Blockchain Technology in Education: a Bibliometric Review

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Abstract

Blockchain technology is beginning to have a significant impact on the field of education. As educational institutions look for ways to improve efficiency, security and transparency in their operations, they are exploring how this technology can play a crucial role in this process. Therefore, this study, through a bibliometric review, shows the perspectives of the use of blockchain technology in education. A sample of 113 documents retrieved from the Scopus database were extracted that had been published in 82 scientific journals, with 2805 references and an average citation count per document of 5,761. These documents are, for the most part, conference papers (61); On the other hand, the list of countries with the greatest impact on research is led by China, with 109 citations and 67 scientific documents. For now, blockchain technology is quite useful for ensuring the storage, exchange and networking of information. It is suggested that technology can be used for better administration of the admission process, evaluating history of participation in extracurricular activities, strengthening the alumni network in schools and colleges, and managing library and information services.

Keywords

bibliometric indicators, research results, education, blockchain, block chain, e-learning.

1. Introduction

The transition to online education and access to and dependence on technology are forcing educational institutions to incorporate systems that help them manage their resources more efficiently in order to avoid fraud and uses other than teaching and learning. The adaptation of students and teachers to these changes has not been easy, since in a short time they were forced to learn new technologies, as well as adapt to a learning environment different from the traditional one (Oliva Córdova et al., 2019; Paucar-Curasma et al., 2022). Thus, technologies such as online learning, virtual and augmented reality, artificial intelligence, educational robotic gamification and blockchain became commonplace in the educational sector.

Blockchain technology is conceived as a registration system that helps verify transactions in a transparent and risk-free way (Tschorsch and Scheuermann, 2016). Among the advantages

offered by this technology is the generation of a distributed registry that allows the storage of information in multiple nodes; use of blocks and chains, a process that gives the technology its name; use of cryptography as a means of security; it is a decentralized system in which transactions are verified by multiple nodes, etc. (Ali et al., 2021). Each of these traits has revolutionized the way we think about trust and security in digital transactions (Tseng et al., 2018).

Blockchain technology has evolved and its use is not only limited to the field of cryptocurrencies but its application is increasingly common in the development and monitoring of supply chains, electronic voting systems, smart contracts, digital identity, digital asset management, property registration and property titles, among others. These applications give blockchain technology the status of an emerging phenomenon whose limits for its use cannot yet be established (Aulia and Yazid, 2021).

The potential that this technology has to transform the various fields of human endeavor is interesting, and the educational sector has not been immune to its incursion, especially after the pandemic where education has felt a significant impact. An example of this is the number of studies that focused on analyzing their incursion into this sector (Amo et al., 2020; Bartolomé Pina and Lindín Soriano, 2018; Chen et al., 2018; Li and Han, 2019; Guo et al., 2020) and its impact on the future of education. Their application in this field has brought various advantages, especially in aspects related to security and effectiveness in data and process management, since they help to verify academic credentials (Sharples and Domingue, 2016), record of academic history, the student identity management (Al Harthy et al., 2019), distributed educational content, global access to courses and resources, as well as performance monitoring and evaluation, just to name a few of its uses.

Bibliometric analysis has experienced notable development in recent decades. Bibliometrics focuses on measuring the size, growth and distribution of scientific documents, as well as the structure and dynamics of the groups that produce and consume them, along with the information they contain (López and Terrada, 1992). In this sense, bibliometrics allows us to quantitatively analyze publications regarding the evolution of the growth of scientific knowledge, the most studied topics, authors, geographical and language coverage, collaborations, journals and citation analysis. The present study aims to analyze the literature available in Scopus on blockchain and education, through a bibliometric and content analysis. The purpose is to identify trends and significant data, in order to contribute to the consolidation of this field of study.

2. Materials and methods

2.1. Search methods

A retrospective descriptive study with a bibliometric approach was carried out to analyze the production by authorship, institutions, countries, co-authorship and international collaboration. The search period was from 2018 to July 23, 2023 in the Scopus database. The terms used were Blockchain and Education. To ensure broad search scope, terms were constantly filtered. Finally, the keywords were established: TITLE = (blockchain AND technology AND education). The data were exported to Microsoft Excel 2016. Once the list was created, it was verified that there were no duplicate articles.

2.2. Data extraction and analysis

A total of 114 international documents published on *blockchain* and *education* were extracted, obtained through the Scopus database. Considering the novelty of the topic, the use of filters was not necessary. After manual evaluation of each document, 113 articles were obtained that met the study criteria. The main requirement considered was thematic, with the articles having to deal with the educational topic. The results were converted to CSV (Comma Separated Values) and RIS (Research Information System) formats, to serve as analytical data (Shoaib et al., 2023).

This data was used for analytical visualization regarding the trend of international publication on *blockchain* and education, as shown in Figure 1.
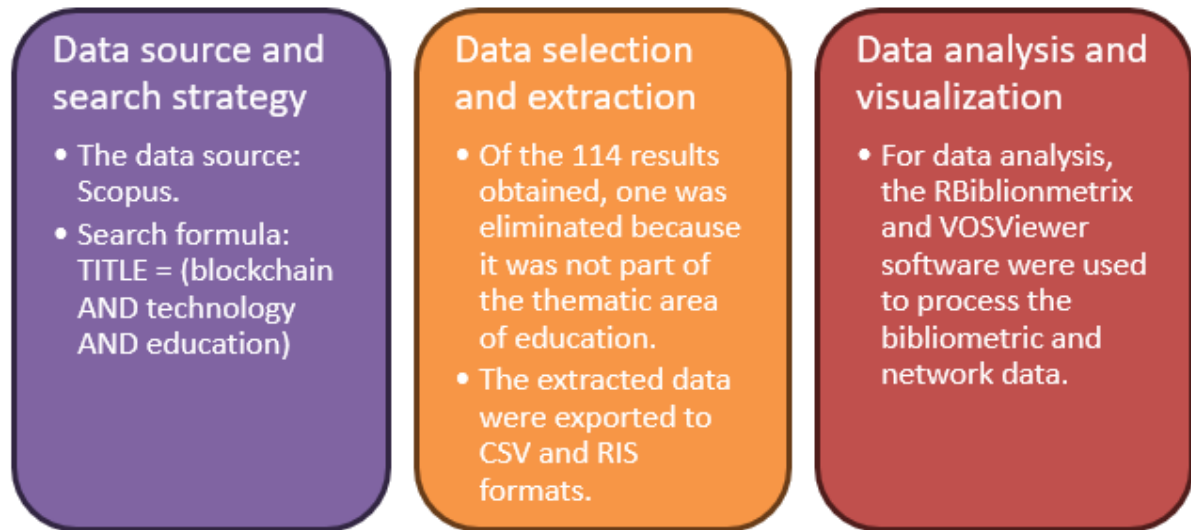

Figure 1. Research stages

3. Results

3.1. Initial data analysis

A total of 113 articles from the Scopus database were analyzed, in approximately 175 journal publications from 2018 to July 2023. Table 1 shows general information about the data. 82 sources were corroborated, while the annual growth rate was 35.1%. A high average of citations close to 6 citations per published document was also verified.

Table 1
Information on the main bibliometric data

Description	Results
Main Data	
Period	2018-July 2023
Sources (magazines, books and others)	82
Documents	113
Annual growth rate	35.1%
Average age of the document	1.8
Average number of citations per document	5,761

Regarding authorship, a total of 305 of the 113 documents collected were obtained, with 22 single authors. The average number of authors (co-authors) per document is 3, with the percentage of co-authorships or international collaborations being 21.24% (see Table 2).

Table 2
Bibliometric information about authors

Description	Results
Main Data	
Authors	305
Single author documents	22
Co-authors per Document	3

Regarding the initial data analysis, it is perceived that the highest production of scientific documents on *blockchain* and education is found in conference documents *(proceedings)* with 55.5%, followed by original or empirical scientific articles (29.1%) and book chapters (10.9%) (see Figure 2).
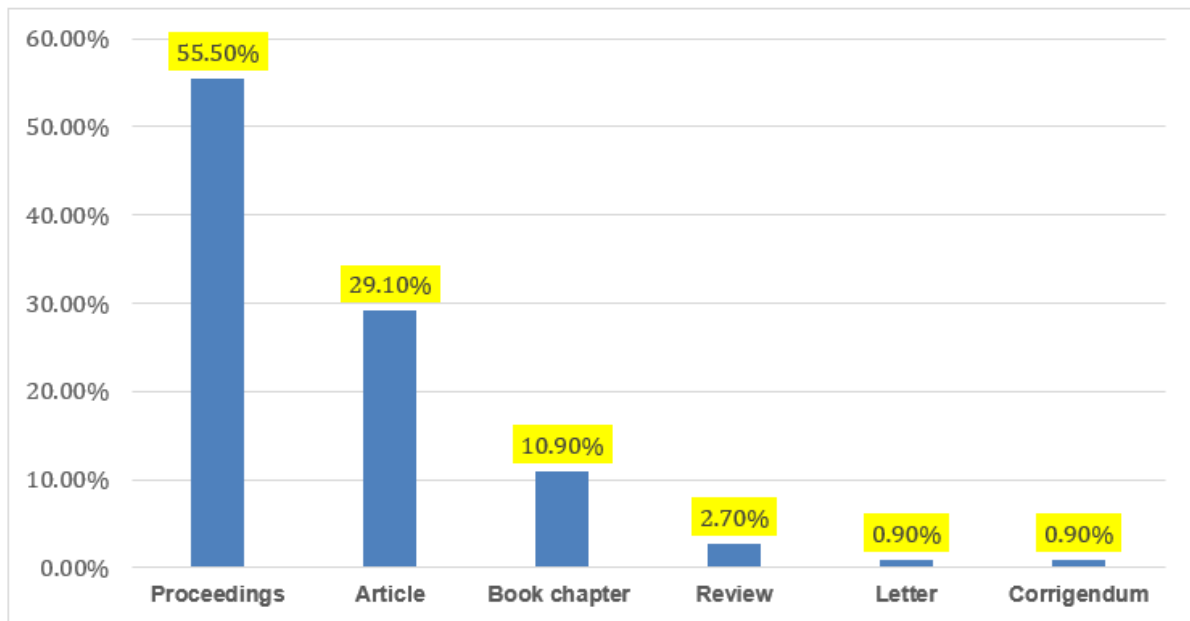

Figure 2. Bibliometric information on type of scientific document

4. Global production on blockchain in educational contexts

The analysis of global research production by year, shown in Figure 3, shows an increase in research production from 4 articles in 2018 to 38 articles in 2022, with the annual growth rate of 35.1%. According to the trend, the forecast of research results for 2023 will be 44 documents (18 currently produced), because the blockchain is a current and attractive topic for researchers, especially in the field of technology. It is important to highlight that the production of peer-reviwed papers on this topic increased considerably in 2020, because education has experienced significant changes due to the covid pandemic. These changes have gone from traditional classroom environments to electronic learning, through hybrid methodologies.

After Covid, the new educational accreditation standards included digitalization, entrepreneurship, social inclusion and the circular economy (Bjelobaba et al., 2022). This is where blockchain technology emerged to manage general topics such as standardized scholarship, behavioral pattern, and digital credentialing (Zhao et al., 2023).
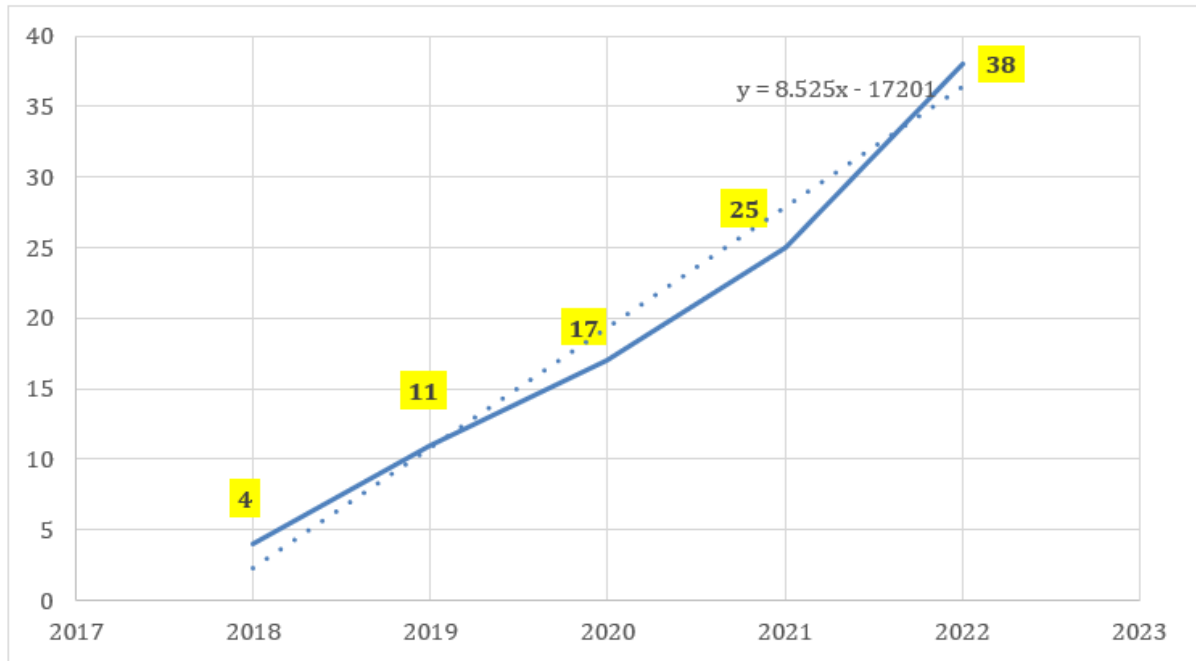
Figure 3. Annual research production

4.1. Relevant publication sources

Regarding the most relevant sources, the *ACM International Conference Proceeding Series* stands out with 10 articles. As for the impact, first comes the German magazine *Lecture Notes In Computer highlights Science* from Springer Nature publishing house with a CiteScore of 2.2 (Q3 from Scopus) (see Table 3).

Table 3
Bibliometric information on the most relevant sources
Note: ACM (for Association for Computing Machinery)

Sources	Documents	Scopus Quartile	Country	Cite Score 2022	Publisher
ACM International Conference Proceeding Series	10	Does not apply	USA	1.1	Conference Procedure
Journal Of Physics: Conference Series	4	Does not apply	United Kingdom	1.0	Conference Procedure
Reading Notes In Computer Science (Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics)	4	Q3	Germany	2.2	Springer Nature
Lecture Notes In Networks And Systems	4	Q4	Swiss	0.7	Springer Nature

4.2. Authors

Table 4 describes the authors with the greatest production in the field based on their publications. The Bulgarian researcher Rocsana Bucea-Manea-Tonis emerges as the author with

the greatest production on the topic (4) until the cut-off date of the study, followed by the Indonesian Untung Rahardja (4). Regarding the impact, Untung Rahardja stands out with an h-index of 21. By author affiliation, the Indonesian university Universitas of Raharja stands out with 7 publications on this topic.

Table 4
Authors with the highest production in publications
Note. Data extracted from the Scopus database.

Authors	Articles	h- Index	Affiliation	Most relevant document
Bucea-Manea-Țoniş, R.	4	7	National University of Physical Education and Sports, Bucharest	Blockchain technology enhances sustainable higher education
Rahardja U.	4	twenty-one	Universities Raharja, Tangerang, Indonesia	Design Framework on Tertiary Education System in Indonesia Using Blockchain Technology
Li Zheng	3	17	Beijing University of Chemical Technology, Beijing, China	Blockchain Technology and Its Application in Higher Education
Lutfiani N.	3	9	Universities Raharja, Tangerang, Indonesia	Blockchain Education Smart Courses of Massive Online Open Course Using Business Model Canvas
Sakhipov A.	3	1	LN Gumilyov Eurasian National University, Astana, Kazakhstan	Application of Blockchain Technology in Higher Education Institutions

5. Most cited articles

Table 5 lists the most cited articles in Scopus on blockchain. From the list, the study titled "Application of blockchain technology in online education" (2021) by Sun, Han; Wang, Xiaoyue and Wang, Xinge stands out. This study proposes a literature review and case analysis, analyzing the basic technical principles and application characteristics of blockchain technology, to propose a solution to the problems of online education based on this technology. The document has been cited 73 times, with an average of 12.17 citations per year since its publication in October 2018, in the International Journal of Emerging Technologies in Learning (IJET) from the International Association of Online Engineering.

Also notable is the article titled "Blockchain Technology: A Data Framework to Improve Validity, Trust, and Accountability of Information Exchange in Health Professions Education" by Eric Funk, Jeff Riddell, Felix Ankel and Daniel Cabrera, published in 2018 in the journal Academic Medicine by Wolters Kluwer Publishing House Health. The study explains that blockchain has emerged as a way to generate networks where validity, trust and responsibility can be generated. Health professions education based on this technology will allow, according to the authors, to improve the monitoring of content and the people who create it, quantify the educational impact on multiple generations of students and build a relative value of educational interventions. The paper had 69 citations in total and 11.50 citations per year.

It is observed that the articles with the highest number of citations addressed various topics related to education and blockchain. These works clearly expose the evolution of this technology,

making it clear that, over the years, it is becoming a complementary technology (López-Sorribes et al., 2023).

Table 5
The most cited articles in Scopus
Note: TC= Total citations.

Author, Year	Magazine	Qualification	T.C.	TC per year
Sun, H., Wang, X., Wang, X., 2018	International Journal of Emerging Technologies in Learning, 13(10), pp.	Application of blockchain technology in online education	73	12.17
Funk, E., Riddell, J., Ankel, F., Cabrera, D., 2018	Academic Medicine, 93(12), pp. 1791–1794	Blockchain technology: A data framework to improve validity, trust, and accountability of information exchange in health professions education	69	11.50
Fedorova, E.P., Skobleva, E.I., 2020	European Journal of Contemporary Education, 9(3), pp. 552–571	Application of blockchain technology in higher education	55	13.75
Rahardja, U., Hidayanto, AN, Hariguna, T., Aini, Q., 2019	2019 7th International Conference on Cyber and IT Service Management, CITSM 2019, 8965380	Design Framework on Tertiary Education System in Indonesia Using Blockchain Technology	43	8.60
Duan, B., Zhong, Y., Liu, D. 2018	Proceedings of the International Conference on Parallel and Distributed Systems - ICPADS, 2017-December, pp. 814–817	Education application of blockchain technology: Learning outcome and meta-diploma	41	6.83

5.1. Countries

The list of countries with the greatest impact on research (see Table 6) is led by China, with 109 citations in Scopus, followed by the United States with 73 citations and India with 39 citations. The country with the largest number of scientific documents on blockchain is China (67), followed by India (62). Now, given that a single document can be written by authors of different nationalities, the countries with the highest number of collaborations are Portugal and Brazil (3 collaborations each). The position of influence of China and the United States is also related to the general ranking prepared by Scimago Lab (https://www.scimagojr.com/) in which these countries occupy the first places in global production in general.

Table 6
Impact by country of origin of publications in Scopus

Country	Total citations	Average citation per article	General Ranking Position
China	109	4.4	2
USA	73	14.6	1
India	39	3.2	7
Serbia	35	17.5	52
Italy	11	11	8
Malaysia	10	3.3	26
Norway	10	10	31
Portugal	10	10	28
Hong Kong	9	4.5	32
Greece	6	3	33

5.2. Co-occurrence analysis

Keyword co-occurrence analysis of the Scopus database generated 5 clusters, 28 elements, 258 links and a total link strength of 924. Cluster 1 (red), about blockchain, had 27 occurrences and refers directly to the blockchain and its impact in the educational context. Group 2 (green), on e-Learning, had 6 occurrences and refers to the general context of online education. Cluster 3 (blue), about students, had 6 occurrences that show the influence of blockchain on students. Group 4 (yellow), about blockchain technology, had 3 occurrences and refers to the various technologies related to the blockchain. Finally, cluster 5 (purple), above higher education, had 3 occurrences and refers to artificial intelligence (see Figure 5). The most significant author keywords were students, education, blockchain and technology, as seen in the word map (see Figure 6). These keywords are the basis of the studies that have been generated in the current context. The axes of interest are directly focused on the impact of blockchain on education and on the population or study units.
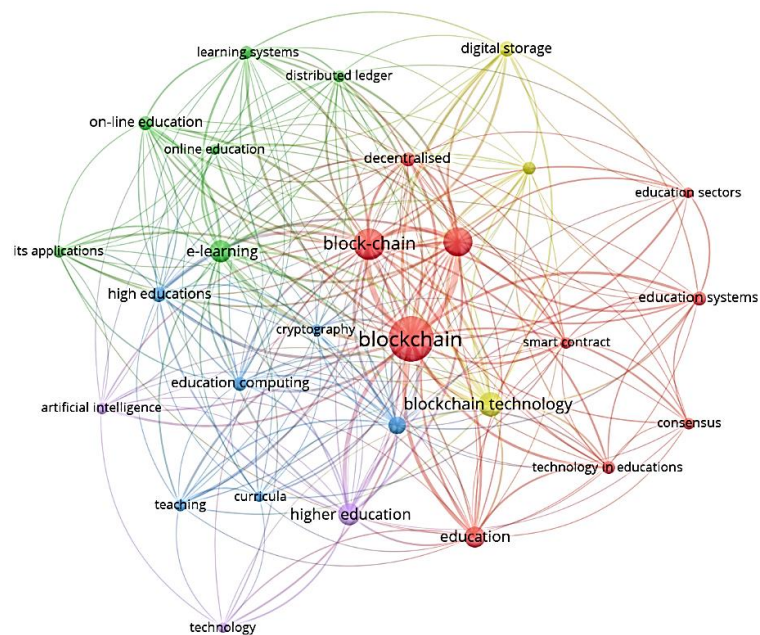

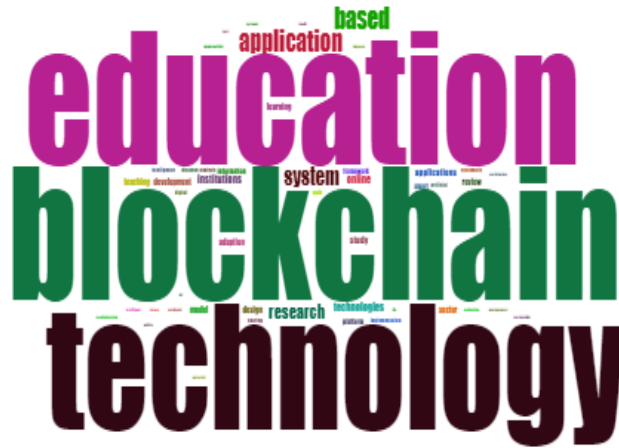**Figure 5.** Network visualization analysis in Scopus

Figure 6. Word Map (Scopus)

5.3. Thematic map

Figure 7 illustrates the thematic map with the driving themes in the upper left quadrant. These topics drive the scientific literature on blockchain, in particular, all issues related to digital transformation, cryptocurrencies and digital certificates. Other important and current topics are *online and digital* education, resource sharing and computer science. Regarding the basic topics, the educational system, blockchain applications and general ledger stand out. Among the niche topics, highly developed internally, but separated from all others, aspects related to security concerns stand out. On the contrary, among the emerging or declining topics, represented by underdeveloped and marginal topics in research, academic certification based on blockchain technology stands out as emerging.
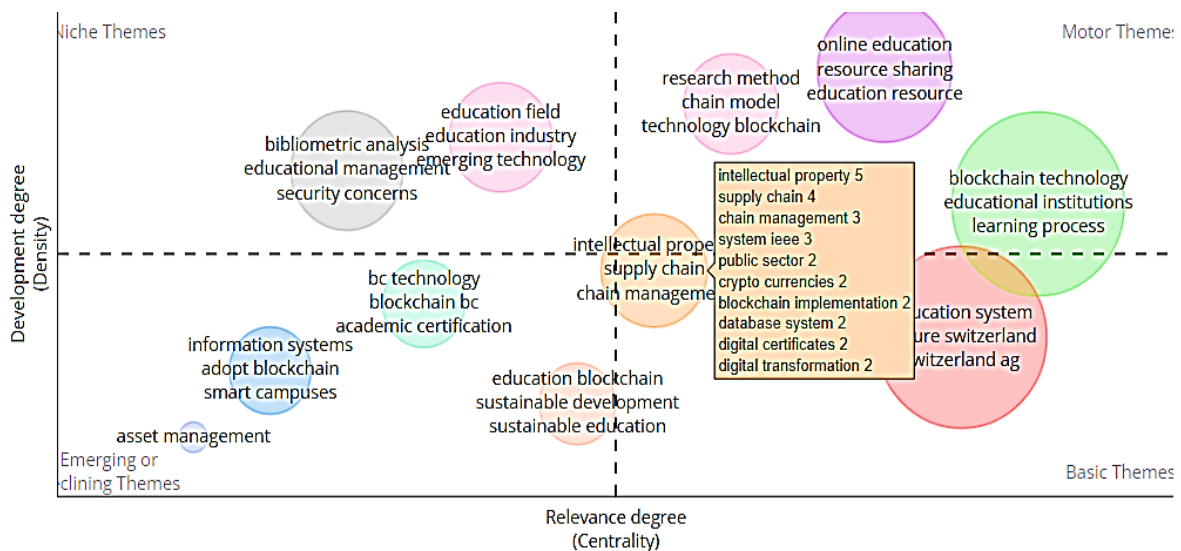

Figure 7. Thematic map (Scopus)

5.4. Factorial analysis

The results of the multiple correspondence analysis (MCA), based on the Conceptual Structure Map (CSM) method, show the conceptual structure of the keywords associated with blockchain used in the articles included in this study (see Figure 8). Keywords closer to the center point have been targeted more frequently in recent years.

In one dimension, the explained variance of dimension 1 (x-axis) reaches 27.94%, which is the highest value. On the contrary, the explained variance of the least relevant dimension 2 (y-axis) is 18.89%. The red group of title words covers topics related to higher education and technology, which are closer to dimension 1, highlighting words such as *technology* and *appliccations.*
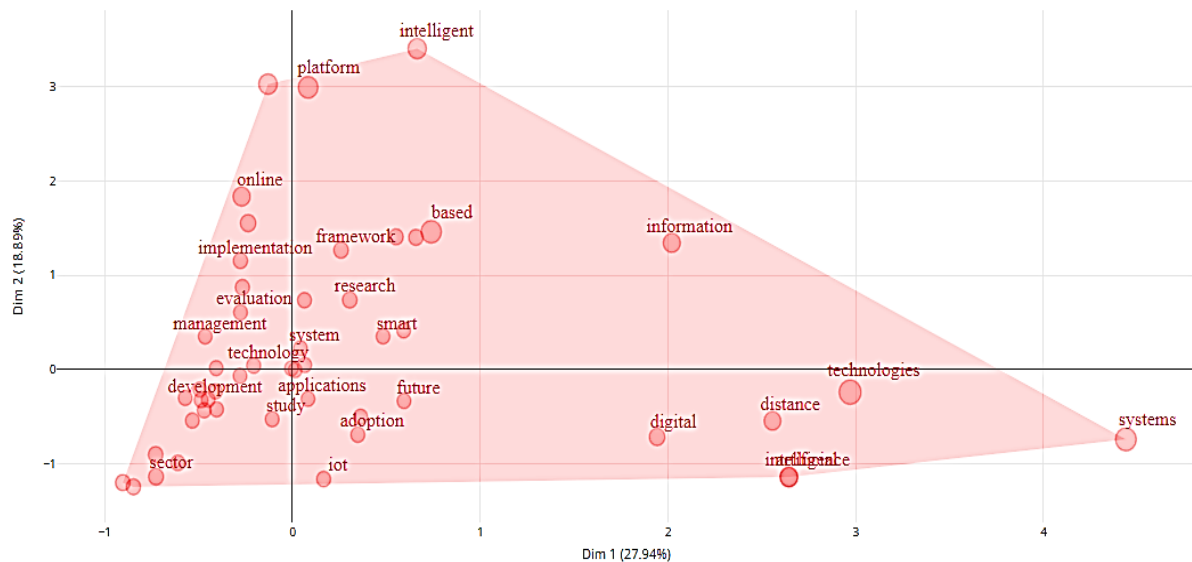

Figure 8. Factor analysis.

6. Conclusions

A bibliometric analysis aims to study the distribution structure, quantitative relationships, and variation in literature using measurement methods such as mathematics and statistics (Adams, 2018). The objective of this study was to carry out a bibliometric review of research objectives on blockchain in the educational context in the Scopus databases. To do this, the characteristics of the publications, authors, sources, collaborations between authors and countries, and research networks were analyzed.

A sample of 113 documents retrieved from the Scopus database were analyzed that had been published in 82 scientific journals, with 2,805 references and an average citation count per document of 5,761. The results of the analysis indicated that there is a greater presence of *conference paper* (61), followed by original articles and book chapters, results that coincided with what was found by Alammary et al. (2019) and Bhaskar et al. (2020) in their review study on *blockchain.* Production on this topic reached its peak in 2022, at the height of the rise of artificial intelligence, maintaining an annual growth rate of 35.10%. The validity of the topic and the importance and interest that it generates for specialized scientific journals in the field of technology and computing is evident.

Due to the pandemic, education had to assimilate all technological aspects to secure its data. In addition to that, the education industry is integrating with technology and has faced several challenges in maintaining academic details documents of each student for long periods (Reis-Marques et al., 2021). This is how false certification (fraudulent degrees and titles) poses a serious problem in today's world since it falsely legitimizes the skills of an individual, which puts the reputation of an organization at risk. Furthermore, the certificate verification process is usually carried out in a centralized manner, cumbersome and slow for the end user, lacking transparency in its issuance by educational institutions. Thus, blockchain has become a promising technology that provides transparent, secure and reliable features, in addition to offering solutions for the educational sector (Babu et al., 2022).

Regarding the most cited article, the study by Sun, Han stands out; Wang, Xiaoyue and Wang, Xinge of the year 2021, titled "Application of blockchain technology in online education", whereas the Bulgarian researcher Rocsana Bucea-Manea-Tonis emerges as the author with the greatest production on the topic (4) until the cut-off date of the study. The list of countries with the greatest impact on research is led by China, with 109 citations in Scopus, and the United States with 73 peer-reviewed papers. Both countries are the main contributors of research articles worldwide, which is why it should not be surprising that they are also the countries that concentrate the greatest number of articles with a high level of impact within the field of *blockchain* and education (Alammary et al., 2019; Alam et al., 2023).

The keyword co-occurrence analysis of the Scopus database generated five clusters, highlighting *blockchain* and its impact in the educational context, e-Learning and online education, the influence of *blockchain* on students and various technologies related to *blockchain.* This result was confirmed by various investigations such as that of Sun et al. (2018) who stated that *blockchain* in online education can solve problems related to the management and accreditation of processes through an intelligent, decentralized and shared education system (Fedorova & Skobleva, 2020). Blockchain technology in education are decentralized open data, the absence of falsifications, the secure storage of information and the reduction of transaction costs related to verification, control and data verification. Sathya et al. (2021) complements the above by adding decentralization, reliability, security, and data integrity as characteristics of this phenomenon.

Regarding the driving themes, the thematic map highlights all issues related to digital transformation, cryptocurrencies and digital certificates. In addition, they highlight topics such as *online and digital* education, resource sharing and computer science. Agarwal et al. (2021) highlight the application of blockchain technology in certificate management as the main topic. This includes handling and storing academic credentials, including transcripts, certificates, academic documents, degrees, etc. Malibari (2020), Jha et al. (2022) and Sawant (2023) highlight key aspects, for example decentralization, reliability, security and veracity of data. Regarding the basic topics, the educational system, blockchain applications and the ledger stand out. Sadasiuvam (2020) highlights the ability of this technology to record transactions as a distributed digital ledger, facilitating the recording, confirmation and exchange of contracts between legitimate parties securely.

Among the niche topics, aspects related to security concerns stand out. Alshareef (2022) highlights four concerns about blockchain technology in the education sector, including privacy and security leaks, processing cost, setting limits, and weakening of school credentials. Bhaskar et al. (2020) highlight scalability, security, and cost as barriers. Dubey & Tiwary (2023) point out as the main concern the limited existence of established standards and protocols for the use of blockchain technology in education. Whereas in emerging topics, academic certification based on this technology stands out. Bhaskar et al. (2020) highlight certificate management, digital guardianship consent, including promoting a collaborative learning environment. Thematically, blockchain and online learning are widely associated, reflected in their popularity in online education or e-learning environments.

In the education sector blockchain technology has been implemented in limited areas, but its potential is still untapped. Although a wide range of applications are rapidly emerging, progress is very slow. Successful adoption of blockchain technology cannot be done without jumping over barriers such as lack of data availability, scalability, immaturity, cost, immutability, boundary setting, trust, and weakening of traditional school credentials. For now this technology is quite useful for ensuring the storage, exchange and networking of information. However, it is suggested to conduct research that delves into technology and its use for better administration of the admission process, which will help evaluate the history of participation in extracurricular activities, strengthen the network of alumni in schools and colleges, and manage the library and services of information. Technology can further benefit teachers and researchers in school through the protection of intellectual property rights.

This paper contributes to the existing body of knowledge by highlighting the current development, benefits, challenges and current application of technology in the educational environment. However, it is recommended to work with or after databases (for example, Web of Science) for future studies, in addition to measuring scientometric indices of other variables related to the blockchain technology to evaluate its impact on education in the research results. On the other hand, bibliometrics does not allow us to fully portray the complexity and multidimensionality of the research impact (López-López et al., 2020) since, although it is possible to carry out bibliometric analyzes with small samples of data when the topics are focused or emerging (Xu and Yu, 2019), it is advisable to wait for further development to observe trends in the area, as has happened in other domains (Wang et al., 2015; Waltman and Van Eck, 2012). However, this study offers researchers an updated view of research trends and topics addressed on blockchain in education.

It is clear that in addition to solving significant challenges of conventional education, blockchain technology will bring immense success to learning. In addition, it benefits environmental sustainability by saving fuel used for transporting students and papers used for documents (educational resources and certificates) (Zhao et al., 2023). Therefore, the topic, like digital credentialing, is expected to be on the agenda for future research opportunities. Therefore, system developers, regulatory bodies, governments and education professionals must encourage the implementation and use of blockchain technology in learning. This technology has the potential to transform education by increasing security, authenticity and efficiency in the management of records, certificates and other educational aspects. As the technology evolves and challenges are resolved, we are likely to see more innovative applications of blockchain in the educational field.

7. Financing

8. Data availability statement

The information included in this article is the result of the analysis carried out by the researchers. Readers or reviewers who require additional information to validate the content of the study may send their queries to the corresponding author(s).

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