Opportunities and Challenges of Blockchain Technology in Education: A Systematic Review

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ABSTRACT

This systematic review explores the opportunities and challenges of blockchain technology in education. The study employed a qualitative research design where the data was collected from 28 peer reviewed journals from various databases. A thematic analysis was adopted as a research strategy. Themes used to extract relevant data were 'opportunities', 'challenges', future prospects', 'blockchain integration, 'education'. The review included scholarly articles published from 2017 to 2025 because they offer the latest research in the field. The primary aim of this research was to identify and synthesize the potential benefits and obstacles associated with the implementation of blockchain in educational settings. Major findings reveal that blockchain offers significant opportunities, including enhanced data security, improved transparency in credential verification, and the facilitation of lifelong learning through portable academic records. However, challenges such as technical barriers, privacy concerns, and the lack of regulatory frameworks impede widespread adoption. Despite these challenges, the literature highlights several promising applications of blockchain technology in education. The analysis highlights the need for educational institutions to navigate these challenges to harness blockchain's full potential. It also highlights that blockchain technology can be integrated into other fields such as health, supply chain, transport and various industries. Future research opportunities include investigating best practices for implementation, developing strategies to address privacy issues, and exploring the impact of blockchain on innovative credentialing models. This review underscores the importance of continued exploration in this domain to inform policymakers and educators about effective integration strategies that can enhance educational outcomes especially in developing countries.

Keywords: Blockchain in Education, Decentralized Systems, Data Privacy, transparency and Security

INTRODUCTION

In recent years, the perception of blockchain has evolved from being seen primarily as the fundamental technology behind cryptocurrencies to being recognized as a technology with significant potential in emerging sectors such as healthcare and education [24]. Although the technology has experienced some achievements in areas like supply chain management [28],[6], it remains in a nascent, "prototyping" stage within the education sector [1].

For blockchain in education solutions to create a meaningful impact on a large scale, cooperation and coordination between the private sector and the public are essential to experiment with, research, develop, implement, and finance such innovations. It is important to emphasize that blockchain should not be viewed as a threat to educational institutions but rather as an innovative technology that can enhance various educational processes making learning more engaging and effective, reducing expenses, increasing trust, and offering improved security and privacy.

Blockchain serves as a decentralized digital ledger that captures transactions across numerous computers in a way that guarantees data security and integrity. In the field of education, this innovation has the potential to transform the documentation and verification of academic accomplishments. Conventional methods of maintaining records are frequently vulnerable to fraud and misrepresentation, resulting in considerable difficulties for both institutions and employers.

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By utilizing the fundamental characteristics of blockchain like immutability, transparency, and decentralization educational participants could possibly establish more secure and effective systems for credential management. However, the shift to blockchain-oriented solutions is made difficult by several elements, such as technological infrastructure, privacy issues, and an absence of regulatory guidelines. As educational organizations investigate these advances, it is vital to comprehend both the possible advantages and the hindrances that could impede successful execution.

The swift progress of blockchain technology offers both obstacles and prospects for the education industry. Although blockchain can improve transparency, security, and efficiency in the administration of academic records and credentials, its deployment is complicated by technical, regulatory, and ethical issues [23].

This research intends to investigate the twofold aspect of blockchain technology in education, pinpointing impediments to its acceptance also emphasizing its revolutionary potential that can significantly alter the trajectory of higher education. Existing literature has predominantly focused on the potential of blockchain in education, yet the question of actual implementation remains underexplored. Therefore, this paper seeks to explore the progress made so far.

This research is important for various stakeholders within the education sector, such as policymakers, educators, administrators, and technologists especially in developing countries. By pinpointing the challenges and opportunities linked to blockchain technology, this study intends to inform decision-making regarding its implementation especially in developing countries. Moreover, it aims to add to the expanding body of literature on educational technology by offering a detailed analysis of how blockchain can transform credentialing methods. In the end, this research hopes to steer future investigations and practical uses in utilizing blockchain to improve educational results.

RESEARCH QUESTIONS

The research was guided by the following research questions

1. What are the opportunities associated with implementing blockchain technology in educational institutions?
2. What are the challenges associated with implementing blockchain technology in educational institutions?
3. What progress has been made in implementation blockchain technology in educational institutions?

RESEARCH DESIGN

This research utilized a qualitative research design, employing a systematic literature review methodology. Academic articles, reports, and case studies were examined to pinpoint significant themes associated with the challenges and opportunities of blockchain in education. Themes used to extract relevant data were ‘opportunities’, ‘challenges’, future prospects’, ‘blockchain integration, ‘education’. The review concentrated on empirical evidence to offer a thorough understanding of the present landscape. The review included scholarly articles published from 2017 to 2025 as they contain the latest information about blockchain. They were thematically analysed, and from the assessed records, 28 articles were evaluated in full text. Within this review, challenges, opportunities and progress made so far were noted and classified accordingly.

LITERATURE REVIEW

International research is presently being undertaken in both academia and industry, implementing blockchain in diverse fields. Numerous studies have examined the possibilities of blockchain in the realm of education. Reference [1] performed a systematic review that underscored the advantages and obstacles of blockchain-based educational applications, focusing on credentialing and administrative procedures.

These applications can be categorized into twelve types: certificates management, management of competencies and learning outcomes, assessing students’ professional capabilities, safeguarding learning

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resources, securing collaborative learning environments, transfer of fees and credits, acquiring digital guardianship consent, management of competitions, management of copyrights, enhancing student interactions in online learning, assessment review, and supporting lifelong learning. However, the research by [4] failed to inform about the actual implementation of these management system which have largely remained theoretical.

Another research conducted by [15] recognized blockchain's significance in overseeing and sharing educational records, promoting transparency and ensuring data integrity. Reference [24] explored the opportunities and challenges associated with the implementation of blockchain technologies within the education sector. The principal blockchain-in-education applications highlighted are the digitalization and decentralization of educational certifications as well as the enhancement and encouragement for lifelong learning.

The researcher pointed out that blockchain should not be viewed as a danger or substitute for educational institutions, but instead, as a ground breaking technology that can add value across a broad spectrum of educational processes making learning more interactive and effective, reducing costs, enhancing trust, offering improved security and privacy, etc.

Gilder briefly describes blockchain as:

A database, similar to a cadastre of real estate titles, extended to events, covenants, patents, licenses, or other permanent records. All are hashed together mathematically from the origin of the series, each record distributed and publicized on decentralized Internet nodes (2018, p. 241)

Reference [9] identified 10 primary challenges that were grouped under the three aspects of the TOE framework. Challenges within the technological aspect consist of operational difficulties, security issues, hardware-related complications, and the expenses associated with new technology. The organizational aspect encompasses attitudinal challenges, human resource-related issues, and financial obstacles. The third aspect, known as the environmental aspect, addressed challenges related to the regulatory landscape, stakeholders, and the competitive context. The authors determined that HEIs cannot overlook this emerging technological advancement and must prepare for its implementation. HEIs are also required to weigh the challenges of adopting blockchain technology against the numerous advantages it provides. Reference [23] concentrate on the significant role that blockchain is playing within the education sector and some practical examples from students and educators.

To be able to successfully implement blockchain, [2] in their research study, examined the applications of blockchain in school administration particularly in keeping records, verifying learning identities, and ensuring content security. Reference [21] assessed 36 research papers related to management of teaching, learning, and student activities, which include administrative functions at schools, colleges, and universities, and suggested a blockchain system intended to streamline all of these processes. Reference [7] presented a reliable online-learning framework aimed at securing online learning platforms (LMSs) and consequently ensuring the requisite quality of teaching and equity in assessments, as well as fostering motivation among students and teachers through blockchain incentive mechanisms.

Reference [10] put forward an Ethereum-based system that employs smart contracts for the management of data pertaining to chemistry education students. Reference [3] unveiled the Ubiquitous learning (U-learning), an interactive multimedia system crafted to promote effective communication between teachers and students within a collaborative learning atmosphere characterized by a high degree of security. Lastly, [5] suggested a blockchain-driven School Information Hub (SIH) created to enhance a school's learning environment by gathering, analysing, and reporting data that can aid and support the decision-making process.

In 2017, the MIT Media Lab trialled a program for providing digital diplomas utilizing blockchain technology. The lab has implemented a blockchain-based system referred to as Blockcerts to issue and authenticate academic certificates, thereby ensuring their validity and diminishing fraud. The University of Nicosia was among the first educational institutions to adopt blockchain technology for issuing digital certificates related to its online courses and degree programs. This effort guarantees that certificates are readily verifiable and

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resistant to tampering. Additionally, the university offers a Master's program in Digital Currency, which encompasses blockchain technology and its various applications.

A. Competencies and Learning Outcomes Management

In order to enhance the learning objectives and boost the achievement of skills within the educational realm, more focus was directed towards developing various blockchain applications. This would assist in improving the learning experience and enrich the education field on a large scale. Given the high effectiveness of blockchain technology, multiple applications were capable of assessing and evaluating student performance through both qualitative and quantitative metrics.

For example, Reference [11] developed a system to monitor student performance across their various learning activities. It aggregates all traces for each activity into a block. Therefore, this learning block can be regarded as self-describing as it contains all metadata regarding numerous activities. Such an application facilitates attaining a significant level of self-efficacy. This is consistent with the findings by [29] who suggested creating a learning environment for students. The system delivers immediate assistance and valuable feedback. It was intended to enhance the learning experience by implementing a broad range of skills and fostering critical thinking and problem-solving through improved collaboration and communication.

B. Opportunities of Blockchain in Education

1. Certificates Management: Blockchain technology can securely store and verify academic records, which helps prevent fraud and confirms authenticity. Students and employers can conveniently access verified transcripts. Universities have the capability to issue digital diplomas on the blockchain, which are immune to tampering and can be quickly verified by employers and other educational institutions.

Reference [27] suggested that with blockchain, students' academic records may become public and are easily shareable with employers and universities for additional personal development opportunities. In this manner, "*the accredited educational timeline could be utilized to forecast future potential based on the individual learning histories of students*." This innovation serves as a powerful tool for students to monitor and distribute their academic advancements. It also aids employers, offering accurate and truthful representations of students' potential grounded in their academic accomplishments (trusted verification).

Leading global universities have joined forces to create an international framework for digital academic credentials known as the Digital Credentials Consortium. This platform can offer advantages to learners by maintaining a verified, lifelong record of educational achievements to share with employers, along with obtaining credentials digitally in a secure manner [7] Learners are no longer required to request or pay their universities for several copies of their transcripts and for organizing credentials received from different institutions. Reference [18] Conversely, suggests that educational institutions gain from managing and sharing students' records in a cost-efficient, secure manner, mitigating identity fraud risks, and achieving streamlined processes for issuing multiple credentials to a single learner source. Companies would profit by easily accessing the verified academic credentials of prospective employees.

2. Obtaining Digital Guardianship Consent: Blockchain replaced the conventional method of obtaining parents' consent to gather it electronically instead. This is achievable thanks to the trust that blockchain technology can offer. The decentralized aspect of blockchain accelerates the collection of consent without compromising privacy. This has simplified the collection and exchange process among a significant number of students, parents, and educational institutions [21].

3. Competition Management: Blockchain technology is utilized to streamline competition operations and to improve efficiency and transparency. Reference [30] proposed a competition model based on the e-commerce operation sandbox, which is a decision-making system to assess students' professional knowledge and expertise. They designed this system to establish an evaluation framework that gauges and manages students' operational proficiencies.

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4. Evaluating Students' Professional Ability: A study by [19] implemented blockchain technology to connect educational institutions and employers in sharing all essential information related to recruitment and industry needs. Likewise, [31] demonstrated an application program created with blockchain to evaluate students' professional skills grounded in their academic achievements and performances. This evaluation system was intended to assess and analyse students' abilities using the clustering algorithm within the blockchain. However, the implementation of blockchain in education is not without challenges. Technical barriers, such as the need for robust infrastructure and interoperability with existing systems, pose significant hurdles. Additionally, concerns regarding privacy and data ownership arise, as students may be apprehensive about how their information is stored and accessed. The lack of regulatory frameworks governing the use of blockchain in educational settings further complicates its adoption.

C. Challenges

Reference [22] have explored the difficulties of integrating blockchain into the education field. The restricted availability and incompatibility of hardware and digital infrastructure may serve as an obstacle to the effective implementation of blockchain technology by educational institutions. Reference [25] argued that complementary digital infrastructure is a vital necessity for the incorporation of blockchain into business operations. However, educational institutions may not consistently have easy access to this infrastructure.

The implementation of DLT-based solutions requires prior access to a broadband connection, whether fixed or mobile [14]. Moreover, adopting complementary technologies may also turn out to be crucial as they will determine the failure or success of the implementation process. The lack of digital infrastructure, especially regarding high-speed broadband connections both mobile and fixed could represent a significant impediment in this regard.

1. Regulatory environment: External factors that may affect the adoption of blockchain in higher education in India include government regulations concerning data privacy and security, the availability of funding and support for technology upgrades, and the overall technological advancement of the education sector.

Reference [11] suggested that to fully harness the advantages of blockchain for emerging market economies like India, it is crucial to create a regulatory environment that encourages competition and investment while also fostering innovation. However, currently, there are specific regulations governing blockchain technology in the context of crypto currency more than its integration into education.

D. Specific Regulations Governing Block Chain

Japan recognizes Bitcoin and other cryptocurrencies as legal property under the Payment Services Act, which regulates exchanges and requires them to register with the Financial Services Agency (FSA). Enacted: April 2017.

FSA - Payment Services Act (https://www.fsa.go.jp/en/news/2017/20170428-1.html)

China has implemented strict regulations against cryptocurrency trading and Initial Coin Offerings (ICOs). In 2017, the People's Bank of China (PBoC) banned ICOs and domestic exchanges. Enacted September 2017.

People's Bank of China Announcement (http://www.pbc.gov.cn/goutongjiaoliu/113456/113469/3477115/index.html)

United Kingdom - The Financial Conduct Authority (FCA) regulates cryptocurrency activities under anti-money laundering (AML) laws. The regulations were updated significantly in January 2020. Enacted January 2020.

FCA - AML Regulations (https://www.fca.org.uk/firms/cryptoassets)

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DISCUSSION

Comparisons with existing literature reveal a convergence of results, specifically in the realm of adopting blockchain in education, affirming the assertions made by [7] in their work on potential future applications of blockchain technology in actual teaching and learning contexts. They identify three domains of learning and instruction that hold significant potential for improvement: Formative assessment, learning activity design/implementation, and tracking learning processes.

As demonstrated by the applications and systems discussed, blockchain technology appears to hold significant promise for use in the education sector. In their publication, [6] suggested various scenarios for integrating technology into existing or forthcoming educational processes. These include certification, accreditation, recognition and transfer of credits, lifelong learning passport, e-portfolios, incentives, payments and funding, and management of intellectual property [18].

Research could also advance in the design and execution of learning activities, monitoring of the learning journey and evaluation of outcomes, assessment, and enhancement of the quality of online education. Future research might additionally concentrate on areas such as job-oriented education and lifelong learning programs, where the demand for blockchain-supported credentialing is expected to rise in the coming years. Particularly with the implementation of smart contracts, there can also be advantages from introducing new secure and streamlined procedures that facilitate collaboration and partnerships not only among educational institutions but also between educators and schools, along with interactions between teachers and students.

Ultimately, blockchain may serve to encourage teachers and students by providing rewards in the form of badges or digital currency to those who achieve the established standards or objectives [8].

A study conducted by [14] noted that emerging technological advancements, including 5G networks, smart and interconnected devices, and the evolution of the Internet of Things (IoT), give rise to a new environment where secure data transfer and storage are essential. In this new environment, blockchain technology can play a vital role as it possesses the capacity to lower costs, enhance transaction speeds, and offer the fundamental framework for the secure and unblemished functioning of systems, in addition to the opportunity to develop innovative services and applications.

Notably, the results demonstrated that it does not matter whether it's a developed country or a developing country when it comes to blockchain integration, they face the similar challenges. A significant trend observed was that researchers are busy in their corners coming up with and actually testing these seemingly isolated systems and programs to wards blockchain integration in education. In the context of blockchain in education the implications of the findings resonate with the propositions put forth by [12] underlining the enduring relevance of blockchain in education. It is essential to build more collaborative efforts towards blockchain technology.

CONCLUSION

In conclusion, while the integration of blockchain technology in education presents notable challenges, its potential to revolutionize credentialing and record-keeping processes cannot be overlooked. The integration of blockchain technology in the education field is currently in the early phase. This technology is primarily utilized for issuing and authenticating academic certificates, sharing students' skills and educational accomplishments, and assessing their professional competencies. Nevertheless, a variety of applications are quickly emerging. Blockchain has the potential to offer considerable advantages to education, such as creating a secure platform for sharing students' information, reducing expenses, and improving trust and transparency.

However, it is important to highlight that the implementation of blockchain technology is not without obstacles. Administrators and policymakers must address issues related to security, privacy, costs, scalability, and accessibility prior to adopting the technology [19]. Finally, it indicates that the sectors of education where blockchain technology has been implemented are still restricted. Consequently, the opportunities for blockchain remain largely unexplored.

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Future research should focus on developing best practices for implementation, addressing regulatory concerns, and exploring user perceptions to fully leverage blockchain's capabilities in enhancing educational outcomes especially in African institutions. This review serves as a foundational resource for educators, policymakers, and technologists seeking to navigate the intersection of blockchain technology and education in developing countries.

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