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Research Article

Blockchain Technology for Enhanced Security of Academic Certificates in Education

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ABSTRACT

The significance of blockchain technology in higher education is profound, as it offers the potential to enhance transparency, security, and efficiency in academic record keeping, credential verification including the overall management of educational data. Blockchain technology operates as a decentralized and distributed digital ledger system. It functions across multiple diverse networks, where nodes work to maintain an accurate record of transactions. The decentralized and immutable nature of blockchain offers significant advantages for digital certification, record keeping, and related applications in academia. The current implementations of blockchain-based solutions for academic credentials are examined, highlighting their benefits in terms of security, transparency, and efficiency. This study aimed to explore the applications, blochchain certificates, and future scenarios of blockchain technology in the context of higher education. Additionally, the study examined how blockchain technology could revolutionize various aspects of education in the future, including evaluation methods, the computation of scholarships, and the management of administrative tasks. These findings suggest that blockchain technology has the potential to redefine trust, security, and data management in the educational sector, ultimately leading to a more efficient and equitable system. However, further research and collaborative efforts are required to completely utilize the benefits of blockchain technology in higher education and overcome associated challenges.

Keywords: Blockchain, Distributed ledger, Decentralized, Digital certification, Smart contracts

1. Introduction

Bitcoin cryptocurrency represents the initial implementation of blockchain technology. Since its emergence in 2008, blockchain technology has garnered significant attention from researchers and industry professionals. The implementation of blockchain technology facilitates the creation of open, decentralized records that are accessible to all relevant parties and generated through computerized events or transactions. These records can be disseminated among all the involved parties. Each blockchain transaction is accompanied by a digital signature that verifies its authenticity. Owing to the utilization of digital signatures and encryption, data stored on blockchains are immutable and secure to governments [1]. This innovative technology has applications in numerous other domains, including education, business, healthcare, and government [2][3]. This widespread adoption is attributed to the fact that all transactions completed within the blockchain are secure, immutable, and transparent.

However, the implementation of this technology requires security measures. Consequently, users should not be concerned with the privacy of their data. Blockchain technology's prospects can be seen as an evolving area due to the worldwide surge in interest in information and communication technology, which has triggered transformations across various sectors, including the field of education. This widespread interest in information and communication technology has contributed to the perception that blockchain technology is an emerging field. Consequently, the

potential of blockchain technology is evident at present [4][5]. Blockchain technology has several advantages. Currently, blockchain is stimulating the education discourse, highlighting key issues while simultaneously proposing an optimal solution. It is conventional to document an individual's values in the form of a certificate, which is subsequently used to represent a person's profile. Recent advancements in blockchain technology have manifested in the form of digital certificates that can be printed [6]. Although paper certificates remain a possibility, digital certificates facilitate efficient management.

Blockchain technology offers an intrinsically open, dependable, and robust platform for fully backing educational programs and credentials. The potential of blockchain technology extends to improving systems for compensating educators, evaluating performance, and calculating student scholarships. Blockchain technology also serves as a deterrent against sophisticated fraud [7]. The administrative processes of scientific journals may benefit from the security features of the blockchain technology, which can support the overall management of journal security. Several educational projects have been introduced to modify the current educational system for user benefits. However, some aspects that require examination and observation are not extensively related to this educational project in a single study. Existing gaps may be used to highlight current educational trends. This article elucidates the gap between the implementation of blockchain technology and current educational trends [8][9]. Additionally, this study investigates the blockchain features offered and utilized by current educational institutions to enhance the adoption of blockchain technology in education through the application of blockchain characteristics.
Academic credentials constitute an essential documentation for securing employment. Upon the commencement of a job search, college graduates are typically required to provide evidence of their educational qualifications to prospective employers. Furthermore, organizations frequently request that applicants submit certificates for verification purposes, a process that may extend over several days or weeks. This time-intensive procedure is necessary for institutions to ascertain the authenticity of credentials and ensure that they have not been subject to fraudulent alteration. Verifying certificates is essential in assessing the authenticity of information provided by applicants. This process entails comparing the submitted certificate with the original document issued by the educational institution. Using this method, employers can identify and select the most qualified candidates who possess exceptional skills and knowledge.

2. Review of Educational Certificate System using Blockchain

Blockchain technology ensures that the data records added to decentralized networks remain immutable [10]. Information disseminated on a peer-to-peer blockchain is secured using cryptographic methods [11]. Owing to the distributed management of records across multiple nodes, which cannot be controlled by a single entity, it is highly improbable, if not impossible, to alter any records associated with a network's physical objects. All transactions within a block are interconnected, allowing the blockchain and its participants to authenticate and sign each transaction by using the decrypted cryptographic proof provided by the blockchain. The initial stage of the node process involves the formation of a block that contains multiple discrete transactions. To ensure validity, the block was verified using a vast majority of the network nodes. Verified blocks are subsequently added to pre-existing chains stored across all systems with the aim of generating both a record of damage evidence and a unique historical record [12][13].

The "Blockchain in Education" report by the European Commission's Joint Research Council [14] indicates that multiple organizations have explored the potential applications of blockchain technology within the educational sector. Consequently, the implementation of blockchain in educational processes has garnered the attention of governmental and community entities. The utilization of blockchain technology in the production of digital certificates may address some of the inherent challenges associated with both traditional paper and conventional digital certificates. Blockchain-based infrastructure aims to enhance the efficiency of securing, sharing, and validating educational accomplishments, despite ongoing challenges in certificate issuance. These challenges include the intricate verification procedures, the broadly recognized standards for digital signatures employed in these certificates, and the considerable role played by third-party certificate issuers. These challenges include the complex verification process, widely accepted standards for digital signatures used in these certificates, and significant influence of third-party certificate providers. This remains the case despite ongoing issues in certificate issuance.

Table 1 Advantages and Disadvantages of Blockchain Technology

Technology	Consortium	Hybrid	Public	Private
Advantages	• Access control • Scalability • Security	• Access control • Performance • Scalability	• Independence • Transparency • Trust	• Access Control • Performance
Disadvantages	• Transparency	• Transparency • Upgrading	• Performance • Scalability • Security	• Trust • Auditability
Use cases	• Banking • Research • Supply chain	• Medical Records • Real Estate	• Crypto currency • Document Validation	• Supply chain • Asset ownership

3. Features of Blockchain

Decentralized

A blockchain is a publicly accessible ledger that comprises interconnected nodes within a network. In a blockchain, authority is decentralized rather than centralized. Decentralization pertains to the processes employed in the blockchain for data storage, preservation, verification, and transmission, which are contingent upon the structure of the distribution framework [15][16].

Traceability

The blockchain's current transaction data will undergo sequential indexing, resulting in a consolidated repository. Furthermore, each existing block will implement cryptographic hash functions to establish linkages with its immediate predecessor and successor blocks. Cloud-based platforms analyze all current blockchains, and they are rewarded if a mining pool has successfully maintained the entire blockchain [17].

Consensus Mechanism

Consensus mechanisms are utilized in both blockchain technology and computer systems within decentralized networks or multi-agent settings to establish agreement on a particular data point.This process was implemented to achieve consensus on the data. The recording process was significantly enhanced by this mechanism. This approach encompasses multiple stages, including DPOS, POW, and POS [18].

Currency

Bitcoin is the first decentralized digital currency to be implemented anywhere in the world at this revolutionary moment when all other cryptocurrency ideas are considered. The operation of crypto currencies is dependent on blockchain technology, which may be thought of as a virtual or digital currency that ensures transactions from beginning to finish, thereby making these transactions trustworthy and secure. These currencies were created using various development algorithms. As a result, the integration of cryptocurrency and blockchain technology can be utilized in various sectors, including finance and accounting.[19].

Smart Contract

A blockchain protocol is required to enable programmers to create financial agreements that can subsequently be activated by all participants. This protocol must be in place before programmers can establish these agreements. In addition to reducing the costs associated with traditional transactions incurred from the outside world, this contract considerably increases the quality and security of transactions. This smart contract was created to safeguard blockchain transactions [20].

Immutability

Once the information is submitted, it cannot be edited again. Because all parties involved controlled the data, it was also impossible to modify it. [21].

4. Blockchain Frameworks

Blockchain frameworks serve as comprehensive toolsets that facilitate the development and implementation of the blockchain technology. These frameworks provide preconfigured components and protocols that streamline the process of creating blockchain applications. Notable examples include Hyperledger Fabric, Ethereum, and Corda, all tailored to specific use cases and industries. Hyperledger Fabric is particularly well suited for enterprise applications

owing to its scalability and flexibility. Ethereum is renowned for its capability to execute smart contracts and support decentralized applications (DApps). Corda was specifically designed to cater to the financial services sector and complex business transactions. These frameworks alleviate the complexity associated with blockchain development, enabling developers to concentrate on innovating and creating valuable applications without the need to construct the entire infrastructure from ground up. As blockchain technology continues to evolve, novel frameworks are being developed that offer enhanced performance, improved interoperability, and specialized features.

Table 2 Blockchain Frameworks Comparison

Details	**Custom**	**Ethereum**	**Hyperledger Fabric**
Ledger Type	Permissioned	Permissionless	Permissioned
Governance	League of Universities using the system	Ethereum developers	Linux foundation
Cryptocurrency	None	Ether	None
Consensus Mechanism	Custom proof of Authority	Proof of work	Pluggable mechanisms
Smart Contract	Yes	Yes	Yes
Smart contract language	Any object-oriented language (C#)	Solidity	Node, JS, Golang or Java
Wallet	Yes	Yes	Yes
Cross-platform	Yes	Yes	Yes

5. Blockchain based Educational Certification System

Traditional methods of issuing and verifying academic certificates are often time consuming, prone to fraud, and lack global standardization. The main reason for implementing a certification system based on blockchain technology is to improve the credentialing process's reliability and effectiveness. The key features of this system include the ability to create permanent, verifiable records of academic achievements that cannot be altered or falsified. This immutability ensures the authenticity of credentials and reduces their risk of academic fraud. Furthermore, blockchain's distributed structure removes the necessity for a centralized authority to oversee and authenticate certificates, potentially easing the administrative load and expenses for educational organizations.

Blockcert

The Massachusetts Institute of Technology initiated an open source blockchain project to provide software developers with a foundation upon which they can build a decentralized application. The purpose of this application is to validate certificates of academic records and credentials. Subsequently, users, such as students and employers, would be able to utilize the blockcert platform for verification purposes by installing the blockcert mobile application when it became available for download. This information cannot be altered because the application relies on the blockchain of Bitcoin as its primary source of confidence [22].

Open Certificates

The creation of educational credentials based on Ethereum smart contracts has been entrusted to a startup called open credentials, which has partnered with Singaporean educational institutions [23].

Decentralized Certification System

The use of essential technology forms the foundation for the creation of a blockchain document verification system. The software for the system was built based on an open source blockchain infrastructure. Three different user groups are active in the system: user-1, a committee for certification issues at the university, user-2, a student or document owner, and user-3, a representative of a third party or corporation with access to the system and the ability to add data to the blockchain. Authorities issue a certificate via the system after the prerequisites have been met. Students can ask questions concerning certificates they have obtained after receiving their certificates. The procedure for uploading certificates into a decentralized distributed database known as blockchain is the responsibility of the certificate provider [24].

CERTbchainIoT

The distributed ledger technology-based system enables companies to authenticate the validity of recorded credentials. A self-executing digital contract was deployed to oversee the processes of inserting, updating, disabling, and restoring entries.A certificate smart contract has been developed to keep student certificates on the blockchain.

Only registered educational institutions were permitted to insert certificates. Any browser can view the certificates stored in a chain. Companies will find it much simpler to comprehend and validate jobseekers' qualifications because of this change. To oversee and manage the certificate verification process, a service manager interface has been implemented [25] that connects users (including educational institutions, students, and employees) with the blockchain network. This implementation guaranteed the accurate execution of the verification procedure.

E-Certificate

One of the key discoveries uncovered by this research is the contribution of blockchain to improving the security of e-certificate data, which has been demonstrated to be efficiently dispersed, and operating expenses can be decreased in all sectors of the global economy. Blockchain technology, particularly in the field of school certification, has a significant impact, because it has the potential to build a worldwide trust network that is immutable, authenticated, widespread, and capable of influencing Indonesia's future as a superpower. The implementation of blockchain technology for e-certificates, particularly utilizing the SHA-256 hash, shows significant promise in educational institutions. When properly applied, this technology has the potential to greatly enhance the assessment and evaluation of prospective human resources within these organizations.

Digital Certificate

The ability of blockchain technology to detect fraudulent certificates is now widely recognized and extensively utilized. The accessibility of blockchain technology has the potential to be useful, could provide a solution to existing problems, and is very beneficial for community activities. The e-certificate system, which uses blockchain technology to verify the authenticity of a certificate, is a technology created to carry out the certification process. Blockchains have several advantages: they give young people opportunities, satisfy the skill requirements of business owners, and foster relationships between academic institutions and business owners [26].

Green Certificate

I-Green (Individual Green) is a blockchain-based system for recording and trading Individual Green certificates with the goal of fostering distributed generation. Individual prosumers and consumers are directly involved and are neither active nor disadvantageous in traditional green certificate markets. Creation of igreencoin, a cryptocurrency, and the green ratio scheme, an incentive system for I-Green, based on theories of social norms and peer impact, and the transparency and immutability of blockchain technology. Proof of generation (PoG), a unique blockchain consensus protocol, is created to synergize the green ratio scheme and increase the effectiveness of the blockchain [27].

BCERT

It is used to distribute academic certifications using blockchain, which adds value to the process of providing certificates in educational institutions while also improving the efficiency with which time is spent on the process. In addition, it addresses all the fundamental aspects of blockchain technology, such as authentication, certification, provenance, and traceability. BCERT reduces expenses associated with the implementation of smart contracts and transactions. The functionality of smart contract transactions is affected by the volume of data added to the blockchain [28].

Edgecoin

Edgecoin has a plan in place for DAap that attempts to reduce efficiency, while also protecting against fraud and reducing costs to offer superior regulation. This edgecoin can be used to store academic documents, such as degrees, and make the system's ends more efficient. They may lower costs for students because they do not have to pay for government employees. By confirming its processes and certificates, Edgecoin may lessen the disruption from outdated and unhealthy education, which is a creative reform step for the entire education industry. Therefore, they are resilient against fraud, loss, and other types of harm [29].

Table 3 Educational Certification system with technologies used and its benefits

Educational Certification System	Technology Used	Benefits
Blockcert	Bitcoin Blockchain	Open-source block chain, distributed application and trustworthy

Open Certificates	Ethereum and Smart contracts	Open-source, Hyperledger fabric, custom and solidity
Decentralized Certification System	Public blockchain	Decentralized and distributed
CERTbchainIoT	Smart contracts	Access control and Security
E-Certificate	SHA-256 hash	Distributed and reduced cost
Green Certificate	Crypto currency & Consensus mechanism	Security & Distributed
BCERT	Smart Contract	reduces transaction and smart contract deployment costs
Edgecoin	Consensus mechanism	protect fraud, and costs reduction

Blockchain-based educational certification systems offer several advantages over traditional methods, including enhanced security, transparency, and record immutability. Various platforms have emerged to address this need, each with its own unique features. For instance, blockcerts, developed by MIT and Learning Machine, provide an open standard for creating, issuing, and verifying blockchain-based certificates. The Sony Global Education system utilizes IBM Blockchain to securely share student records across institutions. APPII focuses on creating verified digital CVs and integrating them into recruitment processes. TrueRec by SAP leverages blockchain to create tamper-proof educational and professional credentials. These systems differ in their underlying blockchain technology, scalability, and integration capabilities with the existing educational infrastructure. Although all aim to enhance credential verification and reduce fraud, their adoption rates and user interfaces vary, influencing their effectiveness in different educational contexts.

Table 4 Comparative analysis of pre-existing surveys on Blockchain

Author	Pros	Cons	Objective
Mettler et al. [27]	The pharmaceutical industry is vulnerable to counterfeit drugs, and database ownership is available to healthcare professionals.	Newer healthcare 4.0 security frameworks are not included.	To learn more about the revolutionary effects of blockchain technology in the medical field
Ylihuumo et al. [28]	Uses a distributed ledger for transactions; identifies areas for future study	Future applications of blockchain technology in healthcare not considered	The goal of this paper is to critically examine the existing blockchain-related studies
Ahram et al. [29]	patient confidentiality is preserved; Strengthened PHI's validity, privacy, security, and privacy's robustness	Data access and security concerns that haven't been addressed	Educating ourselves on the cutting edge of blockchain technology
Weiss et al. [30]	Centralized authority is removed, and there is no longer a single point of failure; all	The most significant limitations are posed by mobile	Incorporating blockchain technology into the public healthcare system

	transactions are permanently recorded and cannot be altered; Data integrity and safety have been significantly bolstered.	bandwidth and data usage.	
Zhang et al. [31]	examines the metrics for success with which blockchain technology in healthcare can be evaluated	Failure to comply with security standards	The goal of this study is to compare the performance of various decentralized healthcare applications that are built on the blockchain.
W.liu et al. [32]	Reversible records computation logic, distributed databases, transparent peer-to-peer transfer, and automatic tracking	There is no mention of public blockchain regulations, and the price tag to adopt one is quite high.	With the goal of learning more about how blockchain technology may improve e-health systems,
Chen et al. [33]	How initial coin offerings work is a topic worth discussing.	There are other uses that have been left out of the discussion.	To investigate the potential of blockchain and other innovations for monetary tokenization.
Gatteschi et al. [34]	Features key developments in the blockchain technology, including immutability, security, decentralization, and transparency.	is not concerned with hardware needs such as power usage or processing speed	Considering Blockchain Technology for Your Project
Nalla Paneni et al. [35]	Specifies crucial IOT security issues and parameters.	does not consider concerns that arise with widespread IoT deployments.	The goal of this study is to evaluate the risks and protections offered by blockchain technology for Internet of Things systems.
Konstantinidis et al. [36]	Explores the potential blockchain has across industries.	Nothing is proposed in terms of architecture or implementation, and the survey results are only hinted at.	The purpose of this session is to talk about how blockchain technology can be used in commercial settings.
Dave et al. [37]	Arguments for and against the use of blockchain technology in IoT contexts.	Integration and scalability	To talk about how blockchain technology can be used in industry 4.0
Monrat et al. [38]	Participants and challenges in the blockchain ecosystem are laid forth.	The blockchain's advantages and drawbacks	Industry 4.0 and blockchain-based applications

Blockchain technology has the potential to revolutionize many industries and aspects of society in the coming years. As the technology matures and becomes more scalable, there would be widespread adoption across sectors like finance, healthcare, supply chain management, and government services. Blockchain could enable more secure and efficient systems for digital identity, voting, property records, and financial transactions. Smart contracts running on

blockchain networks may automate many business processes and agreements. However, challenges around regulation, interoperability between different blockchain networks, and energy consumption will need to be addressed. Overall, blockchain has the potential to increase transparency, reduce fraud, lower costs, and empower individuals by reducing reliance on centralized authorities and intermediaries. While the full impact remains to be seen, blockchain is likely to be a transformative technology in the decades ahead.

6. Conclusion

Blockchain technology shows promise in revolutionizing multiple industries, including higher education. This study explored the applications, challenges, and future scenarios of blockchain in the educational context, focusing on its use in academic credentials and certification systems. The decentralized and immutable nature of blockchain offers significant advantages for digital certification, record keeping, and related applications in academia. Various blockchain-based educational certification systems such as Blockcert, Open Certificates, and BCERT have been implemented, demonstrating benefits in terms of security, transparency, and efficiency. Nevertheless, implementing blockchain technology in higher education institutions encounters obstacles, particularly regarding legal recognition and workforce requirements. The technology is still in its early stages, requiring further research and development to fully realize its potential. The future of blockchain in education appears promising, with potential applications extending beyond certification to areas, such as teacher remuneration, assessment systems, and scholarship calculations. Technology could redefine trust, security, and data management in the educational sector, leading to a more efficient and equitable system. Governmental bodies must monitor significant trends and address legal challenges to facilitate the successful integration of blockchain technology in higher education. Collaborative efforts between educational institutions, technology developers, and policymakers are essential to overcoming the associated challenges and harnessing the full benefits of blockchain in education. In conclusion, while blockchain technology shows great promise for revolutionizing higher education, particularly in the realm of academic credentials, further research and development are necessary to address the current limitations and fully exploit its potential. As technology continues to evolve, it is likely to play an increasingly important role in shaping education's future.

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