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Blockchain technology and its applications beyond cryptocurrency: A review of educational credentialing, records, and governance applications

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Abstract
Blockchain technology is frequently described only as the infrastructure behind cryptocurrencies, yet over the past decade its distinguishing properties — decentralization, immutability, and cryptographic verifiability — have drawn sustained attention from researchers working in digital learning, educational technology, and higher-education policy. This paper synthesizes recent (2019–2025) systematic reviews, bibliometric analyses, and qualitative studies to examine how blockchain is being applied beyond financial transactions, with a particular focus on higher education credentialing, academic-record management, and institutional governance, situated alongside comparable developments in healthcare and supply-chain management to illustrate the technology's broader trajectory. The review approach draws on systematic literature reviews and bibliometric mapping studies published in established databases such as Scopus, Web of Science, and IEEE Xplore. Findings indicate that blockchain applications cluster around four functional areas: micro-credentialing and certificate verification, academic-record and transcript management, learning-analytics and intellectual-property protection, and cross-institutional governance frameworks. Evidence on effectiveness is encouraging at the level of technical performance — verification processes have been shown to complete in under a second in pilot systems — but empirical evidence of institution-wide adoption, cost-effectiveness, and learning-outcome impact remains sparse. Adoption is consistently constrained by technological barriers (scalability, interoperability, standardization), organizational barriers (managerial commitment, budget, absence of skilled staff), and environmental barriers (regulation, data-protection law, and sector-wide governance norms). The paper concludes that blockchain's educational value currently lies less in transforming pedagogy and more in re-engineering the trust infrastructure that underpins credentials and records, and that its long-term success depends on interoperability standards and cross-sector collaboration rather than on the technology alone.

Keywords: Blockchain technology, digital credentialing, higher education, academic records, educational technology adoption, decentralized ledgers

Introduction

When blockchain entered public consciousness through Bitcoin, most early commentary treated the technology as inseparable from cryptocurrency speculation. That framing has become increasingly outdated. Blockchain is, at its core, a distributed ledger architecture that allows multiple parties who do not fully trust one another to agree on a shared, tamper-evident record without a central intermediary. Once this property is separated from its financial origins, it becomes applicable to any domain where the authenticity, provenance, or sequence of records matters — including healthcare data exchange, supply-chain provenance, digital identity, and, increasingly, education.

In educational contexts, the appeal of blockchain rests on a long-standing administrative problem: academic credentials are difficult to verify quickly, degree fraud and diploma mills persist globally, and student records are typically siloed within individual institutions that do not communicate easily with one another. Blockchain-based credentialing promises a decentralized alternative in which a diploma, transcript, or micro-credential can be cryptographically verified by an employer or another institution in seconds, without needing to contact the issuing university directly. Beyond credentialing, researchers have also explored blockchain's role in protecting intellectual property in open educational resources, recording continuous learning achievements across a student's lifetime, and supporting more transparent governance of multi-institutional consortia and quality-assurance processes.

This paper reviews the recent literature on blockchain applications beyond cryptocurrency, with education — and higher education in particular — as the primary lens, while drawing on parallel developments in healthcare and supply-chain management to situate education within the technology's broader diffusion. The purpose is not to advocate for blockchain adoption but to synthesize what the current evidence base actually shows about its models, effectiveness, and the barriers that continue to limit implementation at scale.

Review Approach

This paper adopts a narrative synthesis approach informed by recent systematic literature reviews (SLRs), systematic mapping studies, and bibliometric analyses rather than conducting an original primary-source database search. Sources were identified through targeted searches of academic search engines and publisher platforms (including Springer Link, ScienceDirect, IEEE Xplore, Emerald, MDPI, and Wiley Online Library) using combinations of the terms "blockchain," "education," "credentialing," "higher education," "adoption," "barriers," and "healthcare/supply chain" as comparison domains. Priority was given to peer-reviewed systematic reviews and empirical studies

published between 2019 and 2025, several of which themselves synthesize findings from tens to hundreds of underlying primary studies (for example, a 2024 systematic review in Multimedia Tools and Applications analyzed 150 distinct blockchain-in-education models, while a 2023 review in Knowledge-Based Systems focused specifically on micro-credentialing systems). Because this is a synthesis of existing reviews rather than a full independent systematic review with a registered protocol, findings should be read as an evidence-informed overview rather than an exhaustive or protocol-driven meta-analysis.

Blockchain Beyond Cryptocurrency: The Wider Landscape

Before turning to education specifically, it is useful to note that blockchain's diffusion into non-financial domains has followed a broadly similar pattern across sectors. In healthcare, systematic reviews describe blockchain being piloted for electronic health record interoperability, pharmaceutical supply-chain integrity, and vaccine traceability, with reviewers noting that adoption is often justified by the technology's capacity to give patients more control over who accesses their data and to make tampering with records detectable. A systematic review of blockchain in the healthcare supply chain, drawing on well over a hundred publications, found that interest in the field has grown rapidly since the early 2020s, with the technology frequently discussed alongside the Internet of Things as a complementary pairing for tracking pharmaceutical products and medical equipment. A related review focused specifically on digital health noted that despite enthusiasm about blockchain's potential to protect patient data, comparatively few studies had rigorously examined the practical challenges of deployment, echoing a pattern that, as this paper shows, is also visible in education research. Market analyses reviewed alongside these academic studies suggest the healthcare blockchain sector has grown substantially in market value since 2024, driven largely by supply-chain and data-interoperability use cases rather than by any connection to digital currency. Taken together, these parallel literatures reinforce that blockchain's core value proposition beyond cryptocurrency is the same wherever it is applied: a decentralized, tamper-evident way of establishing trust between parties who would otherwise depend on a single intermediary. Education researchers have imported this same logic directly into the problem of academic-credential trust, which forms the focus of the remainder of this paper.

Main Body: Blockchain Applications and Models in Education

Micro-Credentialing and Skills-Based Certification

One of the most actively researched applications of blockchain in education is the management of micro-credentials — small, competency-focused certificates that sit below the level of a full degree. A systematic literature review of blockchain-based micro-credentialing systems in higher education institutions found that the field remains relatively young, with most underlying implementations proposed between 2016 and 2022, and identified a persistent gap between the conceptual promise of blockchain-secured micro-credentials and the number of systems that have moved past prototype stage. The appeal of blockchain in this space lies in giving learners a portable, learner-controlled record of skills that can be verified by multiple employers or institutions without repeated manual checks, addressing the administrative burden that micro-credential validation otherwise creates for institutions. Related bibliometric work tracking micro-credential scholarship more broadly has identified blockchain application as one of several still-underexplored areas within the wider micro-credentialing literature, alongside gamification and personalized learning, suggesting that research specifically on blockchain-secured micro-credentials is still maturing relative to the broader micro-credentialing movement.

Academic Records, Transcripts, and Certificate Verification

A second major application area concerns the storage and verification of conventional academic records — diplomas, transcripts, and course completion certificates. A large-scale systematic review analyzing 150 distinct blockchain-in-education models found that the majority had progressed to at least prototype or pilot implementation, with privacy, cost, performance, security, and standards emerging as the central technical dimensions researchers evaluate when designing these systems. Certificate-verification architectures typically work by hashing a credential document and storing that hash on a distributed ledger, so that any party can confirm a certificate's authenticity by comparing it against the immutable on-chain record without needing to contact the issuing institution. A 2025 systematic review focused on quality assurance in higher education similarly concluded that blockchain-based systems demonstrably improve verification speed and fraud resistance for academic credentials, describing initial credential registration and near-instantaneous subsequent verification as a core operational strength of the approach, while noting that interoperability across differing institutional systems remains unresolved.

Institutional Governance, Accreditation, and Cross-Institutional Trust

Beyond individual credential verification, researchers have examined how blockchain might restructure the relationships between universities, accrediting bodies, and employers. A bibliometric analysis of blockchain scholarship in higher education, covering peer-reviewed articles published between 2016 and 2021, found blockchain research in this sector positioned at the intersection of digital transformation and institutional trust-building, with authors frequently proposing blockchain as infrastructure for multi-stakeholder accreditation networks in which universities, professional bodies, and employers share a common verification layer. A separate qualitative study conducted in India examined the specific organizational challenges universities face when attempting this kind of institutional integration, applying the Technology-Organization-Environment framework to interviews with higher-education administrators and finding that governance and process-redesign issues were as significant as any purely technical constraint.

Learning Records, Intellectual Property, and Data Management

A smaller but growing body of work explores blockchain's use in managing granular learning-activity records and protecting the intellectual property embedded in open

educational resources. Systematic reviews in this space describe blockchain-based architectures for timestamping learning activity, recording contributions to shared educational content, and enabling more transparent digital-grading and real-time contracting processes between learners and institutions. This use case extends the same trust logic seen in credentialing to a more granular level — establishing a verifiable, tamper-evident record not just of final qualifications but of the learning process itself.

Evidence on Effectiveness

Evidence for blockchain's effectiveness in education is strongest at the level of technical performance and weakest at the level of institutional and pedagogical outcomes. Pilot systems reviewed in the quality-assurance literature report that credential registration and verification can be completed in a matter of seconds, a substantial improvement over manual transcript-verification processes that can otherwise take days or weeks and require direct correspondence between institutions. Reviews consistently frame this speed and fraud-resistance as blockchain's clearest demonstrated benefit, alongside reduced administrative burden for registrars handling verification requests.

However, the evidence base thins considerably beyond these technical performance metrics. The large-scale systematic review of 150 education-sector blockchain models found that most projects remain at prototype or small-scale pilot stage rather than full institutional deployment, meaning claims about cost savings, fraud reduction at scale, or effects on student outcomes are largely projected rather than empirically demonstrated across full student populations. Similarly, the micro-credentialing review noted a persistent gap between proposed systems and functioning, evaluated deployments, limiting the strength of conclusions that can currently be drawn about real-world effectiveness. Where quantitative claims do appear in the literature, they tend to concern narrow technical benchmarks — transaction speed, storage efficiency, verification latency — rather than broader institutional measures such as reduced administrative cost per verification, improved employer trust, or improved learner mobility across institutions. This pattern mirrors what has been observed in adjacent sectors: healthcare-focused reviews likewise report strong technical promise for interoperability and traceability alongside comparatively limited evidence of large-scale, longitudinal deployment outcomes. In short, blockchain in education currently has good evidence that it can work technically, and comparatively thin evidence about how well, how cheaply, or how sustainably it works once scaled across an entire institution or sector.

Barriers and Challenges to Implementation

The literature converges on a recurring set of barriers, frequently organized using the Technology-Organization-Environment (TOE) framework.

Technological barriers. Reviews consistently identify scalability as a central technical constraint: as the number of records stored on a blockchain grows, transaction processing time can increase, which is a concern for institutions handling large student populations. Interoperability is equally prominent — a credential verified on one institution's blockchain system frequently cannot be recognized by a different institution's blockchain infrastructure, undermining the cross-institutional trust that is blockchain's core selling point in education. A 2025 systematic review focused specifically on adoption barriers found that technological concerns, including integration complexity and data-immutability trade-offs, received the most attention in the literature relative to organizational or environmental barriers.

Organizational barriers. Multiple studies point to a lack of managerial commitment and insufficient budget allocation as significant obstacles, particularly where senior administrators remain unconvinced that blockchain's benefits justify the cost and disruption of implementation. A qualitative study of European Union and Canadian higher-education staff identified usability concerns, legal uncertainty, and value conflicts among stakeholders as recurring organizational obstacles, while a related qualitative investigation in the Indian higher-education context found that process-redesign and internal coordination challenges were often as significant as technical limitations.

Environmental and regulatory barriers. Data-protection regulation, most notably frameworks resembling the European Union's General Data Protection Regulation, creates tension with blockchain's immutability, since regulations that grant individuals a right to have their data corrected or erased are difficult to reconcile with a ledger designed to be unalterable. A 2025 qualitative study examining the institutional environment surrounding blockchain adoption in higher education identified government regulation, bureaucracy, and the absence of shared governance standards as environmental barriers operating alongside — and sometimes in tension with — factors such as cost and privacy, which the same study found could function as either enablers or obstacles depending on institutional context. Sustainability concerns also recur in the literature, with several reviews noting that energy-intensive consensus mechanisms associated with some blockchain architectures raise environmental objections that must be weighed against the technology's administrative benefits.

Across these barrier categories, a consistent theme emerges: the obstacles to blockchain adoption in education are only partly technical. Institutional culture, regulatory ambiguity, and the absence of agreed cross-sector standards are at least as significant as any limitation of the underlying distributed-ledger architecture itself.

Discussion and Implications

Read together, the reviewed literature suggests that blockchain's contribution to education is best understood as an infrastructure-level intervention rather than a pedagogical one. Its clearest documented value lies in re-engineering how trust in credentials is established and verified — shifting from a model where an employer or institution must contact the credential issuer directly, to one where authenticity can be checked instantly against a shared, tamper-evident record. This has genuine implications for reducing credential fraud and administrative burden, particularly as micro-credentials and shorter, more modular qualifications become more common in lifelong-learning ecosystems.

At the same time, the maturity gap between technical pilots and institution-wide deployment is a recurring and important caveat. Much of the literature synthesized here is itself methodological in nature — systematic reviews and

bibliometric analyses of a still-emerging field — rather than large-scale outcome evaluations, which is itself informative: it signals that the field has not yet generated a substantial body of longitudinal, real-world effectiveness data to review. This suggests that institutions considering blockchain adoption should treat vendor and pilot-study claims about cost savings or fraud reduction with appropriate caution until multi-year, cross-institutional evidence accumulates.

The interoperability problem carries a particular implication for policy: blockchain's value in education depends heavily on network effects. A credentialing system is far less useful if only one institution uses it, since much of its promised benefit comes from allowing external parties to verify records without contacting the issuer. This implies that the barriers to blockchain adoption identified in the literature — particularly standardization and cross-institutional governance — are not merely implementation details but conditions that determine whether the technology can deliver on its central promise at all. Sector-wide or national-level coordination, rather than isolated institutional pilots, may therefore be necessary for blockchain credentialing to realize its documented technical advantages at scale.

Finally, the parallels with healthcare and supply-chain applications of blockchain are instructive. In both domains, as in education, the technology shows strong pilot-level performance but comparatively immature evidence of broad, sustained deployment, and adoption is similarly constrained by regulatory tension (particularly around data-protection law) and by the need for standardized data formats across independent organizations. This cross-sector consistency suggests that the barriers education researchers describe are not unique to the sector but are characteristic of how a decentralized-trust technology diffuses into any domain built around independent, historically siloed institutions.

Conclusion

Blockchain technology's relevance extends well beyond its origins in cryptocurrency, and education — particularly higher education — has emerged as one of the more actively researched non-financial application domains. The literature reviewed here indicates that blockchain's most credible educational applications lie in micro-credentialing, academic-record verification, and cross-institutional governance, where its decentralized and tamper-evident properties directly address long-standing problems of credential fraud and slow verification processes. Evidence of technical effectiveness is reasonably strong, particularly around verification speed, but evidence of institution-wide, longitudinal effectiveness remains limited, and adoption continues to be constrained by a well-documented set of technological, organizational, and environmental barriers. Realizing blockchain's potential in education will likely depend less on further technical refinement of the ledger itself and more on the harder work of building interoperability standards, securing sustained institutional commitment, and resolving the tension between immutable records and data-protection regulation. Future research would benefit from longitudinal, multi-institutional deployment studies that move beyond prototype evaluation to assess blockchain's actual costs, benefits, and equity implications once implemented at scale.

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