

SMART UNIVERSITIES: GLOBAL TRENDS IN ARTIFICIAL INTELLIGENCE AND EDUCATION 4.0

UNIVERSIDADES INTELIGENTES: TENDÊNCIAS GLOBAIS EM INTELIGÊNCIA ARTIFICIAL E EDUCAÇÃO 4.0

Article received on: 10/9/2025

Article accepted on: 1/9/2026

Wilson Alexander Zambrano Vélez*

*Universidad Estatal Península de Santa Elena, Santa Elena, Ecuador

Orcid: <https://orcid.org/0000-0003-1061-878X>
wzambrano@upse.edu.ec

Elan Ignacio Delgado-Cobeña**

**Universidad Técnica de Manabí, Portoviejo, Manabí, Ecuador

Orcid: <https://orcid.org/0000-0003-4843-8602>
elan.delgado@gmail.com

Cinthy Lisbeth Molina-Santana**

**Universidad Técnica de Manabí, Portoviejo, Manabí, Ecuador

Orcid: <https://orcid.org/0000-0002-7641-490X>
cinthya.molina@utm.edu.ec

Jorge Sebastián Macías-Loor**

**Universidad Técnica de Manabí, Portoviejo, Manabí, Ecuador

Orcid: <https://orcid.org/0009-0003-0848-2251>
sebastian.macias@utm.edu.ec

Kevin Andree Mendoza Vera***

***Pontificia Universidad Católica del Ecuador Sede Esmeraldas, Esmeraldas, Ecuador

Orcid: <https://orcid.org/0000-0002-8622-7622>
kamendoza@pucese.edu.ec

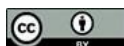
The authors declare that there is no conflict of interest

Abstract

The integration of artificial intelligence into higher education has driven the consolidation of the smart university paradigm within the framework of Education 4.0, promoting the digital transformation of university ecosystems. However, despite the accelerated growth of scientific output in this field, existing research exhibits marked thematic fragmentation and uneven regional distribution. The objective of this study was to analyze global research trends on artificial intelligence and Education 4.0 in the context of smart universities using a bibliometric approach. To this end, a descriptive and exploratory bibliometric analysis was conducted on peer-reviewed scientific articles indexed in the Scopus database during the period 2020–2025, following the guidelines of the PRISMA 2020 statement. The data were processed using the Bibliometrix (R) and VOSviewer tools, considering indicators of scientific productivity, impact, and keyword co-occurrence. The results

Resumo

A integração da inteligência artificial no ensino superior impulsionou a consolidação do paradigma da universidade inteligente no âmbito da Educação 4.0, promovendo a transformação digital dos ecossistemas universitários. No entanto, apesar do crescimento acelerado da produção científica neste campo, as pesquisas existentes apresentam uma fragmentação temática acentuada e uma distribuição regional desigual. O objetivo deste estudo foi analisar as tendências globais de pesquisa sobre inteligência artificial e Educação 4.0 no contexto das universidades inteligentes, utilizando uma abordagem bibliométrica. Para tal, foi realizada uma análise bibliométrica descritiva e exploratória de artigos científicos revisados por pares indexados na base de dados Scopus durante o período de 2020 a 2025, seguindo as diretrizes da declaração PRISMA 2020. Os dados foram processados utilizando as ferramentas



show sustained growth in publications, high author dispersion, and a geographical concentration of production, primarily led by countries in Asia and the Middle East. Artificial intelligence is consolidating its position as a driving force, closely linked to Education 4.0, engineering training, and emerging technologies such as blockchain and educational chatbots, reflecting a transition toward more integrated and intelligent university ecosystems. In conclusion, the findings confirm that research on smart universities is in a phase of expansion and thematic diversification, highlighting the need to strengthen integrative theoretical frameworks and foster greater participation from underrepresented regions, particularly Latin America, to guide digital transformation strategies in higher education.

Keywords: Digital Transformation. Learning Analytics. Smart Campus. Technology Gap. Educational Innovation.

Bibliometrix (R) e VOSviewer, considerando indicadores de produtividade científica, impacto e coocorrência de palavras-chave. Os resultados mostram um crescimento sustentado nas publicações, alta dispersão de autores e uma concentração geográfica da produção, liderada principalmente por países da Ásia e do Médio Oriente. A inteligência artificial está a consolidar a sua posição como força motriz, intimamente ligada à Educação 4.0, à formação em engenharia e a tecnologias emergentes, como blockchain e chatbots educacionais, refletindo uma transição para ecossistemas universitários mais integrados e inteligentes. Em conclusão, os resultados confirmam que a investigação sobre universidades inteligentes está em fase de expansão e diversificação temática, destacando a necessidade de fortalecer estruturas teóricas integrativas e promover uma maior participação de regiões sub-representadas, particularmente a América Latina, para orientar as estratégias de transformação digital no ensino superior.

Palavras-chave: *Transformação Digital. Análise de Aprendizagem. Campus Inteligente. Lacuna Tecnológica. Inovação Educacional.*

1 INTRODUCTION

Over the past decade, higher education has undergone a profound transformation driven by the convergence of advanced digital technologies such as artificial intelligence (AI), machine learning, the Internet of Things (IoT), and data analytics. This process has led to the emergence of the concept of smart universities, understood as an institutional model that integrates disruptive technologies to optimize academic management, personalize teaching–learning processes, and strengthen university sustainability and competitiveness within the framework of so-called Education 4.0 (Zawacki-Richter et al., 2019; Mahariya et al., 2023).

In this context, AI has positioned itself as a strategic axis for the redesign of university ecosystems, as it enables data-driven decision-making, adaptive learning, and the automation of key processes (Quy et al., 2023; Shenkoya & Kim, 2023).

At the global level, scientific interest in the application of AI in higher education has grown steadily, reflecting the need to respond to the demands of the fourth industrial

revolution and to train professionals with advanced digital competencies (Ahmed et al., 2025). Various studies have demonstrated the potential of AI to improve administrative efficiency, learning quality, and pedagogical innovation, as well as to promote smart campus models and personalized educational environments (Al-Maskari et al., 2024; Sposato, 2025).

However, this accelerated growth has also generated a fragmented body of scientific literature, characterized by partial approaches that address artificial intelligence, Education 4.0, or university digitalization in isolation, without a clear conceptual integration of the smart university paradigm. This situation constrains scientific and educational development in this new field of technological convergence (Caccavale et al., 2024; Olusoji & Ajagunna, 2020; Rahiman & Kodikal, 2024).

In the Latin American context, the transition toward smart universities has been shaped by structural factors such as the digital divide, inequality in access to technological infrastructure, and limited alignment between public policies and institutional strategies for educational innovation (Serna et al., 2021). Despite these constraints, recent years have witnessed a gradual increase in research exploring the incorporation of intelligent technologies in higher education, particularly in countries such as Mexico, Brazil, and Colombia. Nevertheless, the region's scientific output remains marginal compared with Asia and Europe, highlighting the need to understand global research dynamics and to position Latin America within this emerging field (Cabero & Llorente, 2020).

In the Ecuadorian case, studies on artificial intelligence and Education 4.0 in the university context are still incipient and are largely concentrated on conceptual analyses or isolated experiences (Villao, 2025; Cañar et al., 2025). This situation reveals a lack of systematic research capable of identifying trends, key actors, and emerging lines of development, thereby limiting institutions' ability to design strategies grounded in scientific evidence. Consequently, there is a clear need for studies that provide a comprehensive overview of the state of the art and the evolution of knowledge surrounding smart universities from a global perspective.

Despite the growing academic interest, there remains a gap in the literature regarding bibliometric analyses that simultaneously integrate artificial intelligence, Education 4.0, and the smart university paradigm, particularly in the post-2020 period, marked by the acceleration of university digitalization and the emergence of technologies

such as deep learning, educational chatbots, and blockchain. The absence of this type of study hinders the identification of research patterns, collaboration networks, dominant themes, and still underexplored areas.

From a scientific and strategic perspective, this study provides a comprehensive and up-to-date overview of the current development of the field, contributing to the theoretical consolidation of the smart university concept and offering relevant empirical evidence for researchers, university administrators, and public policymakers. Moreover, the findings make it possible to outline a future research agenda aimed at strengthening educational innovation and the digital transformation of higher education in global as well as regional and local contexts.

In response to this gap, the present study aimed to analyze global research trends on artificial intelligence and Education 4.0 within the framework of smart universities through a bibliometric analysis of scientific articles indexed in the Scopus database during the period 2020–2025. Specifically, the study sought to identify the temporal evolution of scientific production, the most influential countries and authors, dominant and emerging keywords, as well as the main thematic clusters structuring this field of knowledge.

Accordingly, the following specific objectives were established:

1. To identify the temporal evolution of scientific production on AI, Education 4.0, and smart universities.
2. To determine the most influential countries and authors in the research field.
3. To examine the most frequent and emerging keywords, as well as their co-occurrence.
4. To detect research gaps and potential directions for future development.

2 METHODOLOGY

2.1 Study design

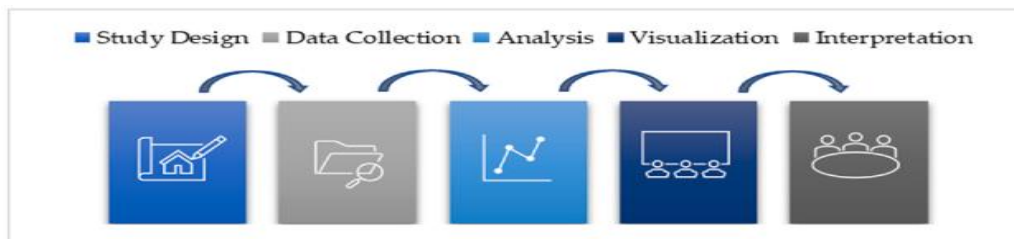
The present study was conducted under a bibliometric approach with a descriptive, analytical, and exploratory scope, aimed at identifying, analyzing, and structuring global research trends related to artificial intelligence and Education 4.0 within the context of

smart universities. Bibliometrics constitutes a robust and widely recognized method for the quantitative analysis of scientific production, enabling the examination of publication patterns, impact, collaboration, and thematic evolution within a specific field of knowledge (Aria & Cuccurullo, 2017).

The methodological design was based on the bibliometric analysis model proposed by Zupic and Čater (2015), which comprises five sequential phases: (I) study design, (II) data collection, (III) data analysis, (IV) data visualization, and (V) interpretation of results. This approach ensures the reproducibility of the study. Figure 1 presents the five phases of the bibliometric design.

Figure 1

Study design



2.2 Data collection

Data collection was carried out using the Scopus database, selected for its broad multidisciplinary coverage and international recognition as a reliable source for bibliometric studies in education and technology. Scopus was chosen due to its consistency in indexing publication metadata, which facilitates the analysis of citations, authorship, and keywords.

The search strategy was designed to maximize the retrieval of relevant documents while minimizing documental noise. A combination of keywords related to three conceptual axes was employed: artificial intelligence, Education 4.0, and smart universities. The final search query was as follows:

- (TITLE-ABS-KEY ((artificial AND intelligence OR machine AND learning)) AND TITLE-ABS-KEY ((education 4.0 OR digital AND education)) AND TITLE-ABS-KEY ((smart AND university OR intelligent

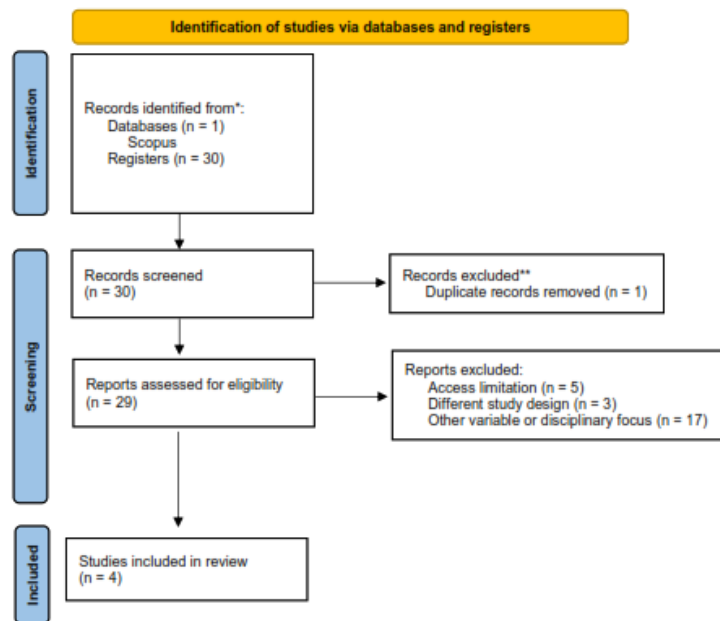
AND university OR digital AND university))) AND PUBYEAR > 2019
AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE , "ar")) AND
(LIMIT-TO (LANGUAGE , "English"))

The temporal delimitation (2020–2025) was established with the purpose of analyzing the most recent scientific production, considering the period of accelerated university digital transformation following the COVID-19 pandemic and the rise of advanced AI applications in higher education focused on online learning platforms.

The inclusion criteria were as follows: (I) peer-reviewed scientific articles, (II) publications in the English language, (III) documents that explicitly addressed the relationship between AI, Education 4.0, and smart universities, and (IV) articles indexed in Scopus within the established period. Conference proceedings, book chapters, narrative reviews, editorial notes, and duplicate documents were excluded in order to ensure methodological homogeneity and the scientific quality of the analyzed corpus. The exclusion of other languages and document types responds to standardization and international comparability criteria, although it is acknowledged as a limitation of the study.

2.3 Data analysis

The selection process was conducted in accordance with the guidelines of the PRISMA 2020 Statement (Page et al., 2021), ensuring transparency and methodological rigor. Initially, the search yielded a total of 30 records. Subsequently, a preliminary screening was carried out to remove duplicates and non-relevant documents using the Rayyan.ai tool, which is specialized in systematic and bibliometric reviews. After applying the inclusion and exclusion criteria, a final corpus of 29 scientific articles was obtained and deemed suitable for bibliometric analysis. Figure 2 illustrates the review process through the PRISMA flow diagram (Haddaway et al., 2022).

Figure 2*PRISMA protocol. Study review process*

Note: The inclusion criteria focused on empirical studies in higher education related to the key terms of the search equation. In turn, the exclusion criteria focused on the following aspects: availability of the full text; methodological designs other than empirical studies; and variables or disciplinary fields other than Educational Sciences.

The bibliometric analysis was conducted using the Bibliometrix package (RStudio) and the VOSviewer software, tools widely employed for scientific mapping and the visualization of knowledge networks. Various bibliometric indicators were calculated, including:

- Scientific productivity indicators: number of publications per year, authors, and countries.
- Impact indicators: number of citations, average citations per document, and mean age of publications.
- Keyword co-occurrence analysis: identification of dominant and emerging terms.
- Thematic maps and clusters: classification of themes according to their centrality and density.

2.4 Data visualization

In order to facilitate the interpretation of the results, graphical visualizations were generated, including: (I) annual evolution of scientific production, (II) geographic distribution maps of publications, (III) most relevant authors, (IV) co-occurrence networks of authors' keywords and the most frequent keywords, and (V) thematic maps that distinguish between motor, basic, emerging, and niche themes. These visualizations contribute to a comprehensive understanding of the development of the field of study.

2.5 Interpretation

The results were interpreted critically by contrasting them with prior literature in the field. This process made it possible to identify research gaps, highlight emerging themes, and propose future lines of development that contribute to strengthening the consolidation of smart universities within the framework of artificial intelligence and Education 4.0.

The study did not involve human subjects or sensitive data; therefore, it did not require approval from an ethics committee. Nevertheless, the principles of transparency, traceability, and scientific reproducibility were respected. The search strategy, selection criteria, and tools employed are described in detail to facilitate replication of the study by other researchers.

3 RESULTS AND DISCUSSION

This section presents the exploratory and descriptive results on global trends in scientific production related to AI and Education 4.0, the productivity indices of countries, as well as the most influential authors and keywords, in addition to the co-occurrence network and thematic map. Figure 3 illustrates the integrity of the data obtained from the Scopus database.

Figure 3*Main information*

The analysis period spanning 2020 to 2025 provides a recent and up-to-date overview of research related to artificial intelligence, Education 4.0, and smart universities. The selection of this timeframe is pertinent, as it encompasses the most contemporary contributions concerning digital transformation in the educational domain. A total of 30 documents distributed across 24 sources were identified, reflecting a relatively broad dissemination across different journals. Although the volume of documents is not high, the diversity of sources suggests multidisciplinary interest and openness across various channels of scientific dissemination.

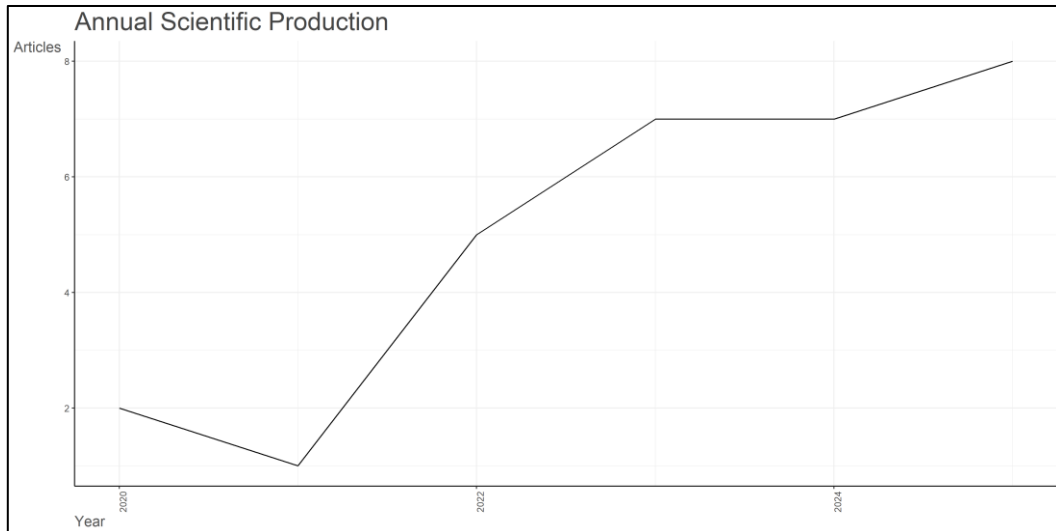
The dynamism of this field is evidenced by an annual growth rate of 31.95%, an indicator that demonstrates the accelerated expansion of research on the topic. This sustained growth highlights that the field represents an emerging line of inquiry with significant potential for consolidation in the coming years. The participation of 98 authors confirms the existence of an active and expanding research community. However, only four documents were authored individually, underscoring a strong preference for collaborative work and the consolidation of academic networks. In this regard, international collaboration accounts for 30% of the documents, reflecting an openness toward scientific cooperation across different contexts and countries.

Complementary bibliometric indicators show that the average number of co-authors per document is 3.43, which further confirms the collective nature of the publications. Likewise, an average of 19.77 citations per document indicates a considerable level of impact within the academic literature, while the mean age of the

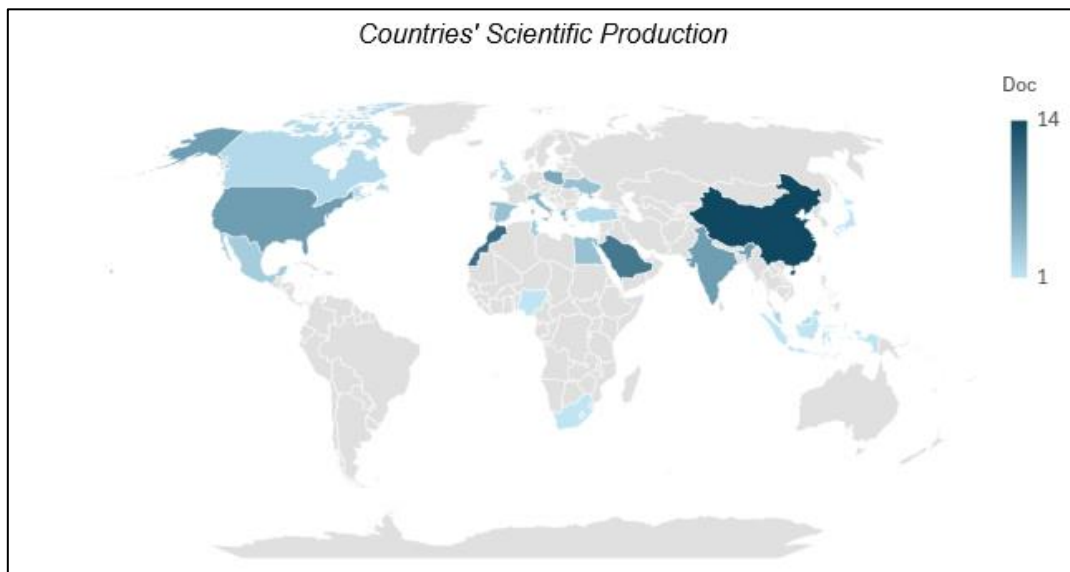
documents (1.67 years) reveals that most of the publications are recent, thereby strengthening the relevance and timeliness of the findings.

Figure 4

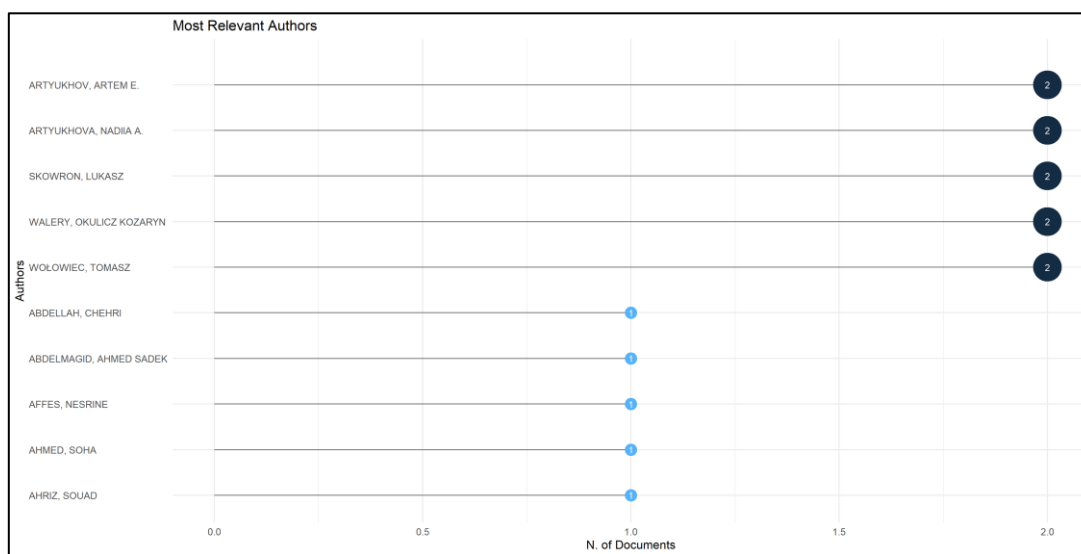
Annual evolution of scientific production



The annual scientific production graph (Figure 4) shows an upward trend in the number of publications between 2020 and 2025. In the initial years (2020–2021), production was low and exhibited a slight decline, decreasing from two articles in 2020 to only one in 2021. However, beginning in 2022, a significant increase is observed, reaching five publications, which marks the onset of a growing trend. This growth is consolidated in 2023 and 2024, with seven publications each year, culminating in a peak in 2025 with eight articles. This trajectory reflects the progressive consolidation of academic interest in artificial intelligence, Education 4.0, and smart universities, suggesting that the field is undergoing rapid expansion and is likely to continue developing.

Figure 5*Countries with the highest scientific production*

The analysis of the top 10 countries (Figure 5) with the highest scientific production in the field of AI, Education 4.0, and smart universities reveals a significant concentration in regions of Asia, the Middle East, and Europe. China leads scientific output with 14 documents, consolidating its position as the main global reference in this field. It is followed by Morocco (11) and Saudi Arabia (10), highlighting the growing prominence of Middle Eastern and North African countries in digital education research. At a second level, India and the United States appear with seven publications each, reflecting the involvement of both a technological powerhouse and an emerging country with strong momentum in educational innovation. Europe is also represented by Poland (6), Greece (5), Italy (5), and Spain (4), demonstrating sustained interest across the continent, while Egypt (4) further reinforces the contribution of North Africa.

Figure 6*Most relevant authors*

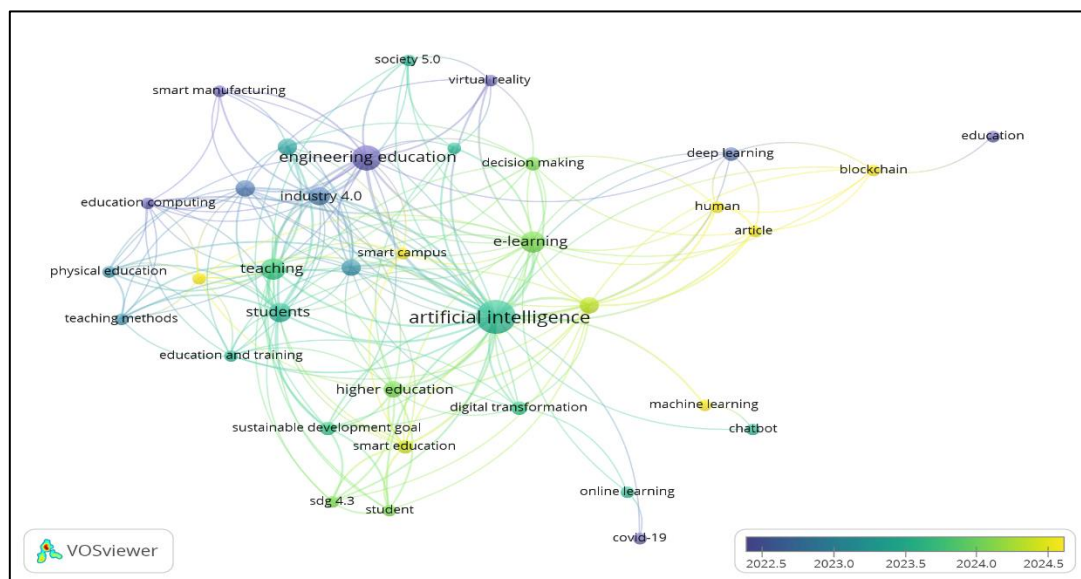
The analysis of the most relevant authors (Figure 6) indicates that scientific production in this field remains fragmented and at an emergent stage, as no author exhibits a clearly dominant output. The researchers Artem E. Artyukhov, Nadiia A. Artyukhova, Lukasz Skowron, Okulicz Kozaryn Walery, and Tomasz Wołowiec stand out with two publications each, positioning them as the most productive authors within the analyzed period. This group demonstrates a significant, albeit still limited, contribution in terms of volume.

At a second level, authors such as Chehri Abdellah, Ahmed Sadek Abdelmagid, Nesrine Affes, Soha Ahmed, and Souad Ahriz appear with one publication each, which confirms thematic dispersion and the participation of multiple researchers without a clear concentration of leadership. This distribution suggests that the field is in a consolidation phase, characterized by parallel research efforts, but without the presence of a strong core of the top 10 globally recognized reference authors.

learning environments mediated by intelligent technologies and centered on the learner. The appearance of concepts such as “sustainable development goal,” “society 5.0,” and “digital technologies” suggests a positioning of smart universities not only as training institutions but also as active agents in the construction of more sustainable societies.

Figure 8

Co-occurrence network of authors' keywords



The visualization of the term co-occurrence network (Figure 8) makes it possible to identify the most relevant conceptual interrelationships in the recent literature on artificial intelligence and Education 4.0 within the context of smart universities. The network shows nodes representing keywords, while the thickness of the links indicates the strength of co-occurrence between terms. In addition, the temporal gradient (from blue to yellow) reflects the evolution of terms over time, from 2022 to mid-2024.

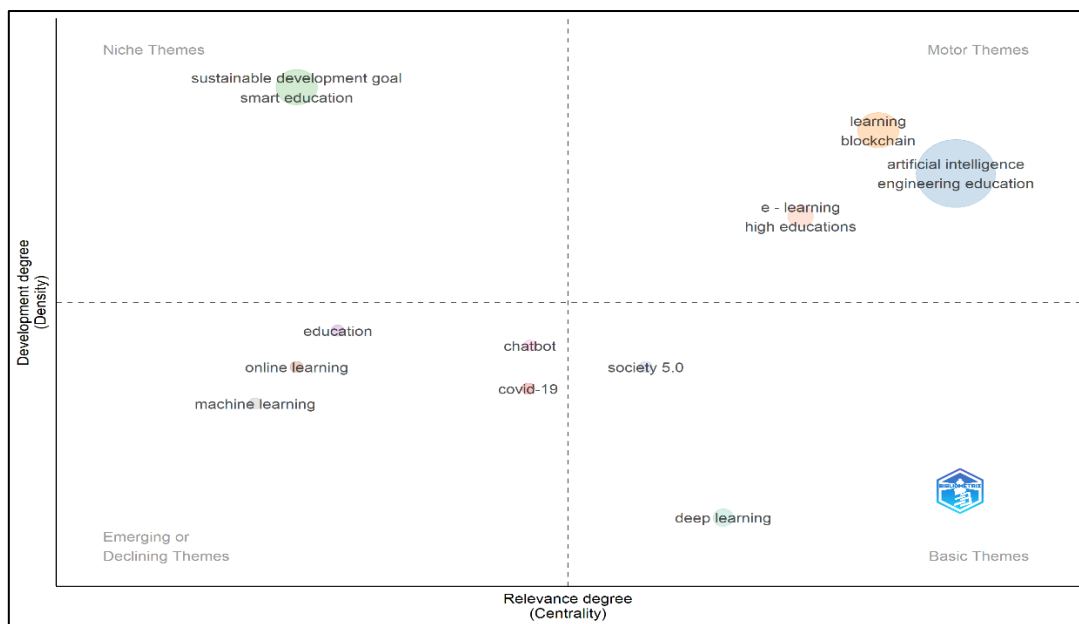
The term “artificial intelligence” occupies the central node of the map, acting as an articulating axis among diverse thematic areas. This centrality highlights its transversal role in linking emerging technologies with educational processes. Surrounding this node are other key concepts, including “e-learning,” “students,” “teaching,” and “higher education,” which confirms the growing interest in the application of AI in digital and personalized learning environments.

Three main interconnected clusters can be observed. The first cluster, with nodes such as “engineering education,” “industry 4.0,” and “smart manufacturing,” represents an orientation toward the integration of advanced technologies in technical and professional training. The second, more pedagogical cluster is composed of terms such as “students,” “teaching methods,” “education and training,” and “curricula,” reflecting concerns related to curricular redesign and the enhancement of teaching practices through digital tools. The third and more recent group, visible in warmer colors such as yellow, includes emerging terms such as “blockchain,” “machine learning,” “chatbot,” and “deep learning,” evidencing a conceptual expansion toward AI applications in educational contexts.

The temporal dimension of the graph shows that concepts such as “machine learning,” “blockchain,” and “chatbot” have gained prominence in more recent publications (2024), whereas others such as “engineering education” and “industry 4.0” display a more consolidated presence in earlier years. This evolution suggests a transition from a technical–industrial focus toward more specific AI applications in teaching and learning.

Figure 9

Thematic map in the field of AI and Education 4.0



The thematic map classifies the main topics identified in relation to AI, Education 4.0, and smart universities according to two dimensions: the degree of development or density (vertical axis) and the degree of relevance or centrality (horizontal axis). This representation makes it possible to visualize the thematic structure of the field and to locate topics within one of four quadrants: motor themes, basic themes, emerging or declining themes, and specialized or niche themes.

In the upper-right quadrant, corresponding to motor themes, concepts such as “artificial intelligence,” “engineering education,” “learning,” and “blockchain” are positioned. These terms exhibit high density and centrality, indicating that they are well developed and play a central role in the thematic structure of the field. The large size of the “artificial intelligence” node suggests that it is the dominant articulating axis, with strong links to multiple lines of research. The presence of “blockchain” within this group indicates its consolidation as an emerging technology with high applicability in smart educational contexts.

The lower-right quadrant, representing basic themes, includes terms such as “society 5.0” and “deep learning.” These topics show high relevance but low density, indicating that although they are fundamental to the development of the field, they still require greater theoretical or empirical depth. In particular, the case of “deep learning” suggests high visibility but a lower degree of maturity in terms of a consolidated body of literature.

In the upper-left quadrant, niche themes such as “sustainable development goal” and “smart education” are located. These exhibit high density but low centrality, meaning that they are well developed internally but less connected to the rest of the field. This can be interpreted as specialized lines of research with the potential to become more influential if they are more strongly linked to central themes.

Finally, the lower-left quadrant, which groups emerging or declining themes, contains concepts such as “online learning,” “education,” “machine learning,” “chatbot,” and “covid-19.” The placement of these terms in this area may be due to two possible situations: either they represent topics that are losing relevance after an initial surge (such as “covid-19”), or they are emerging areas that have not yet achieved substantial development or integration within the literature. In this sense, “chatbot” and “machine

learning” may still be in early stages of applied exploration within the educational domain.

The results of the bibliometric analysis confirm that this line of research constitutes an emerging field with accelerated growth, particularly from 2022 onward. This finding is consistent with previous studies that report a significant increase in scientific production related to the digital transformation of higher education following the COVID-19 pandemic (Zawacki et al., 2019; Serna et al., 2021). The annual growth rate identified in this study (31.95%) reinforces the notion that AI has shifted from being an experimental technology to becoming a structural component of university ecosystems, aligned with the demands of the fourth industrial revolution and the so-called Society 5.0 (Almutairi et al., 2025).

In comparison with earlier bibliometric analyses focused exclusively on AI applied to higher education (Zawacki et al., 2019), the findings of this study reveal a more complex and integrated thematic evolution, in which concepts such as Education 4.0, smart campus, and blockchain appear interconnected. This suggests a transition from predominantly pedagogical approaches toward systemic models that conceive the university as an intelligent ecosystem in which technological innovation, institutional management, and sustainability converge (Pacheco et al., 2024; Liu et al., 2025).

The leadership of countries such as China, Morocco, and Saudi Arabia in scientific production constitutes a relevant finding that partially aligns with recent studies on educational innovation and university digitalization (Ahmed et al., 2025). In the case of China, its dominant position can be explained by state policies oriented toward the development of artificial intelligence and digital education, as well as by strong investments in research and development. Nevertheless, the prominence of North African and Middle Eastern countries, such as Morocco and Saudi Arabia, reflects a geopolitical reconfiguration of knowledge production, in which regions traditionally considered peripheral are emerging as relevant actors in AI-based educational research. This phenomenon has been highlighted by Kamukapa et al. (2024) and Ramírez et al. (2024) as a strategy for international positioning through technological innovation in higher education.

Conversely, the limited presence of Latin American countries among the leading contributors to scientific production confirms the gaps previously identified in the

literature (Cabero & Llorente, 2020; Camacho et al., 2025). Although relevant initiatives and studies exist in the region, their international impact and visibility remain limited. This result is consistent with the observations of Forero & Bannasar (2024), Villegas & Delgado (2024), and Villao (2025), who emphasize that in contexts such as Ecuador, the adoption of AI in higher education is still in its early stages, characterized by a predominance of exploratory studies and the absence of consolidated research lines.

The analysis of the most productive authors reveals a high degree of authorship dispersion, with no clearly consolidated leaders. This pattern is characteristic of emerging research fields and is consistent with the findings of bibliometric studies in rapidly evolving technological areas (Sanabria & Olivo, 2024). The absence of dominant authorship cores suggests that research on smart universities is still at a stage of conceptual construction, which opens opportunities for the formation of stronger and more collaborative international research networks (Azofeifa et al., 2024).

The thematic map reinforces this interpretation by positioning artificial intelligence and engineering education as motor themes—highly developed and central—while technologies such as chatbots and machine learning appear as emerging or consolidating themes. This pattern aligns with the findings reported by Huesca et al. (2024) and Reina et al. (2025), who indicate that smart universities are transitioning from models centered on digital infrastructure toward approaches more oriented to learning personalization and the intelligent automation of academic services.

From a theoretical perspective, these results support the conception of smart universities as complex sociotechnical systems in which technology does not operate in isolation but is integrated into pedagogical, organizational, and strategic processes. They also highlight the need to advance toward research that goes beyond descriptive approaches and explores the real impact of AI on educational quality, equity, and sustainability—issues identified as key challenges in recent literature (Álvarez & Huerta, 2024; Pozzo & Al-Zoubi, 2025).

4 CONCLUSIONS

This bibliometric study made it possible to systematically analyze global research trends on AI, Education 4.0, and smart universities during the 2020–2025 period,

demonstrating that this is an emerging, dynamic, and rapidly expanding field. The sustained growth in scientific production, together with the diversity of countries, authors, and thematic approaches identified, confirms the progressive consolidation of AI as a strategic axis in the digital transformation of higher education.

From a theoretical perspective, the results contribute to strengthening the conceptual framework of smart universities by showing that research has evolved from isolated technological approaches toward systemic models that integrate artificial intelligence, pedagogical innovation, and institutional management. The centrality of AI as a motor theme, as well as its interconnection with Education 4.0, engineering education, and blockchain, reinforces the conception of the smart university as a sociotechnical ecosystem.

In terms of practical implications, the findings provide relevant inputs for university administrators and decision-makers. The identification of leading countries and emerging technologies offers benchmarks for the design of institutional strategies oriented toward the implementation of smart campuses, adaptive learning systems, and data-driven management models. The limited visibility of Latin American production highlights the urgency of fostering international collaboration networks, encouraging publication in high-impact journals, and developing national agendas for university digital transformation aligned with global standards.

Furthermore, the results make it possible to outline a future research agenda. The identified emerging lines—such as the use of chatbots, machine learning, deep learning, and blockchain in educational contexts—require empirical studies that assess their impact on learning quality, educational equity, and institutional sustainability. Likewise, there is a need for comparative research across regions, as well as longitudinal studies that analyze the evolution and maturity of smart universities in different socioeconomic contexts.

It is important to acknowledge that this study presents certain limitations, primarily derived from the exclusive use of the Scopus database, the restriction to the English language, and the focus on peer-reviewed scientific articles. While these methodological decisions ensure rigor and international comparability, they may also exclude relevant contributions published in other languages or formats. Future research

could broaden the scope by incorporating additional databases and mixed methodological approaches.

REFERENCES

- Ahmed, T., Bajpai, S., & Faisal, M. (2025). *Advances in science, engineering and technology*. Springer. <https://books.google.com/books?hl=es&id=thRZEQAQAQBAJ>
- Al-Maskari, A., Al Riyami, T., & Ghnimi, S. (2024). Factors affecting students' preparedness for the fourth industrial revolution in higher education institutions. *Journal of Applied Research in Higher Education*, 16(1) 246–264. <https://doi.org/10.1108/JARHE-05-2022-0169>
- Almutairi, Y. M. N., Al-Saad, A. F., Elmelegy, R. I., Bakr, A. A. H., Abdallah, M. A. E., & Almotairi, K. M. N. (2025). Systematic Literature Review of Fourth Industrial Revolution on Higher Education: Implications for Higher Education Sustainability. *International Journal of Instruction*, 18(2), 285–308. <https://e-iji.net/ats/index.php/pub/article/view/736>
- Alvarez-Icaza, I., & Huerta, O. (2024). Augmented intelligence for open education: Bridging the digital gap with inclusive design methods. *Frontiers in Education*, 9, 1337932. <https://www.frontiersin.org/journals/education/articles/10.3389/feduc.2024.1337932/full>
- Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of informetrics*, 11(4), 959-975. <https://doi.org/10.1016/j.joi.2017.08.007>
- Azofeifa, J. D., Rueda-Castro, V., Camacho-Zuñiga, C., Chans, G. M., Membrillo-Hernández, J., & Caratozzolo, P. (2024). Future skills for industry 4.0 integration and innovative learning for continuing engineering education. *Frontiers in Education*, 9, 1412018. <https://doi.org/10.3389/feduc.2024.1412018>
- Cabero Almenara, J., & Llorente-Cejudo, C. (2020). Covid-19: transformación radical de la digitalización en instituciones universitarias. *Campus Virtuales*, 9(2), 25-34. <https://www.uajournals.com/campusvirtuales>
- Caccavale, F., Gargalo, C. L., Gernaey, K. V., & Krühne, U. (2024). Towards Education 4.0: The role of Large Language Models as virtual tutors in chemical engineering. *Education for Chemical Engineers*, 49, 1-11. <https://www.sciencedirect.com/science/article/pii/S1749772824000198>
- Camacho-Zuñiga, C., Salas-Maxemín, S., Valle-Arce, A. P., Caratozzolo, P., & Chans, G. M. (2025). Toward a continuous learning educational model: insights from the experience of a Mexican private university. *Frontiers in Education*, 10, 1485034.

<https://www.frontiersin.org/journals/education/articles/10.3389/feduc.2025.1485034/full>

- Cañar Torres, M. S., Faican Quinche, E. J., Ninahualpa Aguiar, A. E., Criollo Peralta, D. J., Caiza Hidalgo, L. E., & Estacio Moreno, J. S. (2025). Evaluación automatizada mediante inteligencia artificial: beneficios y limitaciones. *South Florida Journal of Development*, 6(8), e5725. <https://doi.org/10.46932/sfjdv6n8-042>
- Forero-Corba, W., & Negre Bennasar, F. (2024). Techniques and applications of Machine Learning and Artificial Intelligence in education: a systematic review. *RIED-Revista Iberoamericana de Educación a Distancia*, 27(1), 1-35. <https://www.redalyc.org/journal/3314/331475280025/331475280025.pdf>
- Haddaway, N. R., Page, M. J., Pritchard, C. C., & McGuinness, L. A. (2022). PRISMA2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and Open Synthesis. *Campbell Systematic Reviews*, 18, e1230. <https://doi.org/10.1002/cl2.1230>
- Huesca, G., Martínez-Treviño, Y., Molina-Espinosa, J. M., Sanromán-Calleros, A. R., Martínez-Román, R., Cendejas-Castro, E. A., & Bustos, R. (2024). Effectiveness of using ChatGPT as a tool to strengthen benefits of the flipped learning strategy. *Education Sciences*, 14(6), 660. <https://doi.org/10.3390/educsci14060660>
- Kamukapa, T. D., Lubinga, S., Masiya, T., & Sono, L. (2024). Assessing the integration of AI competencies in undergraduate public administration curricula in selected South African higher education institutions. *Teaching Public Administration*, 43(1), 108-125. <https://doi.org/10.1177/01447394241266443>
- Liu, X., Guo, B., He, W., & Hu, X. (2025). Effects of Generative Artificial Intelligence on K-12 and Higher Education Students' Learning Outcomes: A Meta-Analysis. *Journal of Educational Computing Research*, 63(5), 1249-1291. <https://doi.org/10.1177/07356331251329185>
- Mahariya, S. K., Kumar, A., Singh, R., Gehlot, A., Shaik Vaseem Akram, Bhekisipho Twala, ... Neeraj Priyadarshi. (2023). Smart Campus 4.0: Digitalization of University Campus with Assimilation of Industry 4.0 for Innovation and Sustainability. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, 32(1), 120-138. <https://doi.org/10.37934/araset.32.1.120138>
- Olusoji Ilori, M., & Ajagunna, I. (2020). Re-imagining the future of education in the era of the fourth industrial revolution. *Worldwide Hospitality and Tourism Themes*, 12(1) 3-12. <https://doi.org/10.1108/WHATT-10-2019-0066>
- Pacheco-Velazquez, E., Rodes-Paragarino, V., & Marquez-Uribe, A. (2024). Exploring educational simulation platform features for addressing complexity in Industry 4.0: a qualitative analysis of insights from logistics experts. *Frontiers in Education*, 9, 1331911.

<https://www.frontiersin.org/journals/education/articles/10.3389/feduc.2024.1331911/full>

- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., . . . Moher, D. (2021). Declaración PRISMA 2020: una guía actualizada para la publicación de revisiones sistemáticas. *Revista Española de Cardiología (English Edition)*, *74*(9), 790-799. <https://doi.org/10.1016/j.rec.2021.07.010>
- Pozzo, M. I., & Al-Zoubi, A. (2025). University 4.0: Professors' Perceptions' on the Future of Higher Education. Evolutionary Progress or Revolutionary Change?. *Multidisciplinary Journal for Education, Social and Technological Sciences*, *12*(1), 125–155. <https://doi.org/10.4995/muse.2025.23314>
- Quy, V. K., Thanh, B. T., Chehri, A., Linh, D. M., & Tuan, D. A. (2023). AI and Digital Transformation in Higher Education: Vision and Approach of a Specific University in Vietnam. *Sustainability*, *15*(14), 11093. <https://doi.org/10.3390/su151411093>
- Rahiman, H. U., & Kodikal, R. (2024). Revolutionizing education: Artificial intelligence empowered learning in higher education. *Cogent Education*, *11*(1), 2293431. <https://doi.org/10.1080/2331186X.2023.2293431>
- Ramírez-Montoya, M. S., Morales-Menéndez, R., Tworek, M., Escobar, C. A., Tariq, R., & Tenorio-Sepulveda, G. C. (2024). Complex competencies for leader education: artificial intelligence analysis in student achievement profiling. *Cogent Education*, *11*(1), 2378508. <https://doi.org/10.1080/2331186X.2024.2378508>
- Reina Marín, Y., Cruz Caro, O., Maicelo Rubio, Y. D. C., Alva Tuesta, J. N., Sánchez Bardales, E., Carrasco Rituay, A. M., & Chávez Santos, R. (2025). Artificial intelligence as a teaching tool in university education. *Frontiers in Education*, *10*, 1578451. <https://www.frontiersin.org/journals/education/articles/10.3389/feduc.2025.1578451/full>
- Sanabria, Z. J., y Olivo, P. G. (2024). AI platform model on 4IR megatrend challenges: complex thinking by active and transformational learning. *Interactive Technology and Smart Education*, *21*(4), 571–587, doi: <https://doi.org/10.1108/ITSE-07-2023-0145>
- Serna Gómez, J. H., Díaz-Piraquive, F. N., Muriel-Perea, Y. J., & Díaz Peláez, A. (2021). Advances, opportunities, and challenges in the digital transformation of HEIs in Latin America. Radical solutions for digital transformation in Latin American universities: *Artificial intelligence and technology 4.0 in higher education*, 55-75. https://link.springer.com/chapter/10.1007/978-981-16-3941-8_4

- Shenkoya, T., & Kim, E. (2023). Sustainability in Higher Education: Digital Transformation of the Fourth Industrial Revolution and Its Impact on Open Knowledge. *Sustainability*, 15(3), 2473. <https://doi.org/10.3390/su15032473>
- Sposato, M. (2025). Artificial intelligence in educational leadership: a comprehensive taxonomy and future directions. *International Journal of Educational Technology in Higher Education*, 22(1), 20. <https://link.springer.com/article/10.1186/s41239-025-00517-1>
- Villao Alejandro, G. A. (2025). El Rol de la Inteligencia Artificial en la Enseñanza Universitaria: Potencial, Riesgos y Perspectivas Futuras. *Innovarium International Journal*, 3(2), 1-12. <https://revinde.org/index.php/innovarium/article/view/55>
- Villegas-José, V., & Delgado-García, M. (2024). Artificial intelligence: innovative educational revolution in Higher Education. *Pixel-Bit, Revista de Medios y Educacion*, (71), 159–177. <https://doi.org/10.12795/pixelbit.107760>
- Zawacki Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education—where are the educators? *International Journal of Educational Technology in Higher Education*, 16(1), 1-27. <https://doi.org/10.1186/s41239-019-0171-0>
- Zupic, I., & Čater, T. (2015). Bibliometric Methods in Management and Organization. *Organizational Research Methods*, 18(3), 429-472. <https://doi.org/10.1177/1094428114562629>

Authors' Contribution

All authors contributed equally to the development of this article.

Data availability

All datasets relevant to this study's findings are fully available within the article.

How to cite this article (APA)

Vélez, W. A. Z., Delgado-Cobeña, E. I., Molina-Santana, C. L., Macías-Loor, J. S., & Vera, K. A. M. (2026). SMART UNIVERSITIES: GLOBAL TRENDS IN ARTIFICIAL INTELLIGENCE AND EDUCATION 4.0. *Veredas Do Direito*, 23(4), e234872. <https://doi.org/10.18623/rvd.v23.n4.4872>