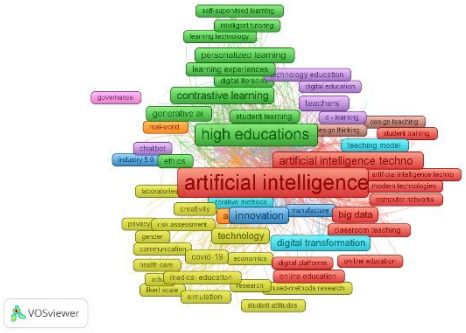

Fig. 7. Co-occurrence network.
Source: Prepared by the authors.

The first cluster, named by the authors "AI technologies and their technical applications," grouped terms focused on the technological foundations that support practical implementation in innovation. As expected, the most relevant terms by co-occurrence were artificial intelligence (345 occurrences), machine learning (34 occurrences), deep learning (21 occurrences), natural language processing (8 occurrences), generative adversarial networks (9 occurrences), and federated learning (32 occurrences).

Exploring the relationships showed a high co-occurrence with applied research through applied processes and tools such as personalized learning (19) and intelligent tutoring systems (4-5 occurrences after term refinement). In this regard, the review showed that the practical application of these resources has been used in multiple environments and is associated with the development of creativity, complex thinking, innovation, and evaluation [55], [56].

Regarding the emergence of lines, federated learning and generative AI (16 occurrences) stood out in this cluster. The complementary review showed that the first explores innovative resources associated with data analytics, developing predictive models focused on local needs and technological adaptation to improve communication between devices [57], [58]. In the second, the multiple applications of generative artificial intelligence offer a rich panorama of resources, adaptations, purposes, and debates about the conditions for its introduction, where innovation constitutes a key category and is not restricted to technical aspects [59], [60].

The second cluster was called Pedagogical Innovation in Higher Education. In this cluster, the identified themes align with the necessary educational transformations associated with innovation processes and the aforementioned paradigm shift taking place in higher education today, as mentioned in the introduction. As seen in the density map (see Fig. 8), many processes associated with technological integration and digital transformation assisted by artificial intelligence appear.

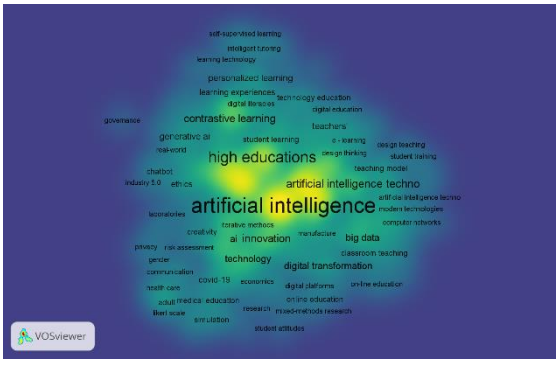

Fig. 8. *Density map.*
Source: *Prepared by the authors.*

Regarding co-occurrence, keywords such as educational innovation (102 occurrences), teaching methods (17 occurrences), active learning (18 occurrences), and blended learning (4 occurrences) stand out.

In this same vein, the analysis identified that innovation occurred in connection with important

structural transformations and agendas such as the Sustainable Development Goals (SDGs) [61]-[65].

The third cluster was called ethics, governance, and social challenges. This cluster featured focused terms that represent the effort to build conceptual bridges between the technical aspects of artificial intelligence and the ethical and social tensions arising from its adoption, whether conscious and organized or spontaneous. Regarding key terms, AI ethics (6 occurrences), ethical considerations (4 occurrences), privacy (6 occurrences), fairness (3 occurrences), and trust (6 occurrences) stand out, as well as digital transformation (23 occurrences), which constitutes a key category for understanding how these processes have been adopted at the institutional level.

A more in-depth analysis revealed that, although privacy and fairness were not particularly relevant, their association with machine learning highlights concerns about algorithmic biases and equity in access to educational technologies. Seminal research conducted by [66] established two levels of bias. The first includes the classic categories of bias according to the authors: race, ethnicity, gender, and nationality, while the second includes emerging factors such as special needs, socioeconomic status, and status associated with specific professions.

From an overall analysis perspective, this group showed less relative weight, but it should be emphasized that its relevance lies in questioning the ethical limits of automation. Furthermore, this cluster reinforces the need for regulatory frameworks that balance innovation and social responsibility, a fact recognized by the specialized literature [67]-[69].

The fourth cluster organized terms related to teacher training and digital competencies. At various points in the analysis, the importance of addressing teachers' adaptation and performance to using artificial intelligence, both their own and that of their students, was mentioned. In this cluster, the thematic lines were directed toward literacy and developing specific competencies.

The key terms identified were "teachers" (16 occurrences), "professional education" (13 occurrences), "digital literacy" (4 occurrences), "AI literacy" (8 occurrences), and "computational thinking" (6 occurrences). As can be seen, there is a clear trend toward teacher training, where the literature shows concern about the determining factors of acceptance and competency development [70]. However, it is also necessary to clarify that, rather than an instrumentalist approach, a framework that facilitates critical and informed interaction is required [71], [72].

The last cluster, called "impact on employability and the productive sector," groups together the lines related to the intersection between higher education systems and labor demands in the digital age. The following terms stood out in this cluster: employability (3 occurrences), industry 4.0 (18 occurrences), entrepreneurship education (9 occurrences), skills (5 occurrences), and STEM education (3 occurrences).

A key finding was the prioritization of modeling and developing competencies for the digital age, particularly in science and technology careers, observed in the co-occurrence of industry 4.0 and STEM education with engineering education (104 occurrences). Finally, the relationship between entrepreneurship education and innovation ecosystems indicated two applied fields where artificial intelligence could be one of the main lines of research for the future.

4. CONCLUSIONS

The first conclusion is that AI-assisted innovation experienced significant exponential growth during this period. While this increase in production and relevance is still small compared to established areas of knowledge, it does highlight the importance and impact of these studies, which should be considered by decision-makers and policymakers in higher education.

Secondly, it is concluded that it is necessary to critically address the barriers limiting artificial intelligence adoption in developing countries. This assertion is supported by the marked asymmetries observed in the geographical distribution of academic production. In the future, integration processes should be accompanied by interdisciplinary studies that examine the sociopolitical, socioeconomic, and sociopsychological determinants that influence the use of artificial intelligence in innovation processes in these nations.

Finally, it is concluded that ethics, although one of the most frequently repeated concepts in the discourse on artificial intelligence, must be integrated into technological and pedagogical frameworks. This assertion becomes more relevant

when considering that the constant emergence of disruptive technologies and systems has occurred disconnected from the development of solid socio-educational theories.

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