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Blockchain in Higher Education: A Systematic Review of Integration Frameworks and Adoption Challenges

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Abstract*—Blockchain has emerged as a promising infrastructure to address persistent inefficiencies in higher education systems, particularly within Learning Management Systems (LMS) and administrative processes, due to its potential to improve transparency, security, and operational efficiency. This review conducts a Systematic Literature Review (SLR), following PRISMA 2020 guidelines, to evaluate blockchain integration approaches in academic contexts. Unlike previous reviews, this review specifically synthesizes literature published between 2020 and 2025, providing a timely and focused analysis of recent advancements. A total of 41 peer-reviewed articles were selected and directly cited in this review. The analysis investigates implementation frameworks, practical use cases, and the technological, organizational, and regulatory factors influencing adoption. Key findings reveal that blockchain facilitates secure credentialing, decentralized identity verification, learner autonomy, and institutional transparency. However, significant barriers such as scalability limitations, legal uncertainty, and interoperability challenges continue to hinder widespread deployment. This review provides a comprehensive synthesis of current practices and offers actionable, research-informed recommendations for policymakers, technology developers, and higher education institutions aiming to implement blockchain-driven solutions.

***Index Terms*—Blockchain; Learning Management Systems; Higher Education; Educational Technology; Credentialing; Systematic Literature Review; PRISMA**

I. INTRODUCTION

Blockchain technology has emerged as a transformative infrastructure with applications spanning diverse sectors, including finance, supply chains, and digital identity management. Within the context of higher education, blockchain presents a compelling opportunity to address persistent limitations inherent in traditional Learning Management Systems (LMS) and administrative frameworks [1], [2]. Academic institutions continue to encounter significant challenges such as credential fraud, fragmented academic records, inefficient administrative workflows, and limited student ownership of personal data. Owing to its core characteristics of decentralization, immutability, and programmable trust, blockchain holds considerable potential to mitigate these challenges by enhancing the security, transparency, and operational efficiency of academic systems [1], [2]. Recent scholarship has investigated blockchain-enabled models for issuing tamper-proof diplomas [3], automating student identity verification [4], deploying micro-credentialing systems [5], [6], and facilitating learner-controlled identities [7]. Initiatives such as EduCTX [3] and SmartCert [8] illustrate the feasibility of blockchain-based solutions, while platforms like Kudos [9] exemplify decentralized academic reputation management. Despite these promising developments and the proliferation of proof-of-concept applications, the widespread adoption of blockchain within higher education remains constrained by legal ambiguities, lack of standardization, and technical complexities [10], [11].

Although a number of earlier systematic literature reviews (SLRs) have examined blockchain applications in education, the majority of these have predominantly focused on early-stage pilot projects or narrowly defined technical use cases, often drawing on studies published prior to 2020. As a result, these reviews have generally lacked comprehensive analyses of architectural trade-offs between blockchain platforms, assessments of implementation maturity, or systematic categorization of adoption barriers.

This review seeks to address these gaps by undertaking a Systematic Literature Review (SLR) in accordance with the PRISMA 2020 guidelines [12]. It synthesizes peer-reviewed research published between 2020 and 2025, with a particular emphasis on the integration of blockchain technology into LMS and administrative systems within higher education contexts. Distinct from previous reviews, this review contributes an up-to-date synthesis of post-2020 advancements, a comparative analysis of architectural

trade-offs among commonly deployed platforms such as Ethereum and Hyperledger, and an examination of implementation maturity levels. Furthermore, it incorporates quantitative visual analyses to illustrate trends in adoption by region, publication year, and use case type, and systematically categorizes barriers into technical, institutional, and regulatory dimensions.

Accordingly, the review seeks to address the following research questions:

1. What approaches have been proposed for integrating blockchain into LMS and administrative systems in higher education?
2. What use cases and frameworks have been developed to support the adoption of blockchain in academic learning and administrative infrastructures?
3. What benefits, challenges, and limitations have been identified in the integration of blockchain technology within these systems?
4. What technological, organizational, and regulatory factors influence the adoption of blockchain within higher education institutions?

By systematically addressing these questions, the present review not only provides a comprehensive overview of contemporary practices but also delineates emergent architectural considerations, adoption maturity levels, and critical research gaps that have yet to be sufficiently addressed in the extant literature. The study aims to generate actionable, evidence-based recommendations for policymakers, technology developers, and educational institutions seeking to effectively implement blockchain-driven solutions.

II. METHODOLOGY

This review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines [12] to ensure methodological transparency, replicability, and rigor. The objective was to systematically identify, appraise, and synthesize scholarly research concerning the integration of blockchain within higher education systems, with particular emphasis on Learning Management Systems (LMS) and administrative operations.

A. Search Strategy:

Relevant literature was retrieved from five major academic databases: IEEE Xplore, Scopus, SpringerLink, MDPI, and ScienceDirect. The search covered publications from January 2020 to March 2025 to ensure the inclusion of the most recent advancements.

The following Boolean search string was applied consistently across all databases:

("blockchain" AND "higher education") OR ("learning management system" AND "university administration") AND (integration OR implementation OR framework)

Additional sources were identified through manual backward and forward reference checks and by consulting grey literature indexed in Google Scholar. To promote reproducibility, the exact database queries, search logs, and selection decisions have been documented and are available upon request as a supplementary file.

B. Inclusion and Exclusion Criteria:

The following criteria guided study selection:

Inclusion criteria:

- Peer-reviewed articles published between 2020 and 2025
- Written in English
- Primary focus on blockchain integration in higher education contexts
- Inclusion of practical use cases, system frameworks, or empirical implementation data

Exclusion criteria:

- Studies focusing exclusively on K–12 education or non-academic sectors
- Research addressing blockchain applications in unrelated domains (e.g., finance, supply chain)
- Purely conceptual or opinion papers lacking technical proposals or empirical validation

C. Screening and Selection Process:

The screening process was conducted in two distinct phases:

1. An initial title and abstract screening to eliminate studies misaligned with the inclusion

criteria.

2. A full-text review to assess methodological rigor, relevance to the research questions, and thematic alignment.

A quality appraisal of each included study was undertaken to evaluate methodological soundness, potential risk of bias, and overall evidence strength. Studies were assessed using criteria adapted from established SLR frameworks, including clarity of research design, data validity, and replicability of findings.

The selection process yielded the following results:

Table 1. PRISMA Screening and Selection of Studies for the Systematic Literature Review

Stage	Number of Records
Records identified	720 (from databases)
Duplicates removed	160
Records screened	600
Full-text articles assessed	100
Full-text articles excluded	59
Included in synthesis	41

After removing 160 duplicates from 720 records, 600 were screened. Of 100 full texts reviewed, 41 articles were selected and cited in this manuscript; others supported thematic synthesis.

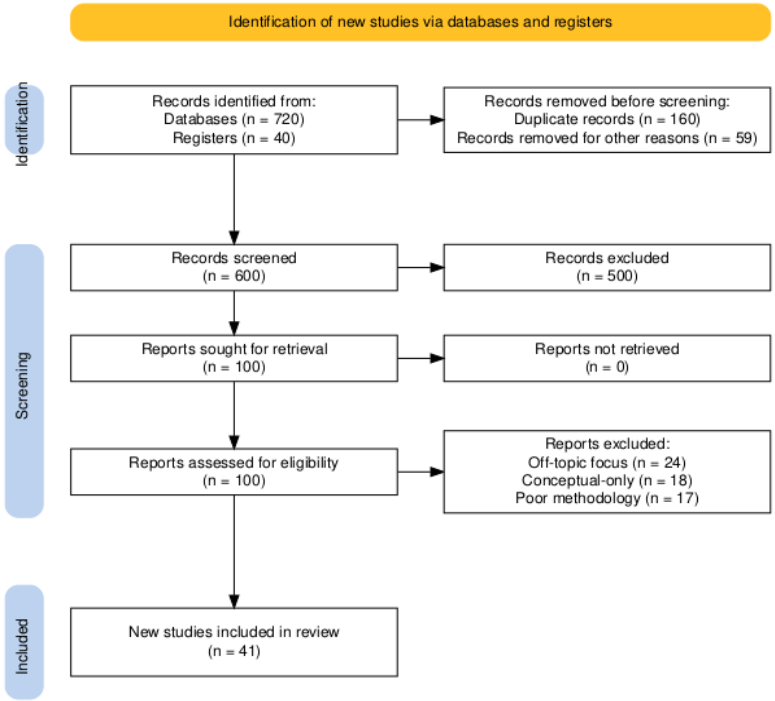

Figure 1. PRISMA 2020 Flow Diagram for Study Selection

III. RESULT

Blockchain integration into higher education has been operationalized through a variety of architectural approaches, including multi-layered frameworks, smart contracts, and modular systems designed to interface seamlessly with existing Learning Management Systems (LMS) and Enterprise Resource Planning (ERP) platforms.

3.1 What are the proposed approaches for integrating blockchain into learning management and administrative systems in higher education?

Recent studies demonstrate that blockchain solutions in higher education commonly adopt three dominant architectural paradigms: multi-layered architectures for layered security and validation, smart contract-based automation for credential issuance, and modular APIs for interoperability with legacy

systems. Collectively, these models aim to improve security, transparency, and operational efficiency while addressing institutional silos.

For instance, [3] introduced EduCTX, an Ethereum-based system employing a three-layer architecture to enable cross-institutional academic credit validation. Similarly, [4] proposed EduRSS, a consortium blockchain that ensures secure educational record storage while preserving privacy and auditability. In the domain of credential management, [5] utilized the BSV blockchain in conjunction with the ECDSA algorithm to guarantee the authenticity and verifiability of academic certificates.

[7] leveraged Hyperledger, integrating modular APIs to connect with government credential registries, thereby enhancing interoperability with official databases. [8] combined a private Ethereum blockchain and IPFS with Moodle LMS, demonstrating a scalable, decentralized learning environment. Financial decentralization was addressed by [13] through BCHEEN, a smart contract-based platform for managing student loans via crowdsourced funding.

Blockchain's utility has also extended to research data management: [10] presented a MultiChain-based ledger to secure contributor attribution, while [11] combined Ethereum and IPFS to develop tamper-proof digital certificates via lifecycle smart contracts. [14] demonstrated blockchain's capacity to streamline institutional data administration, mitigating redundancies and bolstering data integrity.

These studies illustrate how Ethereum-based platforms dominate the landscape due to their maturity and smart contract capabilities, while Hyperledger is favored for private, permissioned environments requiring modular APIs and enterprise-level compliance. This comparative perspective underscores the architectural trade-offs between public and private blockchains, as well as the importance of interoperability in higher education contexts.

Table 2. Architectural Approaches for Blockchain Integration in Higher Education

Study	BLOCKCHAIN PLATFORM	Integration Approach	Target System	Features
[3]	Ethereum (EduCTX)	3-layer (App, Smart Contract, Ledger)	Academic Credit System	Cross-institution validation
[4]	Ethereum (EduRSS)	Consortium blockchain, smart contracts	Educational records storage and sharing	Secure storage, privacy preservation, auditability
[5]	BSV Blockchain	ECDSA algorithm for digital signatures	Academic credential management	Enhanced authenticity, verifiable ownership
[7]	Hyperledger	Modular credentialing APIs	Government Credential DB	Interoperability with official registries
[8]	Private Ethereum	IPFS + LMS Bridge	Moodle LMS	Scalable LMS interface
[13]	Blockchain (BCHEEN)	Crowdsourcing, smart contracts	Higher education student loan platform	Decentralized loans, investor funding
[10]	MultiChain	Research record ledger	Research Archive	Contributor attribution
[11]	Ethereum + IPFS	Lifecycle smart contract	Certificate Management	Tamper-proof transcripts
[15]	Private Blockchain + IoT	LMS	Adaptive Tracking	Smart Attendance

3.2 What are the use cases and frameworks supporting blockchain adoption in academic learning and administrative infrastructures?

The academic literature identifies several prominent use cases and implementation frameworks through which blockchain technology can augment or transform legacy higher education systems. These applications extend beyond credential management to include decentralized identity, cross-institutional credit transfers, learning analytics, and institutional accreditation.

A synthesis of the reviewed studies reveals that credentialing and diploma issuance remain the most mature and widely implemented use case, with frameworks leveraging ECDSA digital signatures, modular credentialing APIs, and lifecycle smart contracts to ensure tamper-proof, verifiable academic credentials across institutional and national boundaries ([16], [17], [5], [7], [11]).

Decentralized identity and student record management represent another core area of focus. Studies such as [4], [9], [10], [16], [18], and [19] have proposed self-sovereign identity (SSI) platforms and research record ledgers that enable students to securely own, control, and share academic data. Consortium blockchains and smart contracts frequently underpin these solutions to maintain privacy while ensuring auditability.

Admissions and credit transfers have benefited from multi-layered blockchain architectures that automate micro-credential verification and facilitate cross-institutional recognition of coursework, thereby reducing administrative friction for learners and institutions ([2], [3]).

Similarly, learning analytics and student engagement tracking are increasingly supported by blockchain-integrated solutions that combine IPFS storage with on-chain verification, ensuring scalability alongside tamper-proof recording of learning interactions ([8], [20], [21]).
Finally, use cases in institutional accreditation and evaluation demonstrate blockchain's potential to create immutable audit trails for quality assurance and regulatory compliance, as noted by [22].

Table 3. Representative Use Cases and Frameworks for Blockchain Integration in Higher Education

USE CASE	Description	Frameworks	Supporting Works
Credentialing & Diploma Issuance	Blockchain ensures verifiable, tamper-proof diplomas, reducing verification delays and preventing forgery. Facilitates decentralized, cross-border credential validation.	ECDSA digital signatures, Modular credentialing APIs, Lifecycle smart contracts	[7], [17], [5], [11], [16]
Decentralized Identity & Student Records	Empowers students to control academic credentials through academic passports and secure sharing. Examples include blockchain-secured SSI platforms and research record ledgers.	Consortium blockchain + smart contracts, Research record ledgers	[9], [16], [4], [10], [18], [20]
Admissions & Credit Transfers	Enables micro-credential verification and cross-institutional course credit recognition through automated smart contracts.	3-layer blockchain architecture	[3], [2]
Learning Analytics & Engagement Tracking	Tracks student progress and activities on-chain, with off-chain storage for scalability, enhancing verifiable engagement records.	IPFS integration for learning data	[20], [21], [8]
Institutional Accreditation & Evaluation	Creates tamper-proof audit trails for performance monitoring, quality assurance, and accreditation lifecycle management.	Blockchain-based accreditation ledgers	[22]

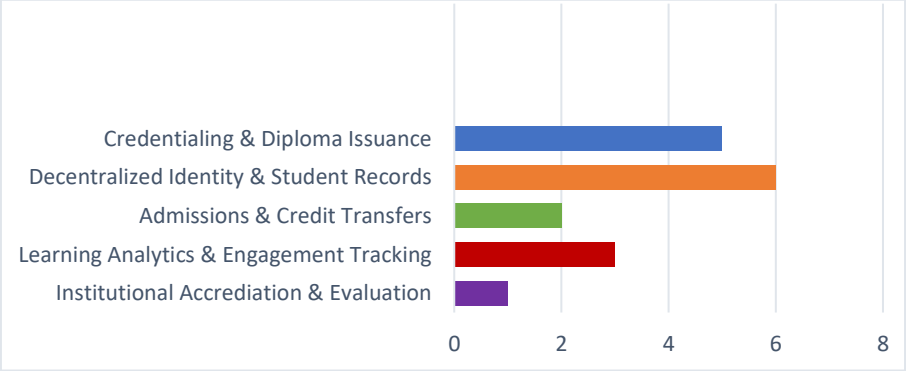

Figure 1. Frequency of Blockchain Use Cases in Higher Education (2020–2025)

This figure shows the frequency distribution of major blockchain use cases from the reviewed studies.

3.3 What benefits, challenges, and limitations have been identified in the integration of blockchain technology within these systems?

Blockchain technology is increasingly examined as an enabling infrastructure to strengthen data integrity, enhance administrative transparency, and automate workflows within academic systems. However, its practical adoption continues to encounter significant regulatory, technical, and institutional barriers, alongside inherent limitations such as the lack of standardization and the limited availability of large-scale, longitudinal evidence. This section synthesizes the principal benefits, challenges, and limitations identified across the reviewed studies.

3.3.1 Benefits:

The literature highlights multiple tangible benefits of blockchain integration for higher education institutions:

Table 4. Key Benefits of Blockchain Integration in Academic Systems

BENEFIT	Description	Supporting Sources
Enhanced Security and Data Integrity	Ensures tamper-proof records, safeguards data confidentiality through digital signatures and tamper detection protocols, and prevents credential fraud using cryptographic methods such as ECDSA.	[4], [5], [23]

Decentralization and Transparency	Eliminates single points of failure, supports distributed trust, and enhances system resilience, particularly with consortium blockchain configurations.	[4], [5]
Efficiency and Automation	Employs smart contracts to automate credential validation, reduce administrative overhead, and streamline student services.	[3]
Scalable LMS Interface	Integrates with IPFS and other decentralized storage mechanisms to deliver scalable, resilient Learning Management System (LMS) infrastructures.	[8]

3.3.2 Challenges:

Despite these benefits, blockchain adoption in higher education remains hindered by multi-faceted challenges. These can be broadly grouped into regulatory compliance issues, technical performance constraints, interoperability concerns, and institutional inertia:

Table 5. Key Challenges in Blockchain Adoption in Higher Education

CHALLENGE	Description	Supporting Sources
Regulatory Compliance	Difficulties aligning blockchain-based solutions with data protection and privacy requirements such as GDPR and FERPA.	[4]
Scalability and Latency	Technical limitations in processing high transaction volumes may compromise performance and responsiveness.	[4], [24]
Interoperability	Complex integration with legacy institutional systems, including ERPs and LMS platforms, poses significant technical hurdles.	[25]
Institutional Inertia	Organizational resistance to change driven by stakeholder scepticism, lack of technical expertise, and limited awareness of blockchain's practical implications.	[5]

3.3.3 Limitations:

In addition to the challenges described above, the current research landscape indicates critical limitations in the maturity and generalizability of blockchain solutions for academic contexts:

Table 6. Key Limitations in Blockchain Adoption in Higher Education

LIMITATION	Description
Lack of Standardization	Absence of universally accepted standards for credential schemas, smart contract design, and platform interoperability.
Limited Real-World Validation	Many implementations remain at the proof-of-concept stage with weak or underdeveloped cybersecurity measures, limited deployment at scale, and insufficient longitudinal performance data ([26]). Consequently, blockchain's effectiveness and trustworthiness within live academic environments remain largely untested.

3.4 What technological, organizational, and regulatory factors influence the adoption of blockchain in higher education institutions?

The successful integration of blockchain within higher education institutions is shaped by an interplay of technological capabilities, organizational readiness, and regulatory frameworks, each of which significantly influences adoption decisions.

From a technological perspective, the choice of blockchain platform remains pivotal. While public platforms such as Ethereum offer decentralization and widespread developer support, they are constrained by challenges including high transaction fees and limited throughput, which may hinder scalability ([27]). Consequently, many institutions have begun exploring permissioned platforms such as Hyperledger, which provide enhanced institutional control and configurable governance structures better suited to academic contexts. Integration with existing Learning Management Systems (LMS), including widely used platforms like Moodle, continues to pose technical hurdles, as most lack native blockchain compatibility and require customized APIs or middleware layers for seamless interoperability ([8]). Furthermore, advanced cryptographic techniques, including Zero-Knowledge Proofs (ZKPs), the Elliptic Curve Digital Signature Algorithm (ECDSA), and multi-signature wallets, are increasingly being proposed to strengthen system security and uphold data privacy standards ([4], [5], [28]).

At the organizational level, blockchain literacy and technical proficiency among faculty, administrative staff, and decision-makers remain significant barriers to implementation ([5], [29]). Limited awareness often contributes to stakeholder scepticism and institutional inertia. Financial and infrastructural constraints further restrict experimentation, particularly within institutions operating with minimal IT resources ([30]). However, collaborative governance models involving partnerships among universities, governmental agencies, and educational technology providers have demonstrated greater promise in overcoming resource limitations and fostering sustainable blockchain initiatives ([7]).

From a regulatory standpoint, the absence of universally recognized legal frameworks for blockchain-issued credentials remains a major obstacle, limiting cross-border acceptance and interoperability ([31]). Data sovereignty and privacy compliance concerns, especially under stringent regional frameworks such as the General Data Protection Regulation (GDPR), also present significant challenges ([4], [32], [33]). Notably, the presence of supportive policy environments, including regulatory sandboxes, pilot frameworks, and standardized credential taxonomies, has been shown to facilitate experimentation and adoption while providing legal clarity and encouraging stakeholder trust ([34]).

Collectively, these factors underscore the complex, multi-level dynamics that higher education institutions must navigate to realize the transformative potential of blockchain technologies in academic contexts.

IV. DISCUSSION:

The systematic synthesis of 41 peer-reviewed studies reveals a rapidly evolving discourse on the potential of blockchain applications in higher education. Yet, in practice, real-world adoption continues to lag behind the conceptual development and pilot implementations identified in the literature. While architectural innovations such as EduCTX ([3]), SmartCert ([17]), and EduRSS ([4]) demonstrate promising alignment with the pressing needs for digital credentialing and secure, verifiable student data, institutional readiness and implementation maturity vary substantially across contexts.

Blockchain's integration within Learning Management Systems (LMS) — for example, through IPFS bridges and modular APIs — suggests a viable pathway towards decentralized and scalable learning environments. However, persistent challenges related to interoperability with legacy Enterprise Resource Planning (ERP) systems, low levels of faculty and administrative digital literacy, and compliance with complex privacy regulations continue to impede widespread deployment. Furthermore, the absence of standardized credential schemas and interoperability frameworks across platforms complicates cross-institutional and cross-border recognition, thereby constraining blockchain's practical utility within global academic ecosystems.

An emergent direction identified in several reviewed studies is the exploration of hybrid architectures that combine blockchain with complementary technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT). Notably, [35] and [36] demonstrate how IoT sensors integrated with blockchain can enhance learning analytics, device-level trust, and data provenance, signalling a gradual shift towards cyber-physical academic ecosystems. Similarly, [37] proposed a student management system that leverages machine learning alongside blockchain to enable adaptive, personalized learning experiences. In the Australian higher education context, [38] and [39] forecast a convergence of AI and blockchain as foundational elements for next-generation digital academic infrastructure. It is important to clarify that these examples were part of the dataset synthesized in this review, rather than purely speculative extensions, highlighting an emerging trend toward multi-technology ecosystems within the reviewed literature. Additionally, [40] introduced a novel blockchain-based tax compliance model to automate financial oversight in higher education operations, further expanding the scope of blockchain-enabled administrative functions.

Despite these advancements, it is evident that most documented implementations remain at the proof-of-concept or pilot stage, with a conspicuous lack of large-scale, longitudinal studies that rigorously evaluate scalability, end-user adoption, and institutional return on investment (ROI). This limits the evidence base available to institutional stakeholders when making strategic decisions regarding resource allocation and governance models. Moreover, regulatory ambiguity—particularly with respect to data sovereignty and privacy compliance under frameworks such as the General Data Protection Regulation (GDPR) and the Family Educational Rights and Privacy Act (FERPA)—adds additional layers of risk and legal uncertainty to blockchain deployment in academic contexts.

Collectively, these insights underscore the need for greater standardization efforts, the development of robust maturity models and benchmarking frameworks, and sustained empirical research that moves

beyond pilot studies to assess the real-world impact of blockchain-based solutions on institutional workflows, student outcomes, and system interoperability. Such steps are critical to transforming the current conceptual promise into operational practice within the higher education sector.

V. CONCLUSION:

This systematic review provides a comprehensive assessment of blockchain integration within higher education, synthesizing insights from 41 peer-reviewed studies published between 2020 and 2025. The findings affirm that blockchain holds considerable potential to enhance academic systems, particularly in digital credentialing, decentralized identity verification, and administrative process efficiency. Frameworks employing smart contracts, decentralized storage, and advanced cryptographic methods are shown to be effective in addressing data integrity and verification challenges within Learning Management Systems (LMS) and Enterprise Resource Planning (ERP) environments. For example, [41] underscores blockchain's dual role in both issuing and verifying academic credentials, thereby strengthening institutional accountability and learner trust.

However, widespread adoption remains constrained by technological complexity, institutional conservatism, and regulatory ambiguity. The absence of unified standards for blockchain-based credentials, limited cross-border acceptance, and interoperability challenges with legacy systems continue to pose significant barriers. Infrastructural gaps and limited blockchain literacy, particularly in developing contexts, further hinder practical implementation.

To unlock blockchain's full potential in higher education, future research and policy efforts should prioritize:

- Rigorous field trials in real-world institutional settings
- Development of international standards for verifiable academic credentials
- Cross-disciplinary collaboration combining expertise in education, law, cryptography, and systems engineering
- Policy innovation, including regulatory sandboxes and legal frameworks that recognize blockchain-issued credentials
- Capacity-building initiatives to enhance digital skills among faculty, administrators, and decision-makers

Ultimately, blockchain should not be viewed as a wholesale replacement for existing academic systems but as a foundational layer that can strengthen trust, transparency, and learner agency. Its successful adoption will require collaborative innovation, sustained empirical testing, and strategic alignment with institutional and policy goals.

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