Revolutionizing Academic Integrity: The Emergence of Blockchain for Credential Verification - A Bibliometric Perspective

Kennedy C. Cuya[1], Thelma D. Palaoag[2]

[1]College of Engineering and Computational Science, Partido State University, Camarines Sur, Philippines.
[2]College of Information Technology and Computer Science, University of the Cordilleras, Baguio City, Philippines.
Email: kennedy.cuya@parsu.edu.ph

This paper examines into the intricate landscape of legal and regulatory challenges accompanying the implementation of blockchain technology for authenticating academic records in the Philippines. Employing a thorough bibliometric analysis, it charts the significant scholarly interest in blockchain, particularly noting a surge in research from 2017 onwards. The study meticulously examines the compatibility of blockchain technology with existing legal frameworks, including the Data Privacy Act of 2012, highlighting the potential for blockchain to revolutionize the verification process of academic credentials through enhanced security, transparency, and efficiency. However, the paper underscores the complexity of navigating legal and regulatory stipulations, emphasizing the need for a collaborative effort among educators, policymakers, legal experts, and technologists. This multidisciplinary approach aims to adapt legal standards to the decentralized and immutable nature of blockchain, ensuring the technology's alignment with privacy rights and intellectual property laws. The findings advocate for regulatory bodies to develop specific guidelines that cater to blockchain's application in educational settings, fostering an environment conducive to technological innovation within the legal and ethical boundaries. This study significantly contributes to the ongoing discourse on legal and regulatory preparedness for integrating emerging technologies like blockchain in the educational sector, setting a foundation for future research and policy development to leverage blockchain technology effectively and lawfully in academic record authentication.

Keywords: blockchain technology, educational credentials, legal frameworks, Philippines, regulatory compliance.

1. Introduction

In the Philippines, higher education institutions are key to nurturing future leaders[1], emphasizing the integrity of academic records. The digital age introduces the need for change in record management[2], with blockchain technology offering enhanced security[3],

transparency[4], [5], and efficiency[6], [7], [8]. While promising, blockchain's integration faces legal and regulatory challenges[9], [10], particularly around data privacy and compliance. This study explores these challenges within the Philippine higher education context, aiming to align blockchain with legal frameworks like the Data Privacy Act of 2012. Addressing these issues is crucial for maintaining academic integrity and supporting individual and national development. Our research seeks to guide policymakers, educators, and technologists in responsibly adopting blockchain, contributing to discussions on legal and regulatory adaptation to technological innovations and keeping Philippine higher education at the innovation forefront.

A. Importance of addressing legal and regulatory considerations

This paper examines the delicate balance between technological advancement and legal compliance in the Philippines' use of blockchain technology to authenticate academic records [11], [12]. Blockchain technology to improve credential verification presents a challenge for Philippine higher education institutions, which are governed by strict laws. This technology is decentralized [13], immutable [14], and transparent [15], improving security and efficiency but also changing data management and privacy. Legal and regulatory issues related to blockchain technology are examined. Blockchain compliance with the Data Privacy Act of 2012 and the E-Commerce Act of 2000 is its goal. The study also addresses data ownership and cross-border data exchange. The study advises educational institutions, policymakers, and legal experts on blockchain-based academic record authentication legal issues. It aims to regulate technology while upholding legal and ethical standards. The paper promotes blockchain technology in education. This would increase the credibility and international acceptance of Philippine academic qualifications while meeting legal requirements.

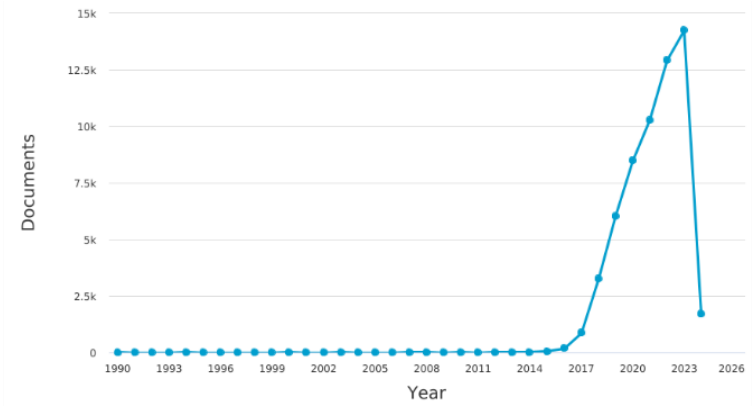

Figure 1 Blockchain-based article from Scopus from 1990 to 2024

Fig. 1, which shows a line graph of 57,954 articles from Scopus, shows a notable increase in the number of documents about blockchain technology over time. From a single document in 1990, there has been a noticeable increase in publications, which sharply increases in 2017 and 2023, when it peaks. There are various reasons for the recent increase in research on blockchain technology. The transformation of blockchain from a cryptocurrency platform to a technology with wider applications has generated interest in multiple industries.

The potential of blockchain technology to revolutionize various fields, including supply chain [16], [17], [18], [19],, digital identity verification [20], [21], and authentication of educational credentials [22], [23], [24], has attracted significant academic interest. The surge in publications around 2021 suggests that blockchain has reached a stage of development where its practical uses are being thoroughly investigated. This trend is especially pertinent to the research topic at hand. There is evidence of an increasing acknowledgement of the necessity for academic research into the legal and regulatory aspects of utilizing blockchain technology for educational objectives.

B. Digitalization of Philippine Government Services

In his State of the Nation Address, President Ferdinand Marcos of the Philippines emphasized the importance of digitalization to enhance services in the Philippine government, including academic institutions. This plan is consistent with the goal of the Philippines becoming a technologically advanced nation and has the potential to improve educational integrity while setting a precedent for modernizing governance. [25]. Blockchain offers efficiency, security, and transparency to the Philippine government's digital initiatives by initializing and utilizing the technology in areas that are susceptible to corruption [26], such as voting, records keeping, financial assets, and other government-issued reports. By digitizing documents and deploying smart contracts for public services, blockchain further enhances productivity and data control. Together with improving national management, this shift positions the Philippines as a new frontier in digital governance, supporting its goals of digital transformation to provide efficient, safe, and transparent public services for the people.

C. Use of bibliometric systematic literature review

A critical perspective on the implications of using blockchain technology for academic verification in the education and legal sectors is provided by bibliometric analysis. By conducting a methodical analysis of prior research, this approach aids in elucidating the way legal frameworks are undergoing transformation in tandem with technological progress. By identifying trends, key themes, and significant studies, this analysis highlights the shifts in legal discourse, particularly concerning privacy and other legal issues. It points out areas that require further investigation, enhancing our existing knowledge. The article highlights global initiatives to integrate blockchain technology into education and underscores the necessity of a multidisciplinary approach to developing comprehensive legal frameworks. Using tools like Scopus and VOS viewer for data collection and visualization allows for an in-depth exploration of the topic, aiding stakeholders in making informed decisions about the integration of blockchain technology in educational settings.

D. Data Sources

Our analysis began with a thorough evaluation of journal articles, employing several rounds of screening to refine the selection process and ensure the inclusion of accurate, original data. We initiated our research with a systematic exploration of the Scopus Database, conducted in three key phases: First, we opted for the Scopus Collection database as our primary source for documentary analysis. Next, we carried out an advanced search, employing specific criteria: "(blockchain) AND (academia OR higher AND education OR

university OR academe) AND (verification OR authentication OR certification) AND (legal OR regulation OR challenges OR constitutional OR statutory OR policies OR policy) AND (LIMIT-TO (DOCTYPE, 'ar') OR LIMIT-TO (DOCTYPE, 'cp') OR LIMIT-TO (DOCTYPE, 're')),'' with all key terms encapsulated in quotes to ensure precise search results. Lastly, our search was limited to documents published from 2015 to the present, aiming to capture the most relevant and recent contributions to the field.

Using this strategy, we reached 3,731 works. With the inclusion and exclusion criteria given in Table 1 applied, we proceeded with 3,298 works that are pertinent to our study on legal and regulatory considerations in the use of blockchain technology for academic record verification. This selection was narrowed down to articles (2148), conference papers (734), and reviews (416), while excluding other document types such as book chapters and retracted articlesOutputs obtained were in the form of files for additional analysis with other tools in CSV and RIS. Data quality was emphasized during the production of 3,298 documents using SciMAT. Preprocessing techniques, including keyword merging and de-duplication, were applied to increase the quality of science mapping, which included the merging of singular and plural forms of words and variants of the same concept. The Levenshtein distance can be defined as the minimum number of single-letter edits needed to change one word into the other; thus, it can compare the similarity between two words. [27], we successfully unified variants such as "BLOCKCHAIN" and "BLOCK-CHAIN" into "BLOCKCHAIN," as well as "AUTHEN-TICATION" and "AUTHENTICATION" into "AUTHENTICATION." This process guaranteed uniformity in the analysis of our dataset.

Table I Inclusion and Exclusion criteria

Inclusion Criteria	Rationale for Inclusion
Research that focuses on the implementation of blockchain technology in educational environments	To ensure that the research remains concentrated on the academic implementation of blockchain technology, which constitutes the primary subject matter of the article.
Literature pertaining to blockchain-related legal, regulatory, or compliance concerns	To capture the breadth of legal and regulatory challenges and considerations that directly impact blockchain implementation in academic records authentication.
Case study or application-based research on blockchain technology for credential verification	To draw from practical instances and real-world applications, providing insights into how legal and regulatory frameworks are applied in practice.
Publications spanning the years 2015 through 2024	By incorporating the latest advancements and discussions in the discipline, the paper guarantees that its conclusions remain current and relevant.
Exclusion Criteria	Rationale for Exclusion
Academic investigations that do not explicitly include blockchain technology	To maintain the focus on blockchain as the primary technology of interest and exclude tangential or unrelated technologies.
Papers that fail to discuss record authentication or legal/regulatory considerations	To focus on studies that are directly relevant to the legal and regulatory challenges of using blockchain for academic record authentication.
Duplicate research or the	To prevent redundancy and ensure each included study

publication of same findings in multiple journals	contributes unique data to the research.

E. Data Processing

The graph of Fig. 2 shows that the overall documents per year appear to increase, with each passing year; further, from around 2017, it appears that the increase became steeper, hence implying that this subject is gaining more attention. The 2021 document bar is extremely tall, indicating either very intense research activity or many documents on the topic that were published at this time. The increases over the years in the number of documents may well just reflect increasing relevance and application of blockchain technology in various fields, among others, in educational credentialing and how to authenticate it, expanding the discourse on possible legal and regulatory considerations.

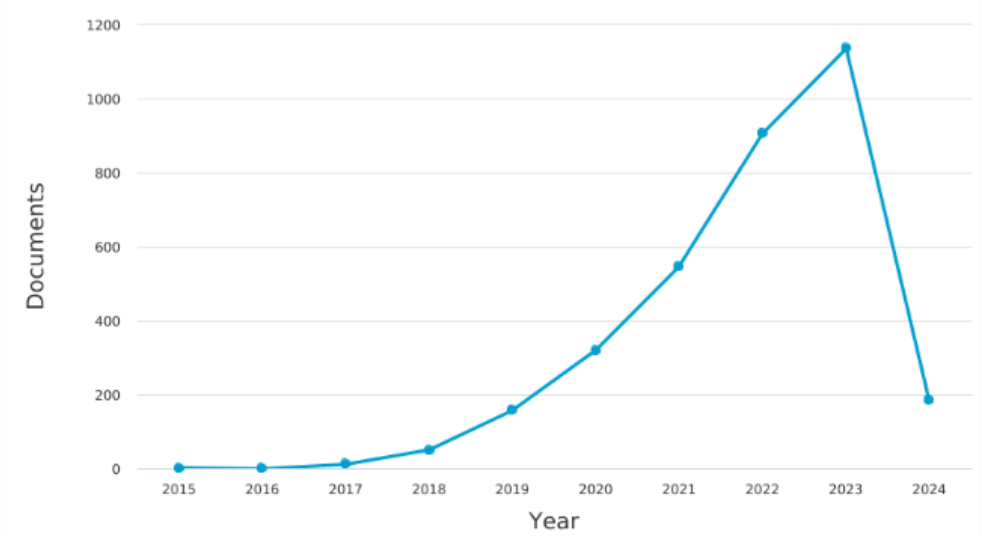

Figure 2 Publication of a blockchain-related article with regards to certification, authentication, and policies

The data on document publication from 2017 to 2023, as presented in Table II, illustrates a significant initial upswing in the number of publications. Following a 231.66% increase in 2017, the publication rate reached its peak at 354.55% in 2018. The observed increase in performance can potentially be ascribed to the introduction of novel initiatives, financial assistance, or policy adjustments. The decline in growth rates from 214% in 2019 to 24.70% in 2023 indicates a gradual stabilization, potentially indicating that the research domain is reaching maturity or encountering capacity constraints. Initial 2024 data indicates a -84.26% decline in growth; however, this represents only the first quarter, and an accurate forecast of the year's trajectory may be hampered by seasonal or other factors. Continuous monitoring is essential for achieving a more comprehensive understanding of the performance over the course of 2024.

Table II Annual Growth Rate of Document Publications from 2015 to 2024

Year	Number of Publication	Annual Growth Rate (%)
2015	1	0
2016	-	0
2017	11	231.66%
2018	50	354.55%
2019	157	214.00%
2020	319	103.18%
2021	544	70.53%
2022	907	66.73%
2023	1131	24.70%
2024	178	-84.26%.

F. Research Period Division

The initial article pertaining to Blockchain, as indexed by Scopus, appeared in 1990. However, it falls outside the purview of our investigation. As depicted in Fig. 1, it was not until 2015 that we observe the emergence of the first blockchain-focused publication addressing aspects of certification[28], [29], authentication[30], [31], and policy measures[32]. This time frame marks the beginning of a significant increase in scholarly literature on the topic, emphasizing the critical areas of authentication[12], [33], [34], [35], security policies[36], and regulatory frameworks within the academic exploration of blockchain technology.

2. Results and Discussion

This section offers a thorough examination of significant metrics related to academic output and impact in the field of blockchain research. We offer a thorough overview of the academic landscape by looking at the contributions of the most prolific authors, the yearly output of documents by source, and identifying the top nations and universities for blockchain research. We also identify the main research areas driving blockchain development and evaluate the impact of these contributions using citation metrics. This synthesis not only clarifies the current state of blockchain research but also emphasizes the multidisciplinary and cooperative efforts that are advancing the field.

The most productive authors

The exploration of blockchain technology for verifying academic records has attracted a broad spectrum of scholars, with a noteworthy concentration of work stemming from a few key individuals. An analysis of publications indexed by Scopus reveals that authors like U. Rahardja[37], [38], [39], [40], [41], [42], [43], N. Kumar[44], [45], [46], [47], M. [48], [49], A. [50], R. [51], and R. [52], [53], [54], among others, have been particularly influential in this field. Rahardja emerges as the most prolific of these contributors, highlighting either a deep research commitment or a leadership role in this niche. This pattern of publication underscores the central figures in the discourse and potential collaborators. Further examination confirms the significant impact these researchers have had on the discussions

concerning the legal and regulatory challenges of applying blockchain in educational contexts.

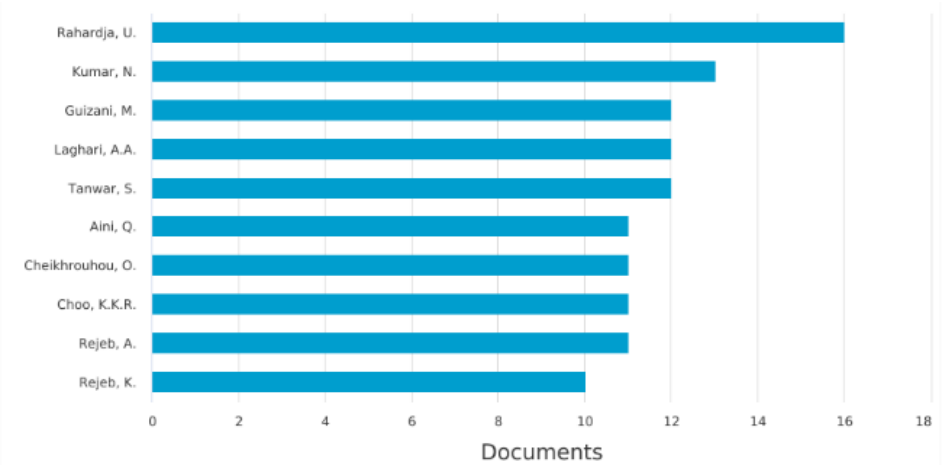

Figure 3 Documents by author comparing document counts for up to 15 authors

Documents per year by source

Noteworthy contributions in the field of blockchain research can be found in respected journals such as 'IEEE Access,' 'IEEE Internet of Things Journal,' 'Electronics Switzerland,' 'Sustainability Switzerland,' and 'Sensors.' The participation of these journals highlights the comprehensive and interdisciplinary nature of blockchain research, encompassing various fields such as technology, sustainability, and sensor studies. This trend suggests that there is a growing interest in exploring the various aspects of blockchain, going beyond its technical foundations to encompass its potential uses in areas such as environmental sustainability and the Internet of Things (IoT). The significance of these journals in blockchain discourse highlights their function in directing both academic research and practical technological advancements in this emerging field.

Table III Top 20 Source

Source	Documents	Citations	Total Link Strength
IEEE Access	157	4609	118
IEEE Communications Surveys and Tutorials	18	2154	39
IEEE Internet of Things Journal	70	2037	58
Sustainability (Switzerland)	86	1396	12
Journal of Network and Computer Applications	20	1338	31
ACM Computing Surveys	18	1111	3
Applied Sciences (Switzerland)	46	1081	15

IEEE Transactions on Industrial Informatics	20	901	30
IEEE Transactions on Vehicular Technology	15	830	25
Sensors	57	636	18
Computer Communications	17	569	18
Electronics (Switzerland)	47	512	21
Future Generation Computer Systems	12	490	12
Sensors (Switzerland)	14	478	3
Computers and Security	13	412	0
Transactions on Emerging Telecommunications Technologies	22	410	10
Energies	21	384	1
International Journal of Production Research	12	373	1
Future Internet	15	369	4
Computers and Industrial Engineering	8	362	2

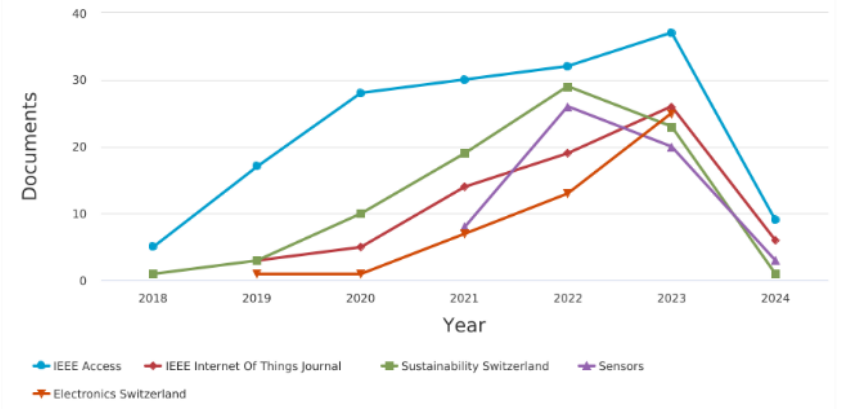

Figure 4 Publication by source*

*Examine the document counts for a maximum of ten sources. View CiteScore, SJR, and SNIP data, and compare sources.

Most productive countries and institutions

This analysis reveals that China, India, the United States, the United Kingdom, and Saudi Arabia are leading in blockchain research, as per the Scopus database. China's position reflects its heavy investment and rapid progress in blockchain technology, followed by India, which aligns with its growing tech industry. The involvement of the U.S., U.K., and Saudi Arabia underscores the widespread interest in blockchain across various sectors worldwide. These countries are at the forefront of exploring blockchain's diverse applications, from

finance to education, contributing significantly to the global conversation on this technology. Their research outputs are crucial in shaping legal and regulatory frameworks around blockchain, especially in academic credential verification.

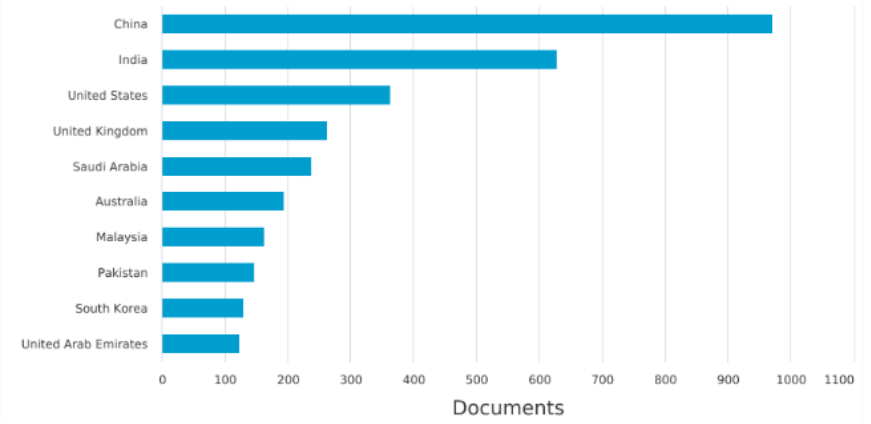

Figure 5 Documents by country or territory comparing the document counts for up to 15 countries/territory

Citation of publication by source

"IEEE Access" is the foremost publisher in blockchain research, with 157 documents that make up 9.58% of the total publications in this field. Following it are "Sustainability (Switzerland)" and "IEEE Internet of Things Journal," accounting for 5.25% and 4.27% of the total publications, respectively. These journals are crucial in promoting discussions regarding the educational uses of blockchain technology. The journal "IEEE Access" leads not only in terms of the number of publications but also in impact, as its articles have received 4,609 citations, accounting for 15.02% of the total citations in the field. Similarly, the journal "IEEE Communications Surveys and Tutorials" has garnered a notable impact, as evidenced by its 2,154 citations from a mere 18 documents. This highlights the journal's esteemed reputation within the academic community.

Fig. 6 shows the VOSviewer network visualization with "IEEE Access" as having the highest total link strength at 118, suggesting its central role in blockchain research. The "IEEE Internet of Things Journal" and "IEEE Communications Surveys and Tutorials" also have notable link strengths, demonstrating their influence. This visualization depicts the academic landscape's key players and their interconnections, highlighting interdisciplinary engagement and idea exchange critical for advancing blockchain in education. The network view shows 'IEEE Access' as a focal point, with surrounding journals illustrating the thematic breadth of blockchain research, from IoT integration to sustainability, based on a dataset of over 3,000 articles from Scopus.

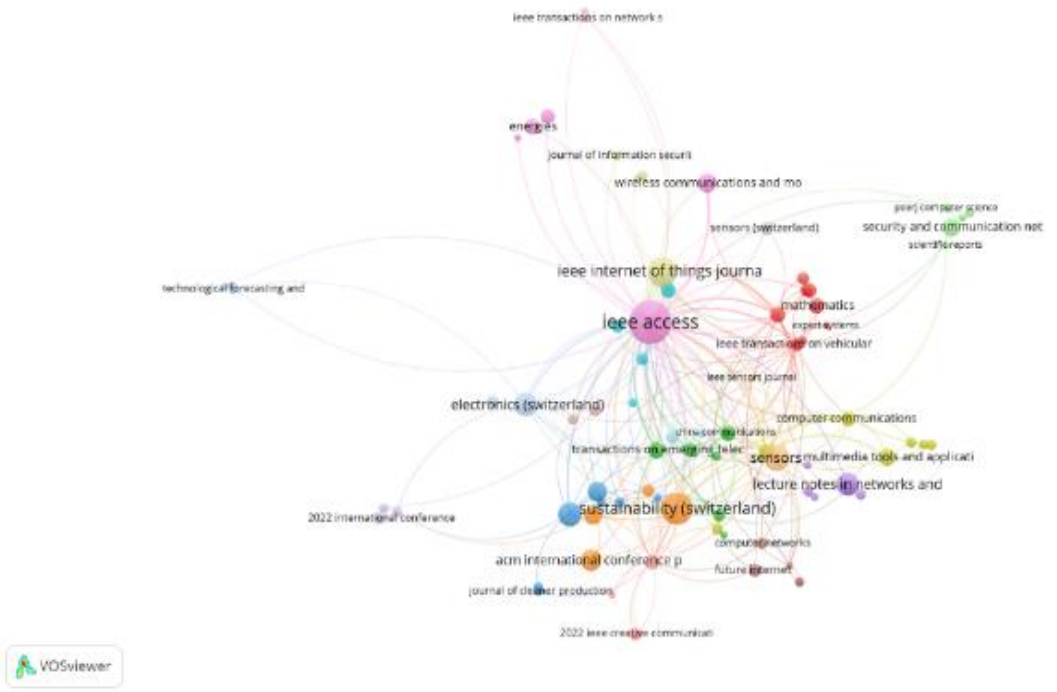

Figure 6 Citation of publication by source

Main Research Areas

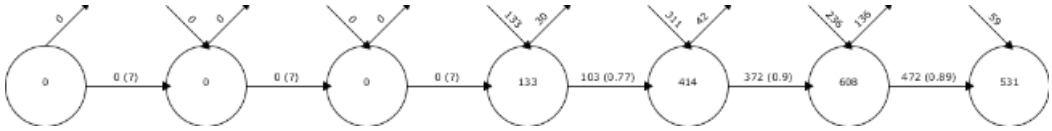

Figure 7 Longitudinal results, overlapping maps

Fig. 7's chronological display of circle sizes from 2010 to 2024 illustrates the evolving volume of blockchain research, initially focused on cryptocurrencies and gradually expanding to broader uses like education. A noticeable increase in publications from 2017 to 2018 signals the start of widespread interest in blockchain's potential beyond finance. This trend continues, with a peak in 2021–2022, indicating heightened research on blockchain's practical applications and regulatory aspects in education. Despite a slight dip in 2023–2024, based on early data, the field remains vibrant, suggesting ongoing innovation and exploration of blockchain in various sectors, especially in verifying educational credentials. The overall trend illustrates how blockchain has evolved from a specialized technology to a major force in reshaping a variety of industries, including education, and it shows how rapidly things have been developing and how much more is possible. The landscape of blockchain technology for academic record authentication has seen substantial scholarly attention and development over the course of seven years, from 2017 to 2024, as evidenced by the changing bibliometric statistics.

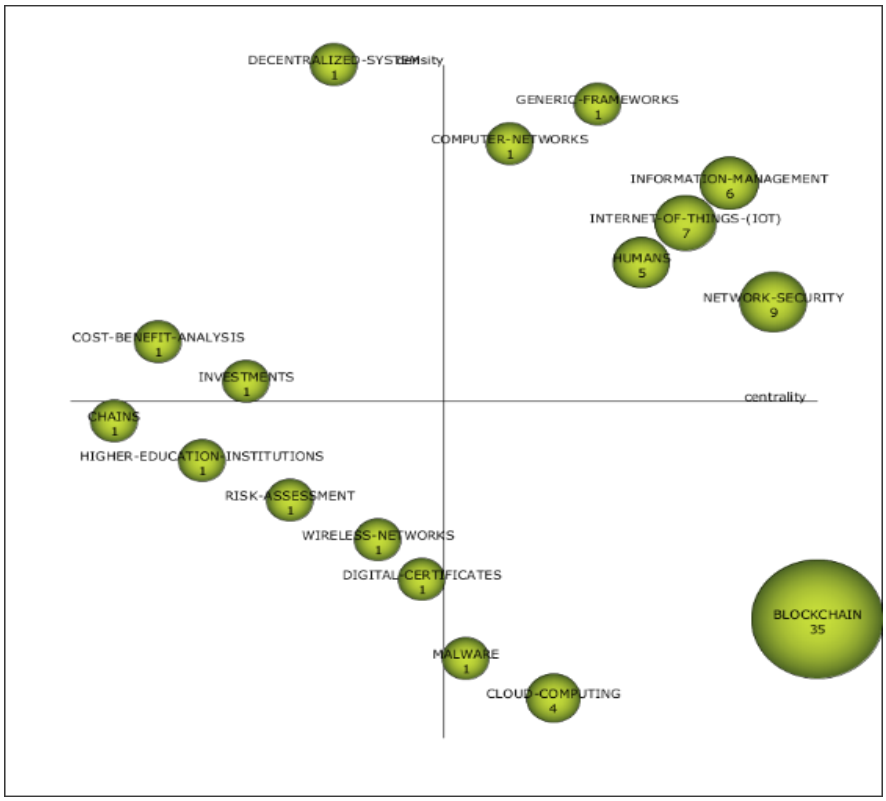

Figure 8 Strategic Diagram, 2017-2018

2017-2018 Period: During this period, Fig. 8 illustrates that blockchain technology began capturing the attention of the academic world, as evidenced by its moderate centrality of 166.61 and a significant density of 136.96. These metrics suggest the formation of an emerging cluster of research, tightly interconnected yet in its infancy. The relatively narrow centrality range (0.82) and density range (0.76) indicate a budding yet swiftly consolidating scholarly conversation around blockchain. This initial phase of research was primarily dedicated to laying down the technical and legal foundations of blockchain as it applies to academic records. It underscored the technology's potential to bolster the integrity and verifiability of academic credentials, marking the start of a profound exploration into blockchain's capabilities and implications in the educational sector.

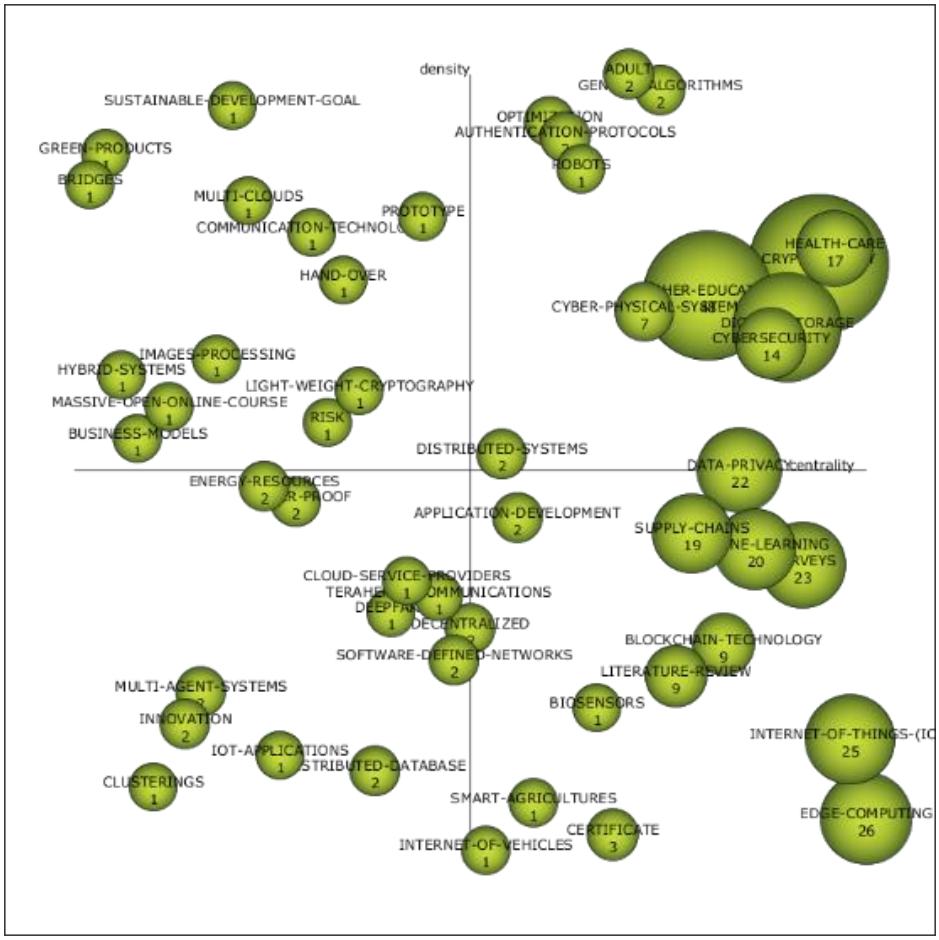

Figure 9 Strategic Diagram, 2019-2020

2019-2020 Period: Fig. 9 reveals a marked increase in blockchain's relevance to academia, highlighted by a centrality score of 249.39 and a density of 90.97, indicating both growth and a deepening of blockchain research. The centrality and density ranges suggest a growing maturity in discussions about blockchain's potential and legal aspects, focusing on standardization and privacy—key for recognizing academic credentials across institutions. This period marks a shift towards a deeper understanding of integrating blockchain in education, aiming for secure, standardized, and privacy-respecting academic verification mechanisms.

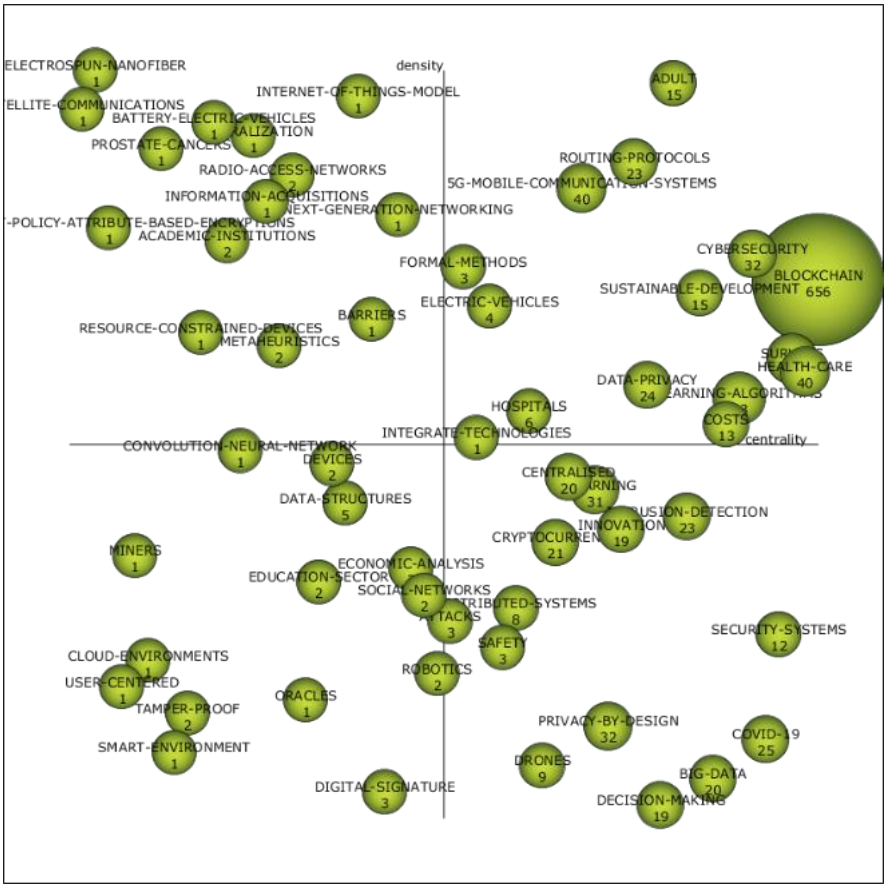

Figure 10 Strategic Diagram, 2021-2022

2021-2022 Period: Fig. 10 indicates a significant uptick in the centrality and density values to 301.51 and 139.38, respectively, signaling a growing and more unified interest in blockchain within academic research. This trend reflects an evolving dialogue, focusing more on the practicalities of blockchain integration and the development of strong legal frameworks. It highlights a collective effort to tackle the challenges of adopting blockchain for credential verification, stressing the importance of technologically effective and legally compliant solutions. This stage represents a concerted push to navigate the complexities of blockchain use, aiming to maximize its benefits for academic credential verification within a conducive legal and regulatory framework.

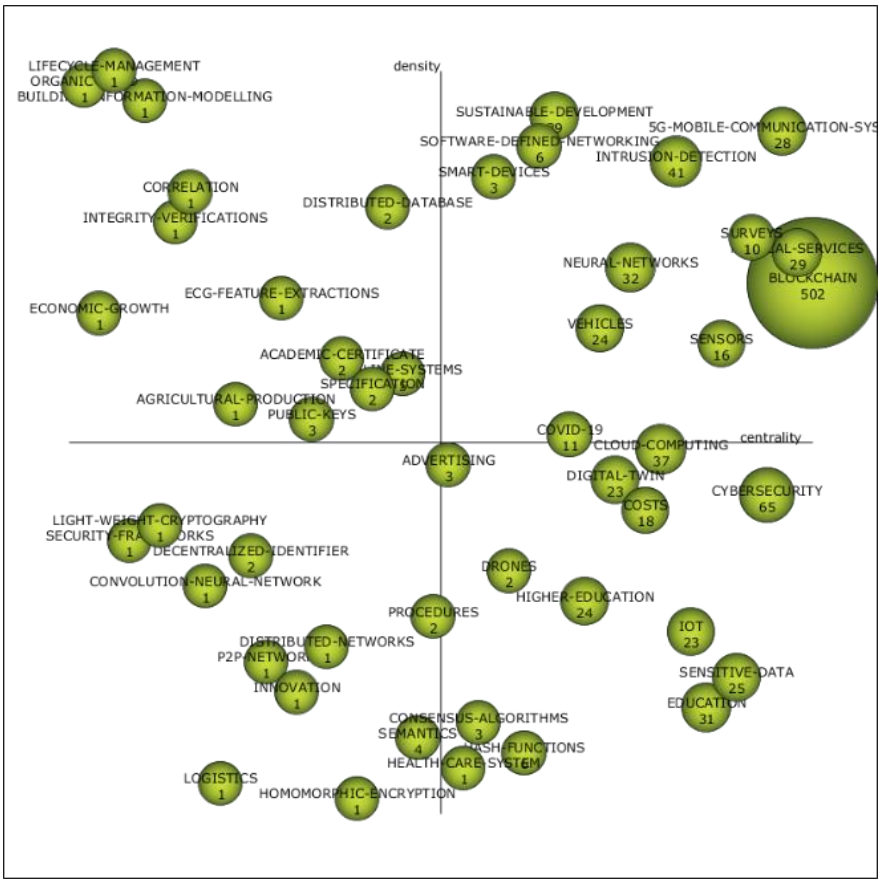

Figure 11 Strategic Diagram, 2023-2024

2023-2024 Period: During this period, Fig. 11 shows the stability in centrality at 182.34 alongside a density of 22.1 indicates that the expansion of blockchain research within the academic sector has reached a plateau, yet it maintains a considerable degree of influence and has evolved into a specialized field. The specific centrality and density ranges, 1 and 0.71 respectively, signify the emergence of a solid, well-established research network. There's a noticeable shift towards refining the legal and regulatory structures necessary for the deployment of blockchain technology in educational settings. This focus on legal and regulatory adjustments reflects an acute awareness of the need for secure, ethical, and robust blockchain applications that can address the unique challenges of educational environments. This phase suggests a mature phase of blockchain research, where the primary concerns revolve around ensuring that blockchain's integration into education is not only technologically sound but also aligns with ethical standards and legal requirements.

Across all periods, the numbers indicate a trajectory of growth from conceptual understanding to practical applications and policy formulation. The increasing centrality and density reflect a community that is not only expanding but also becoming more cohesive as it addresses the complexities of blockchain. This evolution mirrors the necessity for dynamic legal frameworks that cater to the technology's characteristics, such as decentralization, immutability, and transparency, while balancing concerns related to privacy, data protection, and institutional governance. The cumulative insights from these periods reveal the escalating relevance of blockchain technology in transforming the management of academic records, with significant implications for educational policy and regulation globally.

Bibliometric and Content Analysis

Drawing from 3,298 documents in the Scopus database, this study leverages advanced bibliometric techniques to detail the evolution of blockchain research in academia, with a focus on credential verification. By crafting overlapping maps, thematic diagrams, and a thematic evolution map, we offer a deep dive into the field's development, showcasing trends, transitions, and expanding areas of interest. This approach aims to pinpoint opportunities for further policy debate, regulatory developments, and discourse, emphasizing blockchain's transformative impact on education. The study not only highlights the technology's contribution to academic integrity and efficiency but also its changing role in refining educational policies and frameworks.

In this study, we apply bibliometric analysis using the full counting method through VOSViewer to dissect the scholarly landscape and connectivity in blockchain research. Setting a term occurrence threshold of 55, we sifted through 63,002 terms, narrowing down to 419 significant ones, and further refined our focus to the top 60%, or 251 terms, closely aligned with our research on blockchain's legal and regulatory aspects in academic verification. This methodological approach ensures our analysis focuses on the most impactful themes, shedding light on the crucial legal and regulatory considerations of blockchain technology in the academic sphere. Our strategic selection process pinpoints the key concepts and discussions surrounding blockchain's application in education, offering detailed insights into the evolving legal frameworks that govern its use. This precise focus on relevant terms and themes underscores our aim to explore the intricate legalities and regulations influencing blockchain technology's role in authenticating academic records. The network visualization in the bibliometric analysis of blockchain research forms a detailed map of the field's thematic landscapes. It identifies key research areas through clusters differentiated by color, each representing a specific focus within blockchain studies.

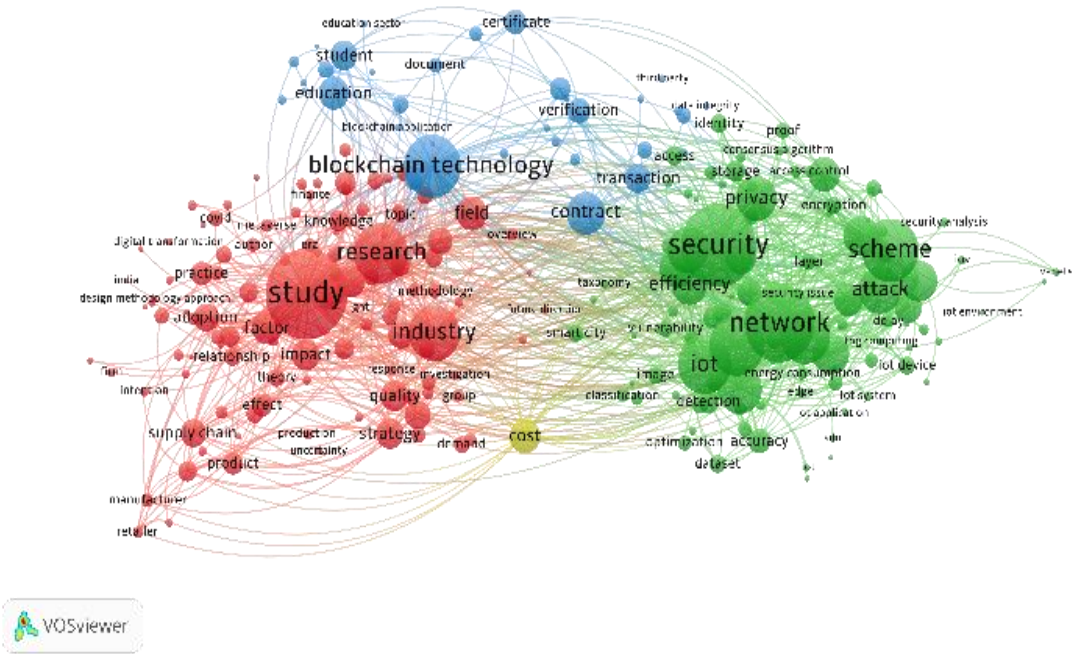

Figure 12 Network Visualization (with 55-term threshold)

Table IV All keywords' data: Occurrence of the 20 most frequently appearing terms in each cluster

Cluster 1 (with 115 items)	Cluster 2 (with 102 items)	Cluster 3 (with 33 items)	Cluster 4 (with 1 item)
study	security	blockchain technology	cost
research	network	contract	
industry	scheme	education	
factor	internet	student	
field	iot	transaction	
literature	algorithm	verification	
supply chain	thing	certificate	
strategy	attack	record	
impact	user	transparency	
adoption	privacy	integrity	
quality	device	university	
value	node	institution	
role	protocol	block	
review	mechanism	document	
practice	efficiency	credential	
sector	authentication	authenticity	
knowledge	architecture	higher education	
effect	communication	party	
organization	vehicle	cryptocurrency	
perspective	cloud	course	

The Cluster 1 (Green) centers on the technical foundations of blockchain, such as security protocols[55] and privacy[56], [57], [58] mechanisms. This cluster underscores the importance of developing secure and private blockchain systems for decentralized transactions, highlighting the core technical challenges and innovations in blockchain technology.

Cluster 2 (Red) explores meta-research, examining the breadth of existing studies on blockchain. This includes systematic reviews[59] and literature analyses[60], aiming to consolidate knowledge, pinpoint research gaps, and suggest future directions. The presence of this cluster underscores the reflexivity within blockchain research, promoting a critical overview of how the field is evolving.

Cluster 3 (Blue) focuses on blockchain's application in the educational sector, touching on topics like credential verification[61], [62] and institutional adoption. Keywords such as "education," "university," and "student" point to a keen interest in how blockchain can revolutionize record-keeping, transparency, and verification processes in academic settings.

Cluster 4 (Yellow), though smaller and focused on "cost," highlights economic considerations in blockchain implementation[63], [64], [65]. It suggests an exploration of blockchain's cost-efficiency and financial implications for various applications, including education.

These clusters illustrate the multifaceted nature of blockchain research, from foundational technical issues to practical applications in education and economic analysis. The emphasis on security and privacy (Cluster 1) aligns with the critical need for trustworthy systems in applications like academic record verification. The exploration of blockchain in education (Cluster 3) directly addresses the potential for enhancing transparency and integrity in credentialing processes. The focus on economic aspects (Cluster 4) reflects the practical considerations of adopting blockchain technologies. Together, these clusters offer a comprehensive view of the current state and future directions of blockchain research, emphasizing its interdisciplinary impact and the ongoing dialogue between technology and its real-world applications.

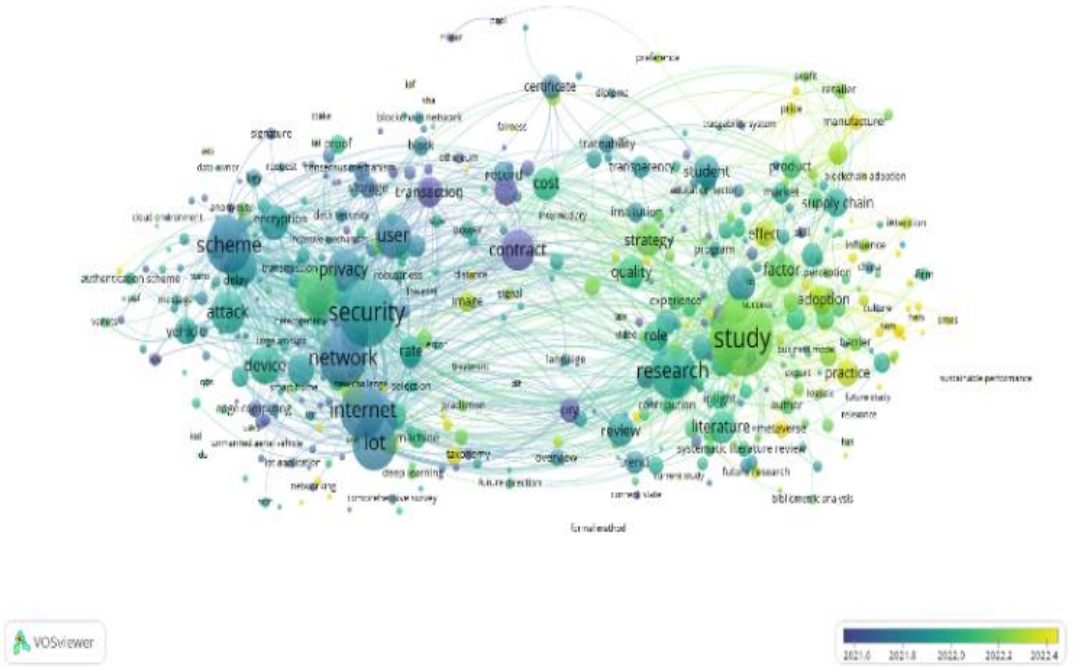

Figure 12 Overlay Visualization

The overlay visualization crafted from the bibliometric analysis presents a rich tapestry of blockchain research, highlighting several key thematic areas. Central themes focus on blockchain's technical and security aspects, marked by terms like "scheme," "encryption," "privacy," "authentication," and "transaction." These terms underscore efforts to strengthen technology's foundation[66], [67]. Expanding outwards, research on blockchain's infrastructure is indicated by terms such as "network," "device," and "IoT," reflecting efforts to build a robust digital architecture that integrates with emerging technologies[68], [69]. A distinct theme revolves around blockchain's educational applications, signaled by terms like "certificate," "student," and "education," exploring its potential in academic credentialing. Legal discussions are also prominent, with terms like "contract," "law," and "institution" highlighting the exploration of smart contracts within legal frameworks. Moreover, the visualization includes meta-research themes, with "research," "study," "literature," and "systematic review" indicating a reflective examination of blockchain's research progression. Additionally, a theme on supply chain management emerges, composed of terms like "supply chain," "product," "manufacturer," and "retailer," pointing to blockchain's role in enhancing global supply chain networks. This figure, depicted through various themes and a temporal color gradient, offers insights into the dynamic evolution of blockchain research, covering its technical foundations, educational and legal applications, and implications for supply chain management. A deeper exploration of this visualization can provide a comprehensive view of the field's growth and thematic diversification.

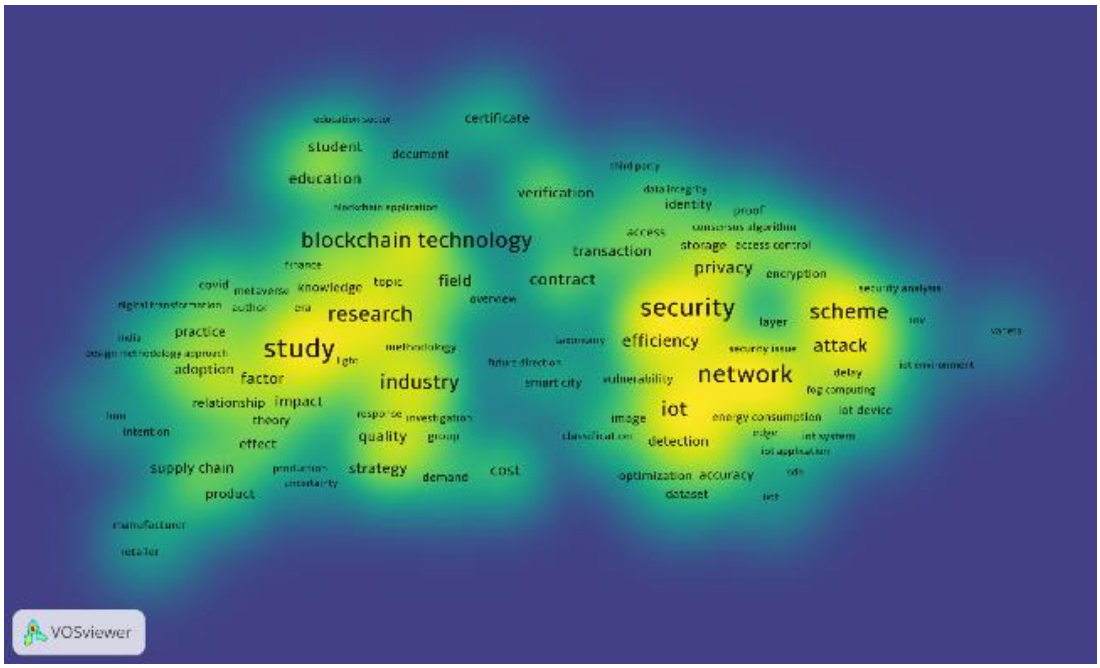

Figure 13 Density Visualization

Fig. 14 presents a network visualization created using VOSviewer, showcasing the interrelatedness of various terms within a specific research domain, likely centered around blockchain technology and its applications. The layout of the terms forms distinct clusters that can be interpreted as follows:

In the central cluster, you'll find key terms like "blockchain technology," "research," "study," "industry," and "education," which are fundamental to the research landscape. These terms seem to represent core subjects, with a focus on how blockchain technology can be used in educational settings, perhaps for tasks like verifying credentials and managing student records. Adjacent to this central cluster is another important group of terms centered around "security," "privacy," "network," and "scheme," with related terms like "iot" (Internet of Things), "encryption," and "attack." This suggests a strong emphasis on cybersecurity aspects of blockchain, including challenges and solutions for securing networked systems and devices, as well as safeguarding privacy. Spread around the edges are terms like "verification," "certificate," "identity," and "consensus algorithm," hinting at specific applications of blockchain technology, such as authenticating academic records and ensuring integrity and agreement within the blockchain. Connections between these terms are shown with lines, indicating relationships between different research areas. For example, the link between "industry" and "supply chain" may suggest an exploration of how blockchain can be used in managing supply chains. Similarly, the proximity of "cost" to "strategy" and "demand" could indicate an analysis of the economic implications of implementing blockchain technology. The overarching theme of the figure and the positioning of the terms suggest a comprehensive examination of blockchain technology's role in various sectors, with particular emphasis on security concerns and the potential for innovation in educational

services and industry applications. The visualization underscores the multifaceted nature of blockchain research, encompassing technical, educational, industrial, and security dimensions.

Clusters

The bibliometric analysis reveals how blockchain's integration into the academic record verification process involves a complex interplay of technology, legality, security, and economics, distributed across different thematic clusters, which is presented in Table V:

Industry Adoption (Red Cluster): This cluster highlights the trend of incorporating blockchain into academic verification, emphasizing the need for legal frameworks to adapt to and foresee the implications of these technological shifts. It calls for legal structures that are responsive to innovations and capable of addressing potential disruptions. Blockchain in Education (Blue Cluster): Focused on document verification and course management within educational settings, this cluster points to legal considerations around the authenticity of blockchain-validated documents. It underscores the need for educational policies and laws to recognize the validity of blockchain-authenticated credentials.

Security and IoT (Green Cluster): Concentrating on technological aspects, especially in the context of IoT, this cluster stresses the importance of addressing security concerns and data privacy within the blockchain-IoT integration. Legal and regulatory discussions must consider the safeguarding of data integrity and privacy protection. Economic Implications (Yellow Cluster): This cluster delves into the economic aspects of blockchain technology, highlighting cost considerations and the demand for secure, cost-effective academic record-keeping solutions. It emphasizes the necessity for financial foresight in legal frameworks to support blockchain's economic viability in education.

Table V Clusters of Keywords

Topic Clustering	Keywords
Cluster 1 (red) Implementation and Impact Analysis	study, research, industry, field, factor, literature, impact, strategy, quality, value, adoption, supply chain, role, review, sector, practice, effect, organization, product, perspective
Cluster 2 (green) Technical Foundations and Security	security, network, scheme, internet, iot, algorithm, thing, attack, user, privacy, device, node, protocol, mechanism, efficiency, authentication, architecture, communication, vehicle, cloud
Cluster 3 (blue) Educational Applications and Credential Verification	blockchain technology, contract, education, student, transaction, verification, certificate, record, transparency, integrity, university, institution, block, document, credential, authenticity, higher education, party, cryptocurrency,

	course, blockchain network, blockchain application, data integrity, third party, education sector, educational institution, learner, higher education institution

By weaving these clusters into a unified narrative, it's evident that blockchain's entry into academic credential verification represents a multidimensional challenge, involving more than just technological advancement. It necessitates a comprehensive and proactive regulatory stance to ensure educational institutions adopting blockchain for record authentication are supported by a conducive legal and regulatory environment. This scenario calls for collaborative efforts among educators, technologists, lawmakers, and regulators to establish a secure, legally recognized, and economically viable blockchain framework for the future of educational credentialing. While this study explores the surge in blockchain research and its potential applications in enhancing security, transparency, and efficiency of academic credential verification, it also highlights that the research and legal discourse have only considered several conditions of law, legal considerations, and regulations. The analysis delves into existing legal frameworks such as the Data Privacy Act of 2012 and the E-Commerce Act of 2000, alongside regulatory bodies' guidelines, yet underscores the complexity of fully addressing the legal and regulatory stipulations necessary for blockchain's successful implementation in the educational sector. The bibliometric analysis underscores an essential aspect of integrating blockchain technology into the authentication of academic records in the Philippine education sector: the concentration on blockchain's technical attributes—such as immutability and security—while highlighting a notable gap in the exploration of legal matters. The analysis reveals that current scholarly efforts, as reflected in the surge of publications post-2017, primarily focus on blockchain's technological prowess, including its application and usability within various sectors, notably education. However, it brings to light the scarcity of discourse on the specific legal considerations and regulatory frameworks that are essential for the technology's comprehensive adoption and operationalization within educational settings. This gap underscores a critical need for further exploration and development in understanding the legal and regulatory landscapes that govern the use of blockchain technology in the Philippines. The document points out that while blockchain offers promising solutions to enhance the verification process of academic credentials through its key features, there's a pronounced necessity to delve into the various statutory and regulatory bodies in the Philippines. These entities are crucial in providing clear, concise, and comprehensive guidelines for the application of blockchain technology that meets all required certifications and compliances, such as international standards like ISO or mandates from relevant Philippines government instrumentalities. Like the Philippines' National Privacy Commission, points several considerations:

1) Compliance with the Data Privacy Act of 2012 which mandates that any processing of personal information through blockchain must uphold principles of transparency, proportionality, and legitimate purpose. This adherence extends to safeguarding the rights of data subjects, particularly concerning access, correction, and erasure of personal data, which poses a unique challenge due to blockchain's immutable nature.

2) The application must fulfill functions of public authority as per constitutionally or statutorily mandated functions, aligning with the objectives of law enforcement or regulatory functions.

3) The establishment of a blockchain-based system for document verification also needs to be consistent with the PPSA's requirement for a centralized online notice-based registry.

4) The system's design should consider international standards and best practices to ensure a robust and compliant framework.

5) Clarifying the roles and responsibilities of all entities involved in the blockchain process is crucial to identify the actual Personal Information Controllers (PICs). This step ensures accountability and the protection of data subjects' rights, addressing potential ambiguities about who bears responsibility for personal information within the blockchain's decentralized structure.

6) Security measures, both organizational and technical, must be rigorously implemented to protect personal information managed through blockchain technology.

7) When engaging third-party service providers, agreements must meticulously outline the rights, obligations, and liabilities of all parties involved.

8) To uphold transparency, it is advised to provide a privacy notice to data subjects, detailing the processing's legal basis, data usage, storage practices, and disclosure policies. This ensures data subjects are fully informed about the handling of their personal information.

9) Conducting a Privacy Impact Assessment (PIA) is recommended to evaluate the risks associated with personal data processing through blockchain technology, aiding in the identification, assessment, evaluation, and management of these risks.

The design of blockchain technology must be approached from a data privacy perspective, potentially enabling more significant control by data subjects over their personal information.

3. Conclusion

Exploring technological solutions to reconcile the challenge of immutability with the exercise of data subject rights is essential. Thorough documentation of all processes and software design changes will facilitate addressing technological issues and determining appropriate resolutions. This exploration is crucial not just for ensuring the operational viability of blockchain-based applications but also for aligning these technological innovations with the country's legal and regulatory expectations. It is necessary to draw attention to a more integrated approach, involving stakeholders from the educational, technological, and legal domains, to collaboratively address these challenges is warranted. It suggests that the Philippines' education sector must embark on a concerted effort to explore and establish a legal and regulatory framework that not only accommodates but also promotes the safe, ethical, and effective use of blockchain technology. This includes

ensuring compliance with existing laws and regulations, adapting legal frameworks to accommodate the unique characteristics of blockchain, and fostering an environment conducive to technological innovation within the legal and ethical boundaries. In essence, the conclusion drawn from the bibliometric analysis calls for a multifaceted investigation into the legal and regulatory considerations specific to the Philippine context. Such efforts should aim to develop a comprehensive understanding that facilitates the inclusion of legal and regulatory provisions necessary for the adoption and implementation of blockchain technology in the education sector. The proactive pursuit of this knowledge and the formulation of appropriate policies and guidelines will be instrumental in realizing the full potential of blockchain technology. It will ensure its contribution to enhancing the integrity, security, and efficiency of academic record authentication in the Philippines, setting a precedent for the digital transformation of education that is both innovative and legally sound.

References

1. B. L. Smith and A. W. Hughey, "Leadership in Higher Education — Its Evolution and Potential," Industry and Higher Education, vol. 20, no. 3, pp. 157–163, Jun. 2006, doi: 10.5367/000000006777690972.
2. O. Henfridsson, L. Mathiassen, and F. Svahn, "Managing Technological Change in the Digital Age: The Role of Architectural Frames," Journal of Information Technology, vol. 29, no. 1, pp. 27–43, Mar. 2014, doi: 10.1057/jit.2013.30.
3. M. Caramihai and I. Severin, "A Blockchain-Based Solution for Diploma Management in Universities," Sustainability, vol. 15, no. 20, p. 15169, Oct. 2023, doi: 10.3390/su152015169.
4. M. Caramihai and I. Severin, "A Blockchain-Based Solution for Diploma Management in Universities," Sustainability, vol. 15, no. 20, p. 15169, Oct. 2023, doi: 10.3390/su152015169.
5. P. Yeoh, "Regulatory issues in blockchain technology," Journal of Financial Regulation and Compliance, vol. 25, no. 2, pp. 196–208, 2017, doi: 10.1108/JFRC-08-2016-0068.
6. I. A. Omar, R. Jayaraman, K. Salah, M. C. E. Simsekler, I. Yaqoob, and S. Ellahham, "Ensuring protocol compliance and data transparency in clinical trials using Blockchain smart contracts," BMC Med Res Methodol, vol. 20, no. 1, Sep. 2020, doi: 10.1186/s12874-020-01109-5.
7. P. C. Franks, "Implications of blockchain distributed ledger technology for records management and information governance programs," Records Management Journal, vol. 30, no. 3, pp. 287–299, Dec. 2020, doi: 10.1108/RMJ-08-2019-0047.
8. G. Drosatos and E. Kaldoudi, "Blockchain Applications in the Biomedical Domain: A Scoping Review," Computational and Structural Biotechnology Journal, vol. 17. Elsevier B.V., pp. 229–240, Jan. 01, 2019. doi: 10.1016/j.csbj.2019.01.010.
9. A. Rustemi, F. Dalipi, V. Atanasovski, and A. Risteski, "A Systematic Literature Review on Blockchain-Based Systems for Academic Certificate Verification," IEEE Access, vol. 11. Institute of Electrical and Electronics Engineers Inc., pp. 64679–64696, 2023. doi: 10.1109/ACCESS.2023.3289598.
10. I. Abu-elezz, A. Hassan, A. Nazeemudeen, M. Househ, and A. Abd-alrazaq, "The benefits and threats of blockchain technology in healthcare: A scoping review," International Journal of Medical Informatics, vol. 142. Elsevier Ireland Ltd, Oct. 01, 2020. doi: 10.1016/j.ijmedinf.2020.104246.
11. D. Gebresenbet Bayyou and C. Atienza-Mendez;, "Blockchain Technology Applications in

Education," 2019. [Online]. Available: https://www.researchgate.net/publication/337670514
12. Amitkumar, M. I. Sanni, and D. Apriliasari, "Blockchain Technology Application: Authentication System in Digital Education," APTISI Transactions on Technopreneurship, vol. 3, no. 2, pp. 37–48, Sep. 2021, doi: 10.34306/att.v3i2.209.
13. E. Y. Daraghmi, Y. A. Daraghmi, and S. M. Yuan, "UniChain: A design of blockchain-based system for electronic academic records access and permissions management," Applied Sciences (Switzerland), vol. 9, no. 22, Nov. 2019, doi: 10.3390/APP9224966.
14. C. Turcu, C. Turcu, and I. Chiuchișan, "Blockchain and its Potential in Education."
15. C. Delgado-Von-eitzen, L. Anido-Rifón, and M. J. Fernández-Iglesias, "Application of blockchain in education: GDPR-compliant and scalable certification and verification of academic information," Applied Sciences (Switzerland), vol. 11, no. 10, May 2021, doi: 10.3390/app11104537.
16. T. Bocek, B. B. Rodrigues, T. Strasser, and B. Stiller, "Blockchains everywhere - a use-case of blockchains in the pharma supply-chain," in 2017 {IFIP}/{IEEE} {Symposium} on {Integrated} {Network} and {Service} {Management} ({IM}), Lisbon, Portugal: IEEE, May 2017, pp. 772–777. doi: 10.23919/INM.2017.7987376.
17. E. Lobachev, M. N. Mahmoud, and A. Patooghy, "Blockchain-based Smart Supply Chain Management," in 2022 9th International Conference on Dependable Systems and Their Applications (DSA), 2022, pp. 203–208. doi: 10.1109/DSA56465.2022.00035.
18. R. Jayaraman, F. AlHammadi, and M. C. E. Simsekler, "Managing Product Recalls in Healthcare Supply Chain," in 2018 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), IEEE, Jan. 2018, pp. 293–297. doi: 10.1109/IEEM.2018.8607403.
19. S. Dhingra, R. Raut, K. Naik, and K. Muduli, "Blockchain Technology Applications in Healthcare Supply Chains—A Review," IEEE Access, vol. 12, pp. 11230–11257, 2024, doi: 10.1109/ACCESS.2023.3348813.
20. D. Peralta-Velecela, M. C. Cáceres-Salamea, and V. Morocho, "Digital Identity Proposal for Unified Medical Record using Blockchain technology," in 2021 IEEE Fifth Ecuador Technical Chapters Meeting (ETCM), 2021, pp. 1–6. doi: 10.1109/ETCM53643.2021.9590679.
21. P. Bhattacharjee, C. Prakash, S. Gairola, S. S. Lala, and P. Mukherjee, "DigiBlock: Digital Self-sovereign Identity on Distributed Ledger based on Blockchain," in 2022 International Conference on Advancements in Smart, Secure and Intelligent Computing (ASSIC), 2022, pp. 1–7. doi: 10.1109/ASSIC55218.2022.10088367.
22. G. Lian, Q. Sun, Y. Zou, Z. Gao, X. Wang, and T.-X. Zheng, "Blockchain Identity Authentication-Based Secure Cooperative Communications for Smart Grid CPS," in 2023 IEEE International Conference on Smart Internet of Things (SmartIoT), IEEE, 2023, pp. 72–79. doi: 10.1109/SmartIoT58732.2023.00018.
23. W. K. Ahmed and R. S. Mohammed, "Lightweight Authentication Methods in IoT: Survey," in 2022 International Conference on Computer Science and Software Engineering (CSASE), IEEE, 2022, pp. 241–246. doi: 10.1109/CSASE51777.2022.9759798.
24. Z. Gong-Guo and Z. Wan, "Blockchain-based IoT security authentication system," in 2021 International Conference on Computer, Blockchain and Financial Development (CBFD), 2021, pp. 415–418. doi: 10.1109/CBFD52659.2021.00090.
25. Official Gazette, "Ferdinand R. Marcos Jr., Second State of the Nation Address, July 24, 2023," GOVPH.
26. G. Vojković and T. Katulić, "Anti-corruption Measures in the New Croatian Public Administration Office Management Regulation," in 2023 46th MIPRO ICT and Electronics Convention (MIPRO), IEEE, 2023, pp. 1526–1531. doi: 10.23919/MIPRO57284.2023.10159839.
27. K. U. Schulz and S. Mihov, "Fast string correction with Levenshtein automata," International

Journal on Document Analysis and Recognition, vol. 5, no. 1, pp. 67–85, Nov. 2002, doi: 10.1007/s10032-002-0082-8.

28. A. Cirne, P. R. Sousa, J. S. Resende, and L. Antunes, "IoT security certifications: Challenges and potential approaches," Comput Secur, vol. 116, p. 102669, 2022, doi: https://doi.org/10.1016/j.cose.2022.102669.
29. M. Litoussi, M. Fartitchou, K. El Makkaoui, A. Ezzati, and Z. El Allali, "Digital Certifications in Moroccan Universities: Concepts, Challenges, and Solutions," Procedia Comput Sci, vol. 201, pp. 95–100, 2022, doi: https://doi.org/10.1016/j.procs.2022.03.015.
30. N. Alam, M. R. Hasan Tanvir, S. A. Shanto, F. Israt, A. Rahman, and S. Momotaj, "Blockchain Based Counterfeit Medicine Authentication System," in 2021 IEEE 11th IEEE Symposium on Computer Applications & Industrial Electronics (ISCAIE), IEEE, 2021, pp. 214–217. doi: 10.1109/ISCAIE51753.2021.9431789.
31. G. Balamurugan and K. K. A. Sahayaraj, "A Blockchain Based Certificate Authentication System," in 2023 International Conference on Computer Communication and Informatics (ICCCI), IEEE, 2023, pp. 1–7. doi: 10.1109/ICCCI56745.2023.10128289.
32. M. Al Amin, A. Altarawneh, S. Sarkar, and I. Ray, "Blockchain Smart Contracts for Policy Compliance: A Healthcare Perspective," in 2023 International Conference on Emerging Trends in Networks and Computer Communications (ETNCC), 2023, pp. 1–6. doi: 10.1109/ETNCC59188.2023.10284947.
33. G. Lian, Q. Sun, Y. Zou, Z. Gao, X. Wang, and T.-X. Zheng, "Blockchain Identity Authentication-Based Secure Cooperative Communications for Smart Grid CPS," in 2023 IEEE International Conference on Smart Internet of Things (SmartIoT), 2023, pp. 72–79. doi: 10.1109/SmartIoT58732.2023.00018.
34. G. Lian, Q. Sun, Y. Zou, Z. Gao, X. Wang, and T.-X. Zheng, "Blockchain Identity Authentication-Based Secure Cooperative Communications for Smart Grid CPS," in 2023 IEEE International Conference on Smart Internet of Things (SmartIoT), 2023, pp. 72–79. doi: 10.1109/SmartIoT58732.2023.00018.
35. R. Raghav and E. A. Chaudhary, "Authentication System and Authorization System Using Blockchain Technology," in 2023 IEEE North Karnataka Subsection Flagship International Conference (NKCon), 2023, pp. 1–6. doi: 10.1109/NKCon59507.2023.10396613.
36. R. Ranchal, B. Bhargava, P. Angin, and L. Ben Othmane, "EPICS: A Framework for Enforcing Security Policies in Composite Web Services," IEEE Trans Serv Comput, vol. 12, no. 3, pp. 415–428, 2019, doi: 10.1109/TSC.2018.2797277.
37. P. A. Suraya, T. Ramadhan, N. Lutfiani, A. Khoirunisa, and U. Rahardja, "Blockchain, Information and Speculation Calculations in Indonesia: Recent Work," in 2022 10th International Conference on Cyber and IT Service Management (CITSM), 2022, pp. 1–8. doi: 10.1109/CITSM56380.2022.9935848.
38. F. P. Oganda, N. Lutfiani, Q. Aini, U. Rahardja, and A. Faturahman, "Blockchain Education Smart Courses of Massive Online Open Course Using Business Model Canvas," in 2020 2nd International Conference on Cybernetics and Intelligent System (ICORIS), 2020, pp. 1–6. doi: 10.1109/ICORIS50180.2020.9320789.
39. F. P. Oganda, N. Lutfiani, Q. Aini, U. Rahardja, and A. Faturahman, "Blockchain Education Smart Courses of Massive Online Open Course Using Business Model Canvas," in 2020 2nd International Conference on Cybernetics and Intelligent System (ICORIS), IEEE, 2020, pp. 1–6. doi: 10.1109/ICORIS50180.2020.9320789.
40. F. P. Oganda, N. Lutfiani, Q. Aini, U. Rahardja, and A. Faturahman, "Blockchain Education Smart Courses of Massive Online Open Course Using Business Model Canvas," in 2020 2nd International Conference on Cybernetics and Intelligent System (ICORIS), 2020, pp. 1–6. doi: 10.1109/ICORIS50180.2020.9320789.
41. U. Rahardja, M. A. Ngad, S. Millah, E. P. Harahap, and Q. Aini, "Blockchain Application in

Educational Certificates and Verification Compliant with General Data Protection Regulations," in 2022 10th International Conference on Cyber and IT Service Management (CITSM), 2022, pp. 1–7. doi: 10.1109/CITSM56380.2022.9935909.

42. U. Rahardja, M. A. Ngad, S. Millah, E. P. Harahap, and Q. Aini, "Blockchain Application in Educational Certificates and Verification Compliant with General Data Protection Regulations," in 2022 10th International Conference on Cyber and IT Service Management (CITSM), IEEE, 2022, pp. 1–7. doi: 10.1109/CITSM56380.2022.9935909.
43. U. Rahardja, M. A. Ngad, S. Millah, E. P. Harahap, and Q. Aini, "Blockchain Application in Educational Certificates and Verification Compliant with General Data Protection Regulations," in 2022 10th International Conference on Cyber and IT Service Management (CITSM), 2022, pp. 1–7. doi: 10.1109/CITSM56380.2022.9935909.
44. S. Kumari and S. Farheen, "Blockchain based Data Security for Financial Transaction System," in 2020 4th International Conference on Intelligent Computing and Control Systems (ICICCS), 2020, pp. 829–833. doi: 10.1109/ICICCS48265.2020.9121108.
45. S. Kumari and S. Farheen, "Blockchain based Data Security for Financial Transaction System," in 2020 4th International Conference on Intelligent Computing and Control Systems (ICICCS), IEEE, 2020, pp. 829–833. doi: 10.1109/ICICCS48265.2020.9121108.
46. S. Kumari and S. Farheen, "Blockchain based Data Security for Financial Transaction System," in 2020 4th International Conference on Intelligent Computing and Control Systems (ICICCS), 2020, pp. 829–833. doi: 10.1109/ICICCS48265.2020.9121108.
47. M. S. Hajar, M. O. Al-Kadri, and H. K. Kalutarage, "A survey on wireless body area networks: architecture, security challenges and research opportunities," Comput Secur, vol. 104, p. 102211, 2021, doi: https://doi.org/10.1016/j.cose.2021.102211.
48. V. Sharma, I. You, J. T. Seo, and M. Guizani, "Secure and Reliable Resource Allocation and Caching in Aerial-Terrestrial Cloud Networks (ATCNs)," IEEE Access, vol. 7, pp. 13867–13881, Jan. 2019, doi: 10.1109/ACCESS.2019.2893775.
49. D. Mebrahtom, S. Hadish, A. Sbhatu, M. Aloqaily, and M. Guizani, "Trust But Verify - Blockchain-Empowered Decentralized Authentication Schema on the Metaverse: A Self-Sovereign Identity Approach," in 2023 International Conference on Intelligent Metaverse Technologies & Applications (iMETA), 2023, pp. 1–8. doi: 10.1109/iMETA59369.2023.10294349.
50. S. R. Ahsan, I. S. Yousuf, Z. Khan, Y. Mehrin, and M. A. Majumdar, "Digital Supply Chain Management Ecosystem Powered by Blockchain Technology," in 2021 IEEE Asia-Pacific Conference on Computer Science and Data Engineering (CSDE), IEEE, 2021, pp. 1–6. doi: 10.1109/CSDE53843.2021.9718436.
51. E. Marquez et al., "Implementation of routine screening for Lynch syndrome in university and safety-net health system settings: successes and challenges," Genetics in Medicine, vol. 15, no. 12, pp. 925–932, 2013, doi: https://doi.org/10.1038/gim.2013.45.
52. Y. Chen, Q. Yang, X. Zeng, D. Yang, and X. Li, "A New Identity Authentication and Key Agreement Protocol Based on Multi-layer Blockchain in Edge Computing," IEEE Access, p. 1, 2024, doi: 10.1109/ACCESS.2023.3347808.
53. W. Xie, J. Yu, and G. Deng, "A Network Access Control Scheme for IoT Terminals Based on Active Scanning," in 2022 International Conference on Blockchain Technology and Information Security (ICBCTIS), 2022, pp. 47–51. doi: 10.1109/ICBCTIS55569.2022.00022.
54. X. Li, H. Zhao, and W. Deng, "BFOD: Blockchain-Based Privacy Protection and Security Sharing Scheme of Flight Operation Data," IEEE Internet Things J, vol. 11, no. 2, pp. 3392–3401, Jan. 2024, doi: 10.1109/JIOT.2023.3296460.
55. K. A. Fasila and S. Mathew, "Blockchain based Protocols for IoT Security using ABE Cryptosystems," in 2020 International Conference on Communication and Signal Processing (ICCSP), 2020, pp. 79–83. doi: 10.1109/ICCSP48568.2020.9182247.

56. A. Qashlan, P. Nanda, X. He, and M. Mohanty, "Privacy-Preserving Mechanism in Smart Home Using Blockchain," IEEE Access, vol. 9, pp. 103651–103669, 2021, doi: 10.1109/ACCESS.2021.3098795.
57. A. Qashlan, P. Nanda, X. He, and M. Mohanty, "Privacy-Preserving Mechanism in Smart Home Using Blockchain," IEEE Access, vol. 9, pp. 103651–103669, 2021, doi: 10.1109/ACCESS.2021.3098795.
58. A. Qashlan, P. Nanda, X. He, and M. Mohanty, "Privacy-Preserving Mechanism in Smart Home Using Blockchain," IEEE Access, vol. 9, pp. 103651–103669, 2021, doi: 10.1109/ACCESS.2021.3098795.
59. H. Nandanwar and R. Katarya, "A Systematic Literature Review: Approach Toward Blockchain Future Research Trends," in 2023 International Conference on Device Intelligence, Computing and Communication Technologies, (DICCT), 2023, pp. 259–264. doi: 10.1109/DICCT56244.2023.10110088.
60. S. K. Lo et al., "Analysis of Blockchain Solutions for IoT: A Systematic Literature Review," IEEE Access, vol. 7, pp. 58822–58835, 2019, doi: 10.1109/ACCESS.2019.2914675.
61. D. Schumm, R. Mukta, and H. Paik, "Efficient Credential Revocation Using Cryptographic Accumulators," in 2023 IEEE International Conference on Blockchain and Cryptocurrency (ICBC), 2023, pp. 1–3. doi: 10.1109/ICBC56567.2023.10174975.
62. D. Schumm, R. Mukta, and H. Paik, "Efficient Credential Revocation Using Cryptographic Accumulators," in 2023 IEEE International Conference on Blockchain and Cryptocurrency (ICBC), 2023, pp. 1–3. doi: 10.1109/ICBC56567.2023.10174975.
63. S. Mercan, M. Cebe, E. Tekiner, K. Akkaya, M. Chang, and S. Uluagac, "A Cost-efficient IoT Forensics Framework with Blockchain," in 2020 IEEE International Conference on Blockchain and Cryptocurrency (ICBC), IEEE, 2020, pp. 1–5. doi: 10.1109/ICBC48266.2020.9169397.
64. G. Solomon, P. Zhang, R. Brooks, and Y. Liu, "A Secure and Cost-Efficient Blockchain Facilitated IoT Software Update Framework," IEEE Access, vol. 11, pp. 44879–44894, 2023, doi: 10.1109/ACCESS.2023.3272899.
65. U. Jafar, M. J. A. Aziz, Z. Shukur, and H. A. Hussain, "Empowering Secure and Cost-Efficient Blockchain Electronic Voting by Optimized ZK-SNARK Algorithm," in 2023 International Conference on Electrical Engineering and Informatics (ICEEI), IEEE, 2023, pp. 1–6. doi: 10.1109/ICEEI59426.2023.10346804.
66. A. G. Chandini and P. I. Basarkod, "A Robust Blockchain Architecture for Electronic Health Data using Efficient Lightweight Encryption Model with Re-Encryption Scheme," in 2022 IEEE International Conference on Data Science and Information System (ICDSIS), IEEE, 2022, pp. 1–6. doi: 10.1109/ICDSIS55133.2022.9915902.
67. Y. Rahulamathavan, R. C.-W. Phan, M. Rajarajan, S. Misra, and A. Kondoz, "Privacy-preserving blockchain based IoT ecosystem using attribute-based encryption," in 2017 IEEE International Conference on Advanced Networks and Telecommunications Systems (ANTS), 2017, pp. 1–6. doi: 10.1109/ANTS.2017.8384164.
68. J. Moghariya and P. G. Shambharkar, "Blockchain-Enabled IoT (B-IoT): Overview, Security, Scalability & Challenges," in 2023 Second International Conference on Trends in Electrical, Electronics, and Computer Engineering (TEECCON), 2023, pp. 210–217. doi: 10.1109/TEECCON59234.2023.10335786.
69. O. Alphand et al., "IoTChain: A blockchain security architecture for the Internet of Things," in 2018 IEEE Wireless Communications and Networking Conference (WCNC), 2018, pp. 1–6. doi: 10.1109/WCNC.2018.8377385.