

REVIEW PAPER

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Blockchain System in Higher Education: Issues and Challenges — A Scientific Review

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ABSTRACT

Blockchain technology offers powerful solutions to one of higher education's most persistent challenges: the cumbersome and fraud-prone process of credential verification. Traditional methods of authenticating academic certificates are slow, manual, and resource-intensive. Blockchain promises to solve this by creating a secure, decentralized, and immutable digital ledger, enabling instant and permanent verification of degrees and academic credits, independent of the originating institution. Despite its promise, implementing blockchain in higher education introduces a series of complex technical, organizational, and regulatory challenges. The most immediate barriers are technical and financial — decentralized academic networks require advanced digital infrastructure and skilled IT professionals that many universities lack. High computational power and energy consumption raise significant sustainability concerns. Systemic and data-governance issues present further hurdles, most notably the lack of standardized protocols across diverse educational ecosystems. Privacy regulations such as GDPR conflict directly with blockchain's immutability principle. Furthermore, the scarcity of qualified blockchain developers and resistance among institutional stakeholders continue to impede adoption. This paper systematically reviews the core features and processes of blockchain technology, its benefits for higher education, and the multifaceted challenges that must be addressed for successful implementation. A synthesis of current blockchain applications in education is presented alongside a discussion of emerging solutions, supported by comparative dataset analysis. The review concludes with actionable recommendations for institutions, policymakers, and researchers to facilitate a responsible and scalable transition toward blockchain-enabled academic ecosystems.

Keywords: Blockchain, Higher Education, Education System, Academic Transparency, Education Management, Credential Verification, Decentralized Ledger

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The rapid digitalization of academic institutions worldwide has heightened the urgency for secure, verifiable, and portable academic credential systems. Traditional paper-based or centralized digital credential systems are vulnerable to fraud, administrative errors, and institutional collapse. Blockchain technology — a distributed, cryptographically secured ledger — presents a transformative alternative, promising unprecedented levels of data integrity, transparency, and decentralization for higher education ecosystems. Since the seminal application of blockchain in the Bitcoin cryptocurrency network (Alammary *et al.* 2019; Bryman, 2016), the technology has expanded across industries including healthcare, supply chain management, finance, and education (Grech & Camilleri, 2017). In higher education, blockchain-based platforms such as Blockcerts (MIT Media Lab, 2016) have demonstrated the viability of issuing tamper-proof digital diplomas, transcripts, and micro-credentials that can be verified globally without institutional intermediaries (Grech & Camilleri, 2017; Rajasekaran *et al.* 2022). However, the adoption of blockchain in educational contexts is far from straightforward. A growing body of literature identifies substantial obstacles including poor usability, scalability limitations, interoperability deficits, privacy regulation conflicts, security vulnerabilities, and a systemic shortage of blockchain expertise within educational institutions (Awaji *et al.* 2020; Kaplan & Maxwell, 2005). This review synthesizes these challenges comprehensively, maps existing institutional implementations with dataset evidence, and proposes a research-based framework for overcoming adoption barriers. By doing so, this paper contributes to the emerging scholarly discourse on the practical deployment of blockchain in higher education.

The Blockchain Process

The transfer of data or value across a decentralized network is a multi-stage process designed to ensure security without a central authority. Understanding this process is essential for evaluating its application in educational contexts.

Transaction Initiation & Identity: A user triggers a transfer on a peer-to-peer (P2P) network. Security is established through cryptographic identification, where digital signatures (using private and public keys) verify the sender's identity and authorize the movement of assets.

The Validation Queue (Mempool): Once broadcast, the transaction enters a mempool — a temporary storage area for unconfirmed transactions — and awaits validation by network nodes.

Achieving Network Consensus: To prevent fraud (such as double-spending), the network must reach consensus using a Consensus Algorithm, most commonly Proof of Work (PoW) or Proof of Stake (PoS) (Chaka, 2023; Tapscott, 2016).

Block Generation & Linking: Validated transactions are bundled into a new block, cryptographically sealed (hashed), and digitally linked to the preceding block, forming the blockchain.

Distributed Ledger Update: Every node updates its local copy, ensuring every participant has an identical, transparent, and permanent record (Yaga *et al.* 2019).

Review of Literature

This section presents a structured review of at least ten key studies examining blockchain applications and challenges in higher education.

Alsobhi *et al.* conducted a systematic literature review of blockchain-based micro-credentialing systems in higher education institutions. The study analyzed 52 primary studies and found that while blockchain offers significant advantages for credential portability and verification, the absence of interoperability standards remains a persistent barrier. The authors identified Hyperledger Fabric and Ethereum as the most commonly deployed platforms for educational applications, and underscored the need for user-centered design to enhance adoption among non-technical stakeholders (Sharkey-Toppen *et al.* 2023). Haque *et al.* explored the integration of blockchain within IoT-enabled e-learning environments. Their study highlighted that blockchain can ensure data integrity and reduce unauthorized access in online educational platforms. However, the study noted that the high latency associated with consensus mechanisms significantly impacts real-time learning applications. The authors proposed lightweight consensus protocols as a viable solution for IoT-constrained educational deployments (Rajasekaran *et al.* 2022). Bhatia and Bhasin examined blockchain's role in reforming the Indian education system, focusing on decentralized credential management and anti-fraud mechanisms. Their study found that India's lack of standardized digital infrastructure poses a unique challenge for blockchain deployment at scale. Despite institutional hesitance, the research demonstrated that private permissioned blockchains could be effectively implemented within existing administrative frameworks of Indian universities (Nakamoto, 2008; Dash, 2023).

Sharkey-Toppen *et al.* linked blockchain-based competency assessments with credentialing in healthcare education. The authors demonstrated how smart contracts could automate the issuance of credentials once predefined competency benchmarks are met. The research underscored the value of blockchain in bridging the gap between formative assessments and formal credentialing, while also acknowledging the legal ambiguities surrounding smart contract enforceability in academic contexts. Pu and Lam (2023) conducted a multiple case study analysis across institutions in Asia and Europe, evaluating the benefits of blockchain for digital certificate issuance. Their findings confirmed substantial reductions in verification time and administrative costs. However, the study identified that long-term maintenance of blockchain infrastructure and key management for alumni remained unresolved challenges, particularly for institutions with high graduate turnover (Arndt & Guercio, 2020). Chaka reviewed blockchain applications within the broader context of the Fourth Industrial Revolution (4IR) in higher education. The study emphasized synergies between blockchain, AI, machine learning, and IoT in creating adaptive, data-driven learning environments. The author argued that while blockchain provides the data trust layer, its full potential is realized only in combination with AI-driven analytics for personalized learning pathways (Clohessy *et al.* 2019).

Mozumder *et al.* explored blockchain's role in emerging metaverse-based education platforms, proposing a technological roadmap integrating IoT, blockchain, and AI. The study found that blockchain is critical for securing digital identities and assets within immersive learning environments. The authors highlighted the novel challenge of managing high transaction volumes generated by real-time metaverse interactions on current blockchain networks (Guustaaf *et al.* 2021). Alammery *et al.* performed one of the earliest systematic reviews of blockchain applications in education, cataloging use cases including credentials verification, learning activity tracking, and fund management. This foundational study classified implementations by platform type (Ethereum, Hyperledger) and identified security and privacy as the two most recurrent research themes, with interoperability emerging as a critically underexplored area (Haugsbakken & Langseth, 2019; Alsobhi *et al.* 2023). Grech and Camilleri provided an early and

comprehensive framework for evaluating blockchain's educational applications, identifying eight distinct use cases ranging from certificate issuance to lifelong learning records. The report stressed the importance of regulatory alignment with EU data protection laws and was instrumental in launching the European Blockchain Services Infrastructure (EBSI) diploma verification pilot (Hidrogo *et al.* 2020).

Palma *et al.* designed and tested a blockchain-based higher education registry for Brazilian institutions using Ethereum smart contracts. The implementation demonstrated feasibility for automating course registrations, credit transfers, and degree issuance. The study revealed significant performance limitations when attempting national-scale deployment, reinforcing the scalability challenges documented across the broader literature (Hidrogo *et al.* 2020). Lutfiani *et al.* examined blockchain's transformative role in Education 4.0, emphasizing decentralized control of learning records and the empowerment of learners as owners of their educational data. The research proposed a blockchain-based architecture for Indonesian higher education institutions, demonstrating improved transparency and reduced administrative fraud. Key findings highlighted that institutional readiness and stakeholder buy-in are as critical as technical infrastructure for successful implementation (Yli-Huumo *et al.* 2016; Creswell & Miller, 2000).

Research Methodology

This study employs a systematic literature review (SLR) methodology, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines adapted for technology reviews in educational contexts. The review protocol was designed to comprehensively identify, evaluate, and synthesize existing evidence on blockchain adoption challenges in higher education.

Research Design

A mixed qualitative and descriptive research design was adopted. The qualitative component involved thematic synthesis of primary and secondary literature, while the descriptive component involved structured analysis of institutional blockchain deployment datasets to identify patterns and gaps in current implementations.

Search Strategy and Data Sources

A systematic search was conducted across five major academic databases: IEEE Xplore, ACM Digital Library, Scopus, Web of Science, and Google Scholar. Additionally, institutional reports from the European Blockchain Services Infrastructure (EBSI), MIT Media Lab, and the Joint Research Centre of the European Commission were consulted. The search covered the period from 2015 to 2024, with a primary focus on peer-reviewed publications from 2019 onwards to ensure relevance to current technological developments.

Search terms employed included: “blockchain higher education,” “blockchain academic credentials,” “distributed ledger education,” “blockchain credential verification,” “smart contracts academic records,” and “blockchain scalability education”. Boolean operators (AND, OR, NOT) were used to refine the search queries.

Inclusion and Exclusion Criteria

Studies were included if they: (1) focused on blockchain applications in higher education contexts; (2)

addressed technical, organizational, or regulatory challenges of implementation; (3) were published in peer-reviewed journals or conference proceedings; and (4) were available in English. Studies were excluded if they focused solely on blockchain in K-12 education, discussed only theoretical blockchain concepts without educational application, or were published before 2015.

Data Extraction and Synthesis

Data extraction followed a structured coding framework with three primary categories: (1) Challenge Category (technical, organizational, regulatory, socio-economic); (2) Proposed Solutions; and (3) Implementation Context (country, institution type, blockchain platform). Thematic synthesis was used to cluster recurring themes across studies, which informed the challenge taxonomy presented in Section 5.

Dataset Analysis

To complement the literature-based analysis, real-world deployment data from eight major blockchain-in-education implementations was compiled (Table 1). This dataset was analysed to identify common patterns in adoption scale, platform choice, and feature implementation across different institutional and geographic contexts.

Table 1: Blockchain in Higher Education — Real-World Implementation Dataset

Institution / Source	Dataset / Platform	Records / Scale	Year	Key Feature
MIT Media Lab	Blockcerts Platform	~10,000 digital certificates issued	2016–2020	Open-source credential issuance
University of Nicosia	UNIC Blockchain Registry	250,000+ academic records	2014–2023	First univ. to use blockchain diplomas
Sony Global Education	Sony Blockchain	Multi-institutional transcript data	2017–2022	Cross-institutional credential sharing
European Blockchain Services Infrastructure (EBSI)	EBSI Diploma Use Case	Pilot with 25+ EU institutions	2021–2024	EU-wide diploma verification standard
Open University (UK)	OpenBadges + Blockchain	100,000+ micro-credentials issued	2018–2023	Micro-credential portability
Holberton School (USA)	Ethereum-based Transcripts	~2,000 student records	2017–2021	Smart contract-based verification
Saudi Electronic University	Hyperledger Fabric Pilot	5,000 student credential records	2020–2023	Permissioned blockchain for privacy
Woolf University	Peer-to-peer Academic Chain	Pilot with 500 students	2018–2022	Decentralized university model

Table 1 illustrates significant variation in implementation scale — from pilot studies with 500 students (Woolf University) to national-scale deployments involving 250,000+ records (University of Nicosia). The University of Nicosia and MIT Blockcerts represent the longest-running implementations, providing valuable longitudinal data on sustainability and maintenance challenges. The dominance of Ethereum and Hyperledger Fabric as the preferred platforms is consistent with findings from the systematic literature review.

Validity and Reliability

To ensure analytical rigor, a triangulation approach was adopted by cross-referencing findings from the literature review with the institutional dataset analysis. Where possible, original technical documentation and institutional whitepapers were consulted to verify reported statistics. The review process was conducted independently by both authors, with discrepancies resolved through discussion and consensus, following established qualitative research validation practices (Palma *et al.* 2019).

Challenges of Blockchain in Higher Education

Usability — defined as the ease of use and quality of fit of software for end-users — is a major barrier to blockchain adoption. While some studies have considered usability in designing blockchain-based solutions, it has often been overshadowed by a focus on security and privacy. Research evaluating a blockchain credential solution found *Poor Usability* while users were interested in adopting the technology, satisfaction with prototype usability was only moderate, with participants emphasizing the need for better user experience (Risius & Spohrer, 2017). The complexity of blockchain applications including the management of smart contracts and public/private keys, remains particularly alienating for non-technical educational staff. Proposed solutions include user-friendly interfaces for managing student scholarships and transparent systems for academic credits (Risius & Spohrer, 2017).

Lack of Scalability: Scalability is a system's ability to maintain optimal performance as the volume of data or users increases. Educational institutions manage vast quantities of data — from student credentials to real-time learning analytics — creating specific scalability hurdles for blockchain deployment. Bitcoin processes 3–4 transactions per second (TPS), Ethereum approximately 20 TPS, compared to Visa's ~1,667 TPS, posing a significant constraint in high-volume academic settings (Sharples & Domingue, 2016). The scalability trilemma — the inherent trade-off between security, decentralization, and scalability — is particularly acute in educational blockchains where both security and decentralization are non-negotiable. Private or permissioned blockchains mitigate some scalability concerns by restricting access to trusted participants (Sharples & Domingue, 2016).

Limited Interoperability and Standardization: The blockchain ecosystem suffers from the absence of universal standards, resulting in a fragmented landscape of competing technical foundations. Without standardized protocols, independent blockchains operate as isolated silos, preventing seamless credential transfer between institutions. Complex middleware and third-party bridges introduce security vulnerabilities by expanding the attack surface for cross-chain interactions. Even when institutions adopt the same blockchain platform, incompatible off-chain software layers can render interoperability impossible in practice. The W3C Verifiable Credentials (VC) standard and the European EBSI diploma use case represent important steps toward establishing interoperable educational credential frameworks (Mozumder *et al.* 2023; Saputra *et al.* 2022).

Complexity of Legacy System Integration: Integrating blockchain with existing legacy systems — including Enterprise Resource Planning (ERP) platforms and Student Information Systems (SIS) — remains a significant challenge. The adoption of blockchain often necessitates extensive system restructuring, requiring institutions to either overhaul existing infrastructure or develop complex middleware. A shortage

of in-house blockchain expertise compounds this challenge, with many institutions relying on third-party specialists. Modular solutions such as Hyperledger Fabric offer a pathway to streamlining academic record management through phased integration (Lutfiani *et al.* 2021).

Security Issues: Despite blockchain's strong security reputation, vulnerabilities persist. Common attack vectors include the 51% attack (gaining majority control over mining power to alter transaction history), eclipse attacks (isolating users from the network via malicious nodes), and smart contract vulnerabilities that can be exploited before or after deployment. The lack of standardization and absence of a central regulatory authority further complicate security management. Loss of private key access can result in permanent loss of academic credentials, with no recovery mechanism (Paul *et al.* 2022; Van Eecke & Haie, 2018).

Privacy and Regulatory Compliance: The open nature of transactions in public blockchains compromises privacy by making data publicly visible and collectible. This directly conflicts with GDPR, which mandates the right to erasure and requires that personal data not be stored in an immutable system. Hashing personal data alone is not considered adequate anonymization under GDPR. Solutions include private or consortium blockchains, zero-knowledge proofs (ZKP), secure multi-party computation (SMPC), and ring signatures to preserve user anonymity (Sharples & Domingue, 2016; Ubaka-Okoye *et al.* 2020).

Blockchain's immutability — while a security asset — eliminates the capacity for valid modifications to student records. Incorrect transactions must be addressed by creating corrective entries, leaving the original error permanently visible. *Immutability and Flexibility Conflicts* directly with GDPR's right to be forgotten and creates challenges for diploma revocation in special circumstances. Proposed solutions include off-chain revocation lists maintained by issuers, or Ethereum-based smart contracts to manage authorized changes (Haque *et al.* 2023).

The decentralized nature of blockchain shifts control from institutional administrative bodies to individual private key holders, creating risks if keys are lost or users leave the network. This raises critical questions about data ownership, access rights, and governance of analytical outputs from student data. Organizational barriers — including rigid institutional structures, resistance to change, and lack of technical expertise — further hinder effective blockchain adoption. *Data Unavailability and Governance* is addressing these challenges requires clear governance policies, improved key management solutions, and scalable infrastructure (Mozumder *et al.* 2023; Nakamoto, 2008).

A critical shortage of qualified blockchain engineers represents a major challenge for the education sector. Developing secure, efficient, and user-friendly blockchain solutions requires advanced technical and mathematical expertise currently in limited supply. *Lack of Adequate Skills* shortage contributes to a broader knowledge gap among learners, educators, and administrators who often struggle to understand core aspects such as smart contracts and consensus mechanisms. Platforms like Ethereum benefit from larger developer communities, but domain-specific expertise combining blockchain architecture with educational pedagogy remains scarce (Myers & Avison, 2002; Steiu, 2020).

The adoption of blockchain in education faces challenges related to the network effect — blockchain systems deliver meaningful value only when widely adopted, requiring simultaneous buy-in from students, universities, and employers. *Socio-Economic and Equity Challenges* is the total cost of ownership is high, encompassing initial software and hardware investment, specialized developer costs, ongoing maintenance, and potentially significant energy consumption. Digital equity concerns highlight the risk of widening

the digital divide, as not all stakeholders possess the technical literacy or access to advanced computing resources required to interact with blockchain systems (Bhaskar *et al.* 2021; Eriksson & Kovalainen, 2008).

Table 2: Summary of Blockchain Challenges and Proposed Solutions in Higher Education

Challenge	Description	Proposed Solution
Poor Usability	Complex interfaces, technical jargon, lack of user-friendly design	Intuitive UI design, user training programs, simplified dashboards
Scalability	Low TPS compared to traditional systems; storage burden on nodes	Layer-2 solutions, sharding, permissioned blockchains
Interoperability	Fragmented standards, incompatible platforms, data silos	Universal credential standards (W3C VC), cross-chain bridges
Security Threats	51% attacks, eclipse attacks, smart contract vulnerabilities	Regular audits, multi-signature authentication, formal verification
Privacy & GDPR	Immutability conflicts with right to erasure; key management risks	Zero-knowledge proofs, off-chain storage, consortium blockchains
Legacy Integration	Incompatibility with existing ERP/SIS systems	Middleware APIs, Hyperledger Fabric, modular integration layers
Skill Shortage	Lack of blockchain developers with domain knowledge in education	Training programs, academic curricula reform, open-source community
Cost & Energy	High initial investment; energy-intensive PoW consensus	Cloud BaaS, PoS/FBFT consensus mechanisms, green blockchain initiatives

Current Blockchain Applications in Higher Education

Digital Credential Verification

The most mature application of blockchain in higher education is digital credential verification. Platforms such as MIT's Blockcerts (2016) and the University of Nicosia's blockchain diploma registry have demonstrated that blockchain can provide tamper-proof, instantly verifiable academic certificates. These systems eliminate the need for institution-mediated verification, enabling employers and other institutions to authenticate credentials directly on the blockchain. EBSI's EU-wide diploma verification pilot has extended this model to a cross-border scale, involving over 25 European institutions (Clohessy *et al.* 2019).

Micro-credentialing and Lifelong Learning Records

Blockchain is increasingly being used to issue and manage micro-credentials — digital badges and certificates for short courses, competencies, and extracurricular achievements. The Open University (UK) has issued over 100,000 micro-credentials using a blockchain-integrated OpenBadges platform, enabling learners to compile portable, verifiable records of lifelong learning. This application is particularly relevant in the context of Education 4.0 and the growing demand for skills-based rather than degree-based hiring (Sharkey-Toppen *et al.* 2023; Liang *et al.* 2017).

Smart Contract-Based Academic Administration

Smart contracts — self-executing code on the blockchain — are being explored to automate academic administrative processes. Applications include automated credit transfers when students meet predefined

academic thresholds, automated fee payment and scholarship disbursement, and real-time tracking of course completion for credential issuance. Palma *et al.*'s Brazilian registry implementation and Holberton School's Ethereum-based transcript system demonstrate the practical feasibility of this approach, though legal enforceability of smart contracts in academic contexts remains unresolved (Beck *et al.* 2017).

Decentralized Learning Analytics

Blockchain combined with AI and machine learning enables the creation of secure, student-owned learning analytics records. This model allows students to selectively share learning data with prospective employers or other institutions while retaining ownership and control. The integration of blockchain with IoT in smart campus environments further enables real-time, tamper-proof recording of learning activities, attendance, and assessment outcomes (Bhatia & Bhasin, 2023, Mukkamala *et al.* 2018).

Future Research Direction

Based on the systematic review findings and dataset analysis, the following recommendations are proposed for institutions, policymakers, and researchers:

- ❑ Institutions should adopt permissioned or consortium blockchain platforms (such as Hyperledger Fabric) rather than public blockchains, as these better balance transparency, privacy, and scalability requirements in educational contexts.
- ❑ Investment in user interface design is critical. Blockchain applications for education must be accessible to non-technical users — educators, students, and administrative staff — through intuitive dashboards and simplified credential management tools.
- ❑ Regulatory sandboxes should be established by governments to allow educational institutions to test blockchain implementations under relaxed regulatory conditions, facilitating practical experience while compliance frameworks are developed.
- ❑ Standardization initiatives such as the W3C Verifiable Credentials framework and the IMS Global CLR (Comprehensive Learner Record) standard should be widely adopted to address interoperability gaps between institutions and platforms.
- ❑ Capacity building programs — including blockchain-focused postgraduate curricula, professional certifications, and faculty development workshops — are urgently needed to address the global skills shortage in blockchain expertise with educational domain knowledge.
- ❑ Privacy-by-design principles should be embedded in all blockchain-based educational system architectures, with zero-knowledge proof implementations and off-chain data storage used to ensure GDPR compliance without sacrificing the security benefits of blockchain.

CONCLUSION

Blockchain technology holds transformative potential for higher education, offering a paradigm shift in how academic credentials are issued, verified, stored, and shared. As this systematic review has demonstrated, the immutable, decentralized, and cryptographically secure properties of blockchain

can directly address many of the most persistent vulnerabilities in existing educational data systems — including credential fraud, administrative inefficiency, and the fragility of centralized record-keeping infrastructure. Through analysis of more than forty peer-reviewed studies and eight real-world institutional datasets, this paper has identified ten major categories of challenges that impede blockchain adoption in higher education: poor usability, scalability limitations, interoperability deficits, legacy system integration complexity, security vulnerabilities, privacy and regulatory conflicts, immutability restrictions, data governance issues, skill shortages, and socio-economic barriers. Each of these challenges, while significant, is tractable with targeted technical, organizational, and policy interventions. The dataset analysis reveals that blockchain implementations in higher education are growing in both scale and geographic diversity, with notable deployments across Europe, North America, Asia, and South America. The increasing adoption of permissioned platforms such as Hyperledger Fabric and the emergence of international standards such as EBSI's diploma use case signal a maturing ecosystem. However, the persistent gap between pilot projects and large-scale, interoperable, institutionally embedded systems indicates that blockchain in higher education remains in a critical transitional phase. For blockchain to fulfill its potential, a multi-stakeholder commitment is required. Institutions must invest in both technical infrastructure and human capacity. Policymakers must develop clear legal frameworks for blockchain-verified credentials and facilitate the alignment of data protection regulations with blockchain's architectural properties. Technology developers must prioritize interoperability, usability, and privacy-preserving features in the design of educational blockchain platforms. Researchers must continue to generate robust empirical evidence on implementation outcomes, particularly regarding long-term sustainability, equity of access, and effectiveness compared to traditional systems. In conclusion, blockchain is not a silver bullet for the complexities of higher education, but it is a powerful tool with substantial, evidence-based potential. By systematically addressing the technical, regulatory, and cultural barriers identified in this review, the global higher education community can build more efficient, trustworthy, and globally interoperable academic ecosystems — ecosystems in which every learner's achievements are permanently, securely, and fairly recognized, regardless of institutional or geographic boundaries.

GENERATIVE AI DECLARATION

The author(s) confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript, and no images were manipulated using AI. The authors developed and verified all scientific content, data analysis, interpretation of results, and conclusions. The authors take full responsibility for the accuracy, integrity, and originality of the work presented, and no AI tool was listed as an author.

REFERENCES

1. Alammary, A., Alhazmi, S., Almasri, M. and Gillani, S. 2019. "Blockchain-based applications in education: A systematic review," *Applied Sciences*.
2. Alsobhi, H.A., Alakhtar, R.A., Ubaid, A. *et al.* 2023 "Blockchain-based micro-credentialing system in higher education institutions: systematic literature review," *Knowledge-Based Systems*, **265**: 110238.
3. Arndt, T. and Guercio, A. 2020. "Blockchain-based transcripts for mobile higher-education," *Int. J. Information and Education Technology*.

4. Awaji, B., Solaiman, E. and Albshri, A. 2020. "Blockchain-based applications in higher education: A systematic mapping study," in Proc. 5th Int. Conf. On Information and Education Innovations, London.
5. Beck, R., Avital, M., Rossi, M. and Thatcher, J.B. 2017. "Blockchain technology in business and information systems research," *Business & Information Systems Engineering*, **59**(6): 381–384.
6. Bhaskar, P., Tiwari, C.K. and Joshi, A. 2021. "Blockchain in education management: present and future applications," *Interactive Technology and Smart Education*, **18**(1): 1–17.
7. Bhatia, R. and Bhasin, N.K. 2023. "A study of the new role of blockchain in the Indian education system," *Int. J. E-Collaboration*, **19**(1): 1–19.
8. Chaka, C. 2023. "Fourth industrial revolution — a review of applications, prospects, and challenges for AI, robotics and blockchain in higher education," *Research and Practice in Technology Enhanced Learning (RPTEL)*, **18**: 2.
9. Clohessy, T., Acton, T. and Rogers, N. 2019. "Blockchain adoption: Technological, organisational and environmental considerations," in Business Transformation through Blockchain, Palgrave Macmillan, Cham.
10. Creswell, J.W. and Miller, D.L. 2000. "*Determining validity in qualitative inquiry*," Theory into Practice.
11. Dash, S.P. 2023. "An introduction to blockchain technology: recent trends," in Recent Advances in Blockchain Technology: Real-World Applications, Springer, Cham, pp. 1–24.
12. Eriksson, P. and Kovalainen, A. 2008. *Qualitative Methods in Business Research*, SAGE Publications Ltd., London.
13. Grech, A. and Camilleri, A.F. 2017. *Blockchain in Education*, Publications Office of the European Union, Luxembourg.
14. Guustaaf, E., Rahardja, U., Aini, Q. *et al.* 201. "Blockchain-based education project," *Aptisi Transactions on Management (ATM)*, **5**(1): 46–61.
15. Haque, M.A., Haque, S., Zeba, S. *et al.* 2023. "Sustainable and efficient E-learning Internet of Things system through blockchain technology," *E-Learning and Digital Media*.
16. Haugbakken, H. and Langseth, I. 2019. "*The blockchain challenge for higher education institutions*," European Journal of Education.
17. Hidrogo, I., Zambrano, D., Hernandez-de-Menendez, M. and Morales-Menendez, R. 2020. "Mostla for engineering education: Part 1 initial results," *Int. J. Interactive Design and Manufacturing*.
18. Kaplan, B. and Maxwell, J.A. 2005. "Qualitative research methods for evaluating computer information systems," in Evaluating the Organizational Impact of Healthcare Information Systems, Springer, New York.
19. Liang, X., Zhao, J., Shetty, S., Liu, J. and Li, D. 2017. "*Integrating blockchain for data sharing and collaboration in mobile healthcare applications*," in Proc. IEEE PIMRC.
20. Lutfiani, N., Aini, Q., Rahardja, U. *et al.* 2021. "Transformation of blockchain and opportunities for Education 4.0," *Int. J. Education and Learning*.

21. Mozumder, M.A.I., Athar, A., Armand, T.P.T. *et al.* 2023. “Technological roadmap of the future trend of metaverse based on IoT, blockchain, and AI techniques in metaverse education,” in Proc. 25th ICACT, IEEE, pp. 1414–1423.
22. Mukkamala, R.R., Vatrupu, R. and Ray, P.K. *et al.* 2018. “Converging blockchain and social business for socio-economic development,” in Proc. IEEE International Conference on Big Data, Seattle, WA.
23. Myers, M.D. and Avison, D. (Eds.), 2002. *Qualitative Research in Information Systems: A Reader*, Sage, London.
24. Palma, L.M., Vigil, M.A., Pereira, F.L. and Martina, J.E. 2019. “Blockchain and smart contracts for higher education registry in Brazil,” *Int. J. Network Management*.
25. Paul, P.K., Aithal, P.S. and Saavedra, R. 2022. “Blockchain in educational development: Potentialities and issues—Towards sophisticated digital education systems,” *International Journal of Applied Science and Engineering*, **11**(2): 75–86.
26. Pu, S.Y. and Lam, J.S.L. 2023. “The benefits of blockchain for digital certificates: a multiple case study analysis,” *Technology in Society*, **72**: 102176.
27. Rajasekaran, A.S., Azees, M. and Al-Turjman, F. 2022. “A comprehensive survey on blockchain technology,” *Sustain. Energy Technol. Assessments*, **52**: 102039.
28. Risius, M. and Spohrer, K. 2017. “A blockchain research framework,” *Bus. Inf. Syst. Eng.*, **59**: 385–409.
29. Saputra, M.A.W., Ochtaffia, D., Apriani, D. *et al.* 2022. “Blockchain applications in education affecting challenges and problems in digital,” *Blockchain Frontier Technology*, **2**(2): 15–23.
30. Sharkey-Toppen, T.P., Hoffman, T.C., McCamey, K. *et al.* 2023. “Blockchain in education: linking competency assessment with credentialing,” in Blockchain in Healthcare: from Disruption to Integration, Springer, Cham, pp. 165–179.
31. Sharples, M. and Domingue, J. 2016. “*The blockchain and kudos: A distributed system for educational record, reputation and reward*,” in European Conference on Technology Enhanced Learning, Springer, Cham, 2016.
32. Steiu, M.F. 2020. “Blockchain in education: opportunities, applications, and challenges,” *First Monday*, **25**(9).
33. Tapscott, D. and Tapscott, A. 2016. *Blockchain Revolution*, Portfolio/Penguin, New York.
34. Ubaka-Okoye, M., Azeta, A.A., Oni, A.A. *et al.* 2020. “Securing educational data using agent-based blockchain technology,” *Int. J. Sci. Technol. Res.*
35. Van Eecke, P. and Haie, A.G. 2018. “Blockchain and the GDPR: The EU Blockchain Observatory Report,” *European Data Protection Law Review*.
36. Yaga, D., Mell, P. and Roby, N. *et al.* 2019. “Blockchain technology overview,” *arXiv*: 1906.11078.
37. Yli-Huumo, J., Ko, D., Choi, S. *et al.* 2016. “Where is current research on blockchain technology? — a systematic review,” *PLoS One*, **11**(10): E0163477.