A Blockchain-based framework for secure Educational Credentials

Shadab Alam[1], Huda Abdullah Yousef Ayoub[2], Rafan Abdulhaq Ahmed Alshaikh[3], Asmaa Hayawi Hussen AL-Hayawi[4]

[1]Department of Computer Science, College of CS & IT, Jazan University, Jazan, KSA
[2]Department of Computer Science, College of CS & IT, Jazan University, Jazan, KSA
[3]Department of Computer Science, College of CS & IT, Jazan University, Jazan, KSA
[4]Department of Computer Science, College of CS & IT, Jazan University, Jazan, KSA
[1]s4shadab@gmail.com

Article History: Received: 10 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 28 April 2021

Abstract: Blockchain provides a creative approach to storing information, executing transactions, conducting tasks, and building trust. Some see Blockchain as a revolutionary technology for cryptography and cybersecurity, with applications ranging from cryptocurrency to healthcare, smart contracts, Internet of Things, smart grids governance, supply-chain etc. This research work would offer a detailed analysis of blockchain Security, Privacy and Trust. It further studies the applications of blockchain technology in the domain of education and involved challenges. Finally, it proposes a blockchain-based framework for secure and reliable student's record management.

Keywords: Blockchain, Education, Digital Certificate, Educational Credential, Security, Privacy

1. Introduction

Blockchain provides a creative approach to storing information, executing transactions, conducting tasks, and building trust. Some see Blockchain as a revolutionary technology for cryptography and cybersecurity, with applications ranging from cryptocurrency to healthcare, smart contracts, Internet of Things, smart grids governance, supply-chain etc. This research work would offer a detailed analysis of blockchain Security, Privacy and Trust. It further studies the applications of blockchain technology in the domain of education and involved challenges. Finally, it proposes a blockchain-based framework for secure and reliable student's record management [1].

Blockchain, the technology underpinning the Bitcoin currency, is a decentralized sharing ledger that records data from the various parties participating in the Bitcoin network's transactions. The Bitcoin network, in particular, uses the Blockchain to store the history of transactions as well as other transaction-related information, such as the time that the transaction was completed, the sender's (or spender's) address, and the receiver's address. It will assist the spenders in avoiding double-spending. To secure the Blockchain's privacy, all of the information is encrypted.

The Blockchain can also be defined as a shared ledger since it holds all of the information about all Bitcoin transactions [2]. The world of education is transitioning into the modern age. Indeed, technology and education are an excellent match that has grown in popularity in recent years. As a result, educational technology has become a worldwide phenomenon. However, we cannot discuss the use of technologies without discussing the issue of protection. Failure to adhere to adequate protection procedures will result in increased financial and human resource use. Researchers and practitioners have proposed various recommendations, approaches, and strategies that help the decision-making process on the security steps to be adopted after the early implementation of technology in education. Blockchain technology, which has powerful encryption features, is one approach that has recently gained traction. A bibliographical quest was conducted to explore the current status of blockchain technology in education. This study aims to provide a formal classification of existing practices as well as a synthesized summary.

This project aims to recognize various blockchain implementation fields that are already in use and potential blockchain applications in education. It focuses on three key themes: (1) blockchain-based educational technologies, (2) the opportunities that blockchain technology could bring to education, and (3) the complexities of implementing blockchain technology in education. Document authentication is a critical topic with a variety of challenging and time-consuming procedures to authenticate. Various reports are also available, including banking notes, government documents, transaction documents, and educational certificates [3].

Educational credentials are the most important records granted by universities to students. Fake certificates are easy to make since the issuance mechanism is not straightforward and verifiable. A well-crafted false certificate is often challenging to spot and can be mistaken for the real thing [4]. This work aims to discuss the practical

applications of Blockchain and further analyses the specific application of Blockchain in the educational system. We propose to examine the different facets of blockchain technology's protection and privacy and its implications in the educational process. We also advocate creating a blockchain-based system for keeping track of students' academic records. This project would include immutable student documents that can be independently checked at some point in the process. The suggested system would safeguard student information, thus allowing students to check for their degrees even after a period of time has passed. A fake degree cannot be produced, and it can be uniquely confirmed.

2. Background

2.1. Hashing

Hashing is a mathematical process that generates a value or values from a string of text. When a message is meant for a single recipient, hashing is one way to ensure confidentiality during the transmission process. The hash is produced using an algorithm, which helps to protect the transmission's protection from tampering. Hashing is also a tool for efficiently sorting key values in a database table.

MD5 and SHA-1 are traditional cryptographic hash functions with a single goal: transforming the source input (message) into a fixed-length bit string (hash) [5]. And if they all have a somewhat different function, they are often referred to as (digital) signatures, checksums, or simply hash values. Inverting cryptographic hash functions, that is, recreating the input data solely from its hash value, is considered virtually impossible [6].

2.2. Blockchain Technology

A blockchain is a novel technology that is continuously evolving and being applied in various domains. Its inception is from the famous digital currency proposed by Satoshi Nakamoto [2]. Initially, it was used only for financial transactions, but now it is being used or being proposed in every domain that needs immutable and secure record-keeping or ledger. Blockchain is a collection of generated blocks using cryptographic hash functions and connected together with the previous block in the form of a secure chain using cryptographic algorithms [7]. It's a special form of distributed ledger technology that operates on a peer-to-peer (P2P) network. It uses a consensus algorithm to validate a new block, and once validated and added into the Blockchain, these blocks can not be altered.

2.3. Types of Blockchain

Private and public blockchains are the two main styles of blockchains. There are, however, several variants, such as Consortium and Hybrid blockchains. Any Blockchain is made up of a group of nodes linked by a peer-to-peer (P2P) network. Each network node has a copy of the mutual ledger, which is maintained regularly. Each node has the ability to validate transactions, send and receive messages, and building blocks.

2.3.1. Public Blockchain

A public blockchain is a non-restrictive, permissionless distributed ledger system. As an authorized node, anybody with an internet connection can access a blockchain platform and become a network user. A public Blockchain node or user can search current and historical records, verify transfers, proof-of-work incoming blocks, and mine. Cryptocurrency mining and trading are the most common uses of shared blockchains. As a result, the most commonly used decentralized blockchains are Bitcoin and Litecoin. Public blockchains are largely secure if users closely apply safety guidelines and procedures [8].

2.3.2. Private Blockchain

A permissioned or limited blockchain can only be used in a protected network known as a private blockchain. Private blockchains are usually used by an organization or business where only a small number of users can join a blockchain network. The level of conformity, authorizations, licenses, and accessibility are all determined by the governing organization. As a result, private blockchains are functionally similar to public blockchains, but their network is smaller and more limited. Private Blockchain is generally applied in voting, supply-chain, digital identity, wealth management, and other applications.

2.3.3. Consortium/ Federated Blockchain

A consortium blockchain is a semi-decentralized ledger that a group of companies or institutions manages. In comparison, a private blockchain, which a single person owns, looks like this. More than one person may act as a node in such a Blockchain for transacting data or mining. Government departments, financial institutions and other organizations also use consortium blockchains [9].

2.3.4. Hybrid Blockchain

A hybrid blockchain combines the benefits of both proprietary and public blockchains. It incorporates features from all forms of blockchains, allowing for both a private permission-based and a public permission-less scheme. Users will monitor who has access to which data held in the Blockchain with a hybrid network like this. A few of the Blockchain's data or documents will be made available, with the remainder remaining private in the private network. Users will conveniently access a private network or several public blockchains thanks to Blockchain's hybrid framework.

2.4. Blockchain Features:

Blockchain technology is not only used for cryptocurrencies but it is being used in various diverse applications and being proposed in many more due to the following features [10]:

a. **Immutability:** One of the most important blockchain characteristics is immutability, which ensures that the technology remains where it is – a stable, unalterable network.

b. **Decentralized:** The network is decentralized, which means there is no one controlling body or individual in charge of the system.

c. **Improved Security:** Since there is no need for a central authority, no one can simply adjust network features to their advantage. Encryption adds another layer of protection to the device.

d. **Distributed Ledgers:** A public ledger typically contains details about a transaction and its participants. There's nowhere to hide because it's just out in the open. The argument for private or federated Blockchain, on the other hand, is a little different. However, in such situations, a large number of people will see what is actually going on in the ledger. It is because all those users on the device maintain the ledger on the network. To get a better result, the computing power was spread through the machines.

e. **Consensus:** Consensus is a community of participating nodes on the network's decision-making mechanism. The nodes will accept easily and reasonably quickly in this case.

f. **Faster Settlement:** As opposed to conventional banking schemes, Blockchain allows for a quicker settlement. It will enable a person to pass funds more quickly, which saves time in the long run.

3. Application Area for Blockchain

Since cryptocurrencies account for a significant portion of current blockchain networks, most scholars divide them into financial and non-financial categories. Others categorize them based on blockchain versions. We present some blockchain-based applications:

3.1. Financial applications

Blockchain technology is currently being used in various financial areas, including business services, financial asset settlement, prediction markets, and economic transactions. Marketplace systems (PMS), which operate as oracles or intelligence sources, are another fascinating area that can influence companies and cryptocurrencies. Blockchain is set to play a critical role in the financial economy's long-term viability, benefiting investors, the existing banking system, and society as a whole [12].

3.2. Governance

Governments have been tasked with managing and maintaining official accounts of residents and/or businesses for several years. Through disintermediating transactions and record-keeping, blockchain-enabled applications can transform the way local and state governments function [10]. Blockchain's transparency, automation, and security for managing public information could potentially prevent corruption and improve government services. Blockchain may be used as a secure networking network for combining physical, social, and industrial infrastructures in a smart city framework [13]. Blockchain governance aims to have the same resources as the state and its related public bodies in a decentralized and effective manner whilst retaining the same legitimacy.

3.3. Citizenship and user service

The incorporation of emerging technology into daily life necessitates systems such as Blockchain to reliably identify and certify users' primary attributes such as identity, address, credit history, and other personal characteristics [14].

3.4. Voting

E-voting is being proposed as a promising and game-changing technology to ease out the election process, reduce the law and order complications and reduce time and financial expenditure. Still, due to security issues and cybersecurity threats, it has not gained momentum. Blockchain can provide a trusted and secure platform for e-voting that can remain consistent with domestic laws.

3.5. Internet of Things (IoT)

The application of the Internet of Things (IoT) to population growth has resulted in its applications in each daily life domains and become critical for growth [15]. Although there are many advantages of using IoT, various security threats outnumber these advantages [16]. Due to limited hardware capabilities, the traditional cryptographic security mechanism can not be applied in such an environment. Blockchain can provide a platform and mechanism for securing the IoT network, and it can provide an open IoT network for a secure, reliable and interoperable IoT network [17].

3.6. Healthcare management

Blockchain technology may provide a critical solution for the healthcare providers that have implementations in healthcare management, demographic healthcare history, electronic insurance claims settlement and remote patient patients medical data sharing. It will provide user-oriented medical investigation, stop counterfeit products & medicines, and manage clinical trial data [18]. In specific, Blockchain alongwith Smart Contracts, may solve issues such as clinical trial outcomes' scientific credibility and patient informed consent [19].

3.7. Privacy and security

Significant amounts of confidential and classified knowledge are amassed through centralized institutions, both public and private. Despite the GDPR's goal of regulating the production of this data, there is still a significant gap to be filled. Compared with other reliable computing mechanisms that use data mining techniques, Blockchain is seen as a way to improve the reliability and scalability of big data [20]. As a result, the literature contains privacy and security-oriented applications based on blockchain technologies [13].

3.8. Business and industrial applications

Blockchain may become an important source of novelty in business and management through reinforcing, optimizing, and automating enterprise processes. The IoT and the Blockchain are spawning a slew of innovative e-business models. In a business model, SCs are used to carry out transactions between devices on a distributed network based on Blockchain [21].

3.9. Supply chain management

Blockchain is expected to improve supply chain efficiency and accountability, allowing for more flexible value chains. Blockchain-based technologies, in particular, have the potential to revolutionize supply chains in three areas: visibility, optimization, and demand. Blockchain can be used in distribution, counterfeit commodity detection, document load collection, origin monitoring, and buyers and sellers to trade directly without intermediaries [22].

3.10. Energy sector

Blockchain's potential applications in the energy market are many, and they would have a significant impact on both processes and networks. Blockchain can minimize costing and enable new business models, while marketplaces and grids could be best equipped to manage sophistication, data security, and ownership [23]. It can also make the power grid operate more efficiently and effectively control demand response and provide a foundation for more proficient resource consumption monitoring and billing in energy sources [14].

3.11. Data management

Blockchain is a very suitable technology for data management. Since all of their processes are verifiable, implementations and frameworks built on this technology have improved data protection and allowed by default auditability. This final section on blockchain-based applications cites related literature aimed at data storage that is reliable, safe, and verifiable [24].

3.12. Miscellaneous applications

Crowdfunding is a suitable use case of blockchain technology. In the humanitarian and philanthropic fields, blockchain implementations may be used to tackle hunger. Blockchain can also build intelligent, secure, distributed, and autonomous transportation networks and securely manage event tickets in smart city contexts. Edge computing and the creation of computational resource sharing networks, grid computing, cloud computing, and the usage of Blockchain as a device connector are several of the IT-related blockchain applications that are of particular concern.

4. Blockchain in Education

The Blockchain can help educational institutions strengthen their ability to assist teachers, deliver knowledge to guardians and community members, empower new learning systems, and expand and provide learning opportunities for more students. Figure 1 depicts the general structure of Blockchain and users in the domain of education. There are several uses and advantages of using blockchain technology in the field of education:

4.1. Online Education

Online education, also known as distance learning or electronic learning, uses data and internet technology to deliver information and facilitate learning. It's referred to as a web-based learning technique. With blockchain invention, an ideal solution to online learning issues, such as legitimacy and protection, will be offered. The Blockchain will also create non-modifiable learning documents for online teaching without the need for third-party oversight, ensuring that course credits are adequately recognized.

4.2. Student records

Academic transcripts are one of the most time-consuming and labour-intensive processes in higher education. Each entry must be manually checked for authenticity before a validated record of a student's grades is available. Course content certification is another type of student record that is often sought. Each page should be signed and stamped for each student who requests this record (to ensure accuracy). If material courses and academic accomplishments were stored on a blockchain, an individual could get an accurate, authenticated record with just a few taps [25].

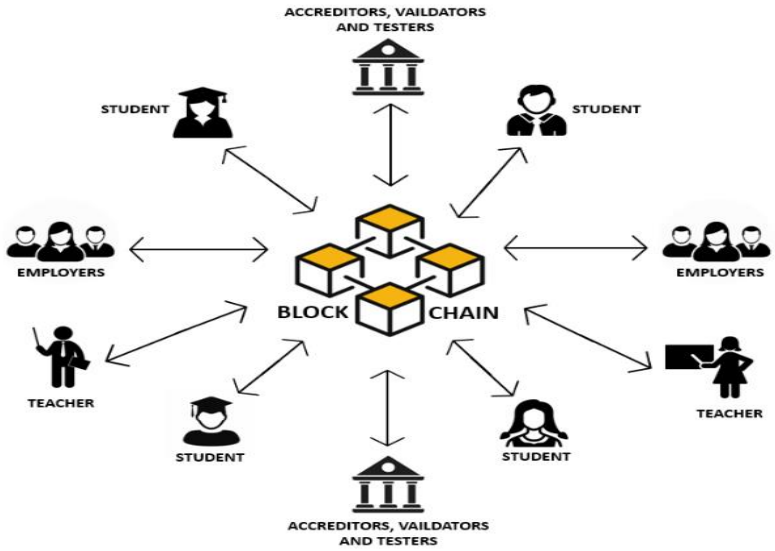

Figure 1: Blockchain in Education

4.3. Diplomas and certificates

Diplomas and certificates for students could be provided and stored on a blockchain, much like grades. Employers will then need to be given a referral to a digital certificate instead of requiring the agency that issued the diploma to certify a paper copy. It is also in progress. Since most of the available instructive credential administrations are unable to guarantee the confidentiality and reliability of student data. Although using Blockchain to address confidence problems could be a viable solution, Blockchain has drawbacks that limit its complete adoption. Small throughput and access time are found in Blockchain [26]. It stops users from using fake degrees or certificates to possible employers or institutions for higher education.

4.4. Badges

Aside from degrees, a standard resume provides a wealth of additional details that employers can find helpful. We're talking about qualities like foreign language proficiency, engineering competence, or unique talents that aren't inherently relevant to one's occupation. However, these abilities are difficult to prove. However, an individual may hire a third-party professional to validate their competence and issue a credential or badge. If these are stored on a blockchain, they can be used to show that an individual has the necessary skills. Open Badge Passport, for example, is the first step in this direction.

4.5. Student Examination and Evaluation

Students will then take the test remotely using personal computers or smartphones, with the Blockchain performing the evaluation. Teachers would have more time to devote to other scholarly or cultural pursuits if they didn't have to grade tests. Teachers can use smart contract and Blockchain with defining the correct answers and scoring criteria for evaluation. Student's will then appear for the examination on their PC or devices. Students' academic success and academic successes in education, preparation, tournaments, work, and other events outside of school can be measured using blockchain technologies to assess their capability, which benefits both students and businesses looking to hire them. A blockchain-based student technical skill assessment system that can test student ability measurement methods using a clustering algorithm. The framework can also allow for the development of a student skill assessment ecosystem.

4.6. Lessons and courses.

Many blockchains also support smart contracts. It ensures that lessons and courses can be coded into the Blockchain and run spontaneously when those criteria are encountered. An instructor may assign students assignments. The smart contracts on the Blockchain could verify the execution of each mission automatically. Teachers could be paid in crypto tokens for finishing all assignments, and students can get credits. This method may be used to layout whole classes also.

4.7. Intellectual property protection and Publishing

Undergraduate and graduate students, instructors, scholars, and researchers actively produce high-quality content, but getting it published is difficult. Although growth in the amount and types of ways to publish academic work, questions about peer review accuracy, plagiarism, the lack of audience and patient participation, publication prejudice, predatory reporting, the expense of open access publishing, and the opacity of science research's "pedigree" remain. Academic transparency, reproducibility, and the prevention of evidence falsification and manipulation are all at the centre of debates aimed at preserving public interest in the scientific method. Blockchain can sort out these issues.

4.8. Admission Process

Most educational institutions operate based on a model in which they have authority over students' records and qualifications. As a result, there's a chance the data will be changed, lost, or destroyed. Data can be securely shared to interested parties using distributed ledger technologies running on a decentralized network. It will also help to prevent theft. It will inspire students to adopt mobile learning modes, as they will be able to effectively complete the admission requirements of various universities around the world [27].

4.9. Benefits of blockchain technology in education

Blockchain technology is an innovative new field of blockchain technology with a lot of potentials to transform the education industry. The advantages of blockchain technology in education range from data management to data authentication without jeopardizing legitimacy. The blockchain data is accessible and verifiable 24 hours a day, seven days a week, with complete accountability. Blockchain technology is commonly used to issue and authenticate educational credentials such as degrees, transcripts, and students' competencies, qualifications, and technical abilities, which employers can check all over the world. The credential process is streamlined thanks to blockchain technologies, and employers can expend less time verifying academic performance. It supports the education sector by offering a secure forum for sharing student data, increasing confidence, lowering costs, and increasing accountability. Blockchain technology holds a complete record of the course in data blocks that are ordered by timestamps in a chronological sequence. The cryptographic algorithm avoids computer tampering and frauds by preventing the deletion of old and new data blocks. It creates a virtual infrastructure for paper collection and keeps track of students' qualifications and accomplishments throughout their lives.

4.10. Issues of applying blockchain technology in education

It is undeniable that using blockchain technology in education could have drawbacks. Teachers must subjectively evaluate all cognitive patterns and learning outcomes, such as essays and educational presentations, as part of a complex structure. Without human interaction, a pre-programmed smart contract can't test these kinds of learning activities. If educational blockchain technology was introduced in schools, all students' academic data will be integrated into blockchain ledgers. It is undeniable that using blockchain technologies in education could have negative consequences. As part of a dynamic system, teachers must subjectively analyze both processing behaviours and learning outputs, such as essays and instructional presentations. A pre-programmed smart contract can't measure these types of learning experiences without human intervention. Students' educational data can be incorporated into blockchain ledgers if educational blockchain technology is implemented in classrooms [28].

Blockchain technologies' immutability would have a double-edged effect. It reduces the possibility of modifying a student's school records for legitimate reasons for certain applicants. Furthermore, many technical barriers or roadblocks to using Blockchain in education have not been addressed. The standard Proof of Work consensus method, for example, is a waste of time. It has a low number of transactions per second, which adds to the expense and prevents it from being used in classrooms [24].

5. Blockchain-based Framework for Digital Credential in Education

Online qualifications have everything from digital badges to digital certificates. In the online environment, the alternative for paper-based qualifications, medals, and prizes. It's easy to give, maintain, and check digital credentials. Degrees from educational institutions, recognition for completing a course or subject, and awards for acquiring a personal or technical competence are some of the most popular examples [29].

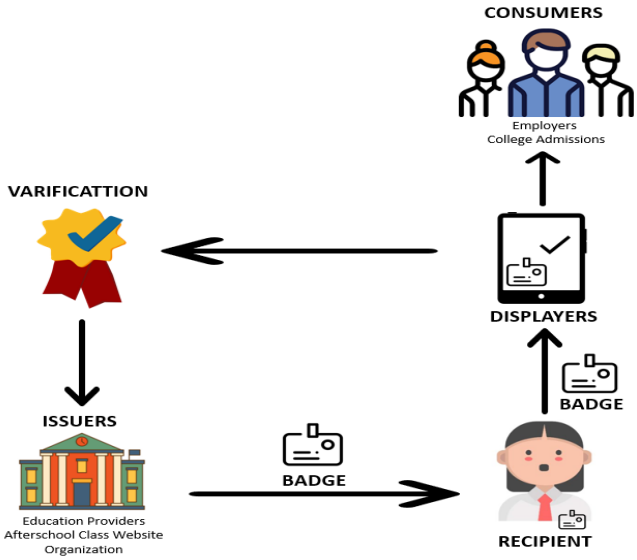

Figure 2: Digital verification of academic records

Digital certificates denote and convey valuable knowledge regarding the credential holder's competence, and the agency or entity the verifies that competency. Figure 2 provides a general scheme of digital verification of academic records. Most certificates have a symbol that identifies the competency and the granting institution, such as this Faculty Development badge of Course and Curriculum Mastery from the Colorado Community College System. University transcripts will become increasingly outdated and useless as a result of digital certificates [30]. Although employers will continue to value degree completion, transcript entries of course grades are also unreferenced in the career application process. Digital credentialing has benefits in terms of tracking and disseminating comprehensive learning accomplishments.

5.1. Issues with digital certificates

As professional credentials have gained market importance in the last decade, the manufacture of fake academic credentials has become a universal issue. The rise in false diplomas is often attributed to the economic downturn, with desperate people forging credentials in order to gain work qualifications. Recent evidence, however, reveals that diploma counterfeiting affects not only lower-level employees but also activists, government officials, and university candidates. According to a recent study, transcript issuance administration and management face several challenges [31].

A transcript is easy to exploit and barely verifiable in its physical nature. Transcripts, even though digitized, are difficult to exchange between organization or employer networks and are highly vulnerable to security vulnerabilities. From a financial standpoint, these challenges will come at a high cost and have no reward for those who want to solve them. Many academics have suggested blockchain technologies to swiftly issue academic certificates and authentication to address the issue of cumbersome and time-consuming secretarial work [25].

5.2. Proposed Blockchain-based Framework for Digital Credential in Education

The time-consuming method of manually verifying university documents can be digitalized in smart cities to make it easier and more reliable. Figure 3 shows a blockchain-based architecture for digitally verifying academic documents. A student's grades or competencies are inserted into the scheme for each research unit in this architecture when available. An educational institute may define a research unit as a semester or a module. To be loyal to the blockchain network, the teacher of that study unit sends the grades using the institutional grade endorsement mechanism. All grades for all research units will be registered in the Blockchain regularly in this manner. Once a student has finished all of the study units in his academic program, an algorithm will check whether all of the requirements for a degree have been fulfilled and provide the applicant with a digital transcript and diploma. Graduates can earn digital academic credentials and specific identity, such as a Uniform Resource Identifier (URI), which they will send to anybody who wants to check their academic credentials. The credentials from the Blockchain may be verified by an external person, such as an employer or government official, using the identifier. Figure 3 presents a step by step process for academic certification management process using Blockchain. The credentials from the Blockchain may be verified by an external person, such as an employer or government official, using the identifier. The documents displayed by the Blockchain would be legitimate and would not need any more notarization since the blockchain records are permanent.

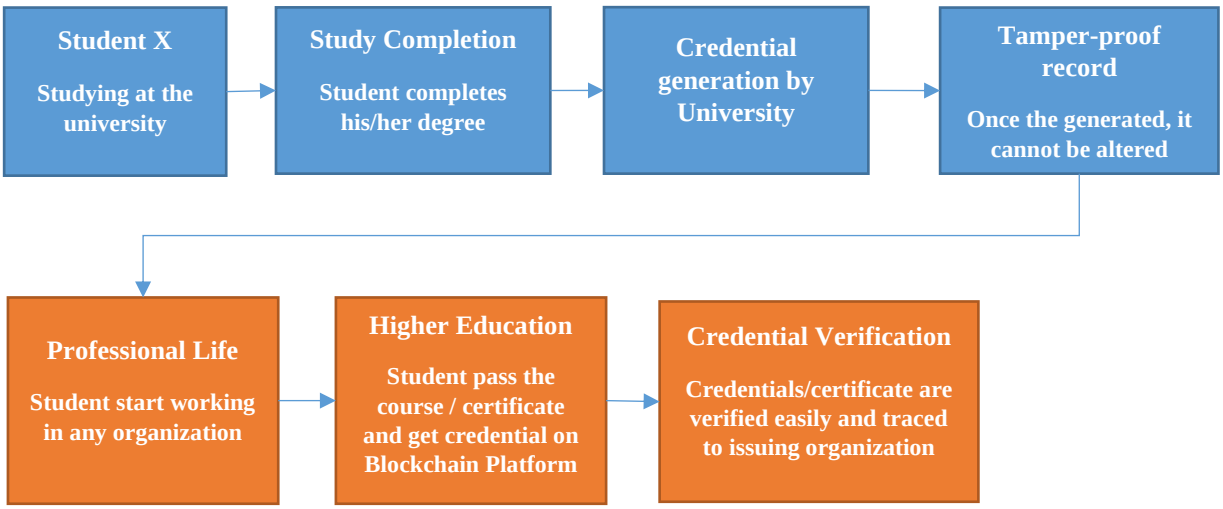

Figure 3: Academic certification management process using Blockchain

For the maintenance of student academic data, we suggest a blockchain-based system. This project would include immutable student documents that can be independently checked at some point in the process. The proposed system would safeguard student information, thus allowing students to check for their degrees even after a period of time has passed. A fake degree cannot be produced, and it can be uniquely confirmed. Figure 4 provide a Digital Certificate Issue Process, and Figure 5 gives the verification process using Blockchain.

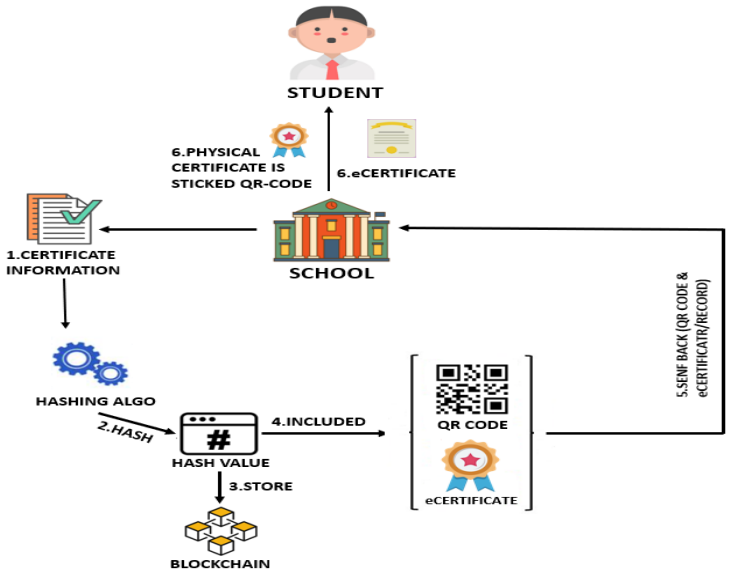

Figure 4: Digital Certificate Issue Process using Blockchain

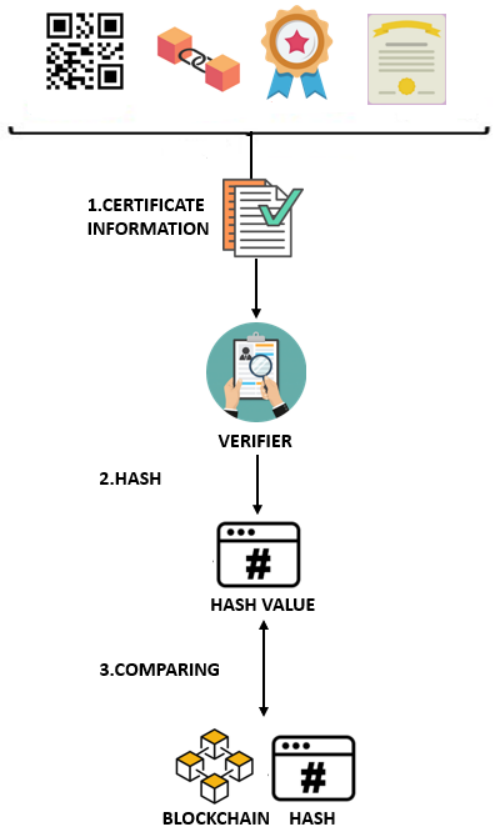

Figure 5: Digital Certificate verification process using Blockchain

6. Conclusion and Future Work

Blockchain is a ground-breaking system that enables people to record transactions on a decentralized, public ledger without the need for a central authority. The educational system will benefit from Blockchain in a variety of ways. The technology is ideal for storing, exchanging, and networking sensitive data in a safe manner. Many systems can be made quicker, simpler, and better with the aid of this advanced device. It bridges the difference between credentialing, copyright rights, and speedy connectivity. These traditional systems would almost certainly benefit from Blockchain in the near future. New innovations are introduced into our lives, and we must use them responsibly for change to go in the right direction. Current students will be living in a brand-new world! We should encourage them, accept the reforms, and learn how to improve things. Blockchain is a rapidly spreading technology, and it will be a pillar for many applications in the next few years. A suggestion for future work is to continue this work by conducting more interviews to identify some additional characteristics for the current application areas of Blockchain. In particular, the field of education in detail. Make Educational courses that explain blockchain technology at a reasonable cost so many people can join and review the smart contracts in more detail and study the potential risks within this area.

References

[1] P. Fraga-Lamas and T. M. Fernandez-Carames, "A Review on Blockchain Technologies for an Advanced and Cyber-Resilient Automotive Industry," *IEEE Access*, vol. 7, pp. 17578–17598, 2019, doi: 10.1109/ACCESS.2019.2895302.

[2] S. Nakamoto, "Bitcoin: A peer-to-peer electronic cash system," 2008.

[3] I. T. Imam, Y. Arafat, K. S. Alam, and S. Aki, "DOC-BLOCK: A Blockchain Based Authentication System for Digital Documents," in *2021 Third International Conference on Intelligent Communication Technologies and Virtual Mobile Networks (ICICV)*, 2021, pp. 1262–1267.

[4] A. Alammary, S. Alhazmi, M. Almasri, and S. Gillani, "Blockchain-based applications in education: A systematic review," *Appl. Sci.*, vol. 9, no. 12, p. 2400, 2019.

[5] M. U. Bokhari, S. Alam, and S. H. Hasan, "A Detailed Analysis of Grain family of Stream Ciphers.," *Int. J. Comput. Netw. Inf. Secur.*, vol. 6, no. 6, 2014.

[6] M. U. Bokhari and S. Alam, "BSF-128: a new synchronous stream cipher design," in *Proceeding of international conference on emerging trends in engineering and technology*, 2013, pp. 541–545.

[7] M. Aamir, R. Qureshi, F. A. Khan, and M. Huzaifa, "Blockchain based academic records verification in smart cities," *Wirel. Pers. Commun.*, pp. 1–10, 2020.

[8] S. T. Siddiqui, R. Ahmad, M. Shuaib, and S. Alam, "Blockchain Security Threats, Attacks and Countermeasures," in *Advances in Intelligent Systems and Computing*, 2020, vol. 1097, pp. 51–62, doi: 10.1007/978-981-15-1518-7_5.

[9] A. Gorkhali, L. Li, and A. Shrestha, "Blockchain: a literature review," *J. Manag. Anal.*, vol. 7, no. 3, pp. 321–343, 2020, doi: 10.1080/23270012.2020.1801529.

[10] M. Shuaib, S. Alam, and S. M. Daud, "Improving the Authenticity of Real Estate Land Transaction Data Using Blockchain-Based Security Scheme," Springer, Singapore, 2021, pp. 3–10.

[11] M. Salimitari and M. Chatterjee, "A survey on consensus protocols in blockchain for IoT networks," *arXiv*. Sep. 2018.

[12] J. Abou Jaoude and R. George Saade, "Blockchain Applications – Usage in Different Domains," *IEEE Access*, vol. 7, pp. 45360–45381, 2019, doi: 10.1109/ACCESS.2019.2902501.

[13] S. Alam, M. Shuaib, and A. Samad, "A Collaborative Study of Intrusion Detection and Prevention Techniques in Cloud Computing," in *Lecture Notes in Networks and Systems*, vol. 55, 2019, pp. 231–240.

[14] M. Shuaib, S. Alam, S. Mohd, and S. Ahmad, "Blockchain-Based Initiatives in Social Security Sector," in *EAI 2nd International Conference on ICT for Digital, Smart, and Sustainable Development (ICIDSSD)*, 2020, p. 8.

[15] M. A. Khan, M. T. Quasim, F. Algarni, and A. Alharthi, *Decentralized Internet of Things: A blockchain perspective*, vol. 71. Springer Nature, 2020.

[16] S. Abdus, A. Shadab, S. Mohammed, and B. Mohammad.Ubaidullah, "Internet of Vehicles (IoV) Requirements, Attacks and Countermeasures," *5 Int. Conf. "Co mputing Sustain. Glob. Dev.*, no. March, pp. 4037–4040, 2018.

[17] A. Raghuvanshi, U. Kumar Singh, M. Shuaib, and S. Alam, "An investigation of various applications and related security challenges of Internet of things," *Mater. Today Proc.*, Mar. 2021, doi: 10.1016/j.matpr.2021.01.821.

[18] M. Shuaib, S. Alam, M. Shabbir Alam, and M. Shahnawaz Nasir, "Compliance with HIPAA and GDPR in blockchain-based electronic health record," *Mater. Today Proc.*, 2021, doi:

https://doi.org/10.1016/j.matpr.2021.03.059.

[19] M. T. Quasim, A. A. E. Radwan, G. M. M. Alshmrani, and M. Meraj, "A Blockchain Framework for Secure Electronic Health Records in Healthcare Industry," in *2020 International Conference on Smart Technologies in Computing, Electrical and Electronics (ICSTCEE)*, 2020, pp. 605–609.

[20] S. T. Siddiqui, S. Alam, R. Ahmad, and M. Shuaib, "Security Threats, Attacks, and Possible Countermeasures in Internet of Things," in *Lecture Notes in Networks and Systems*, vol. 94, 2020, pp. 35–46.

[21] D. Dann, C. Peukert, C. Martin, C. Weinhardt, and F. Hawlitschek, "Blockchain and Trust in the Platform Economy: The Case of Peer-to-Peer Sharing," in *WI2020 Zentrale Tracks*, no. 2018, Mannheim, Germany 2018: GITO Verlag, 2020, pp. 1459–1473.

[22] P. Gonczol, P. Katsikouli, L. Herskind, and N. Dragoni, "Blockchain Implementations and Use Cases for Supply Chains-A Survey," *IEEE Access*, vol. 8, pp. 11856–11871, 2020, doi: 10.1109/ACCESS.2020.2964880.

[23] A. Samad, M. Shuaib, and M. Rizwan Beg, "Monitoring of Military Base Station using Flooding and ACO Technique: An Efficient Approach," *Int. J. Comput. Netw. Inf. Secur.*, vol. 9, no. 12, pp. 36–44, Dec. 2017, doi: 10.5815/ijcnis.2017.12.05.

[24] F. Casino, T. K. Dasaklis, and C. Patsakis, "A systematic literature review of blockchain-based applications: Current status, classification and open issues," *Telematics and Informatics*, vol. 36. pp. 55–81, Mar. 2019, doi: 10.1016/j.tele.2018.11.006.

[25] L. Liu, M. Han, Y. Zhou, R. M. Parizi, and M. Korayem, "Blockchain-based certification for education, employment, and skill with incentive mechanism," in *Blockchain Cybersecurity, Trust and Privacy*, Springer, 2020, pp. 269–290.

[26] A. Averin, D. Snegireva, and A. Ladejshchikov, "Model of a Monitoring System for Academic Performance and the Issuance of Diplomas Using Blockchain Technology," in *2020 International Conference Quality Management, Transport and Information Security, Information Technologies (IT&QM&IS)*, 2020, pp. 88–91.

[27] P. Bhaskar, C. K. Tiwari, and A. Joshi, "Blockchain in education management: present and future applications," *Interact. Technol. Smart Educ.*, 2020.

[28] A. Nabil, K. Nafil, and F. Mounir, "Blockchain Security and Privacy in Education: A Systematic Mapping Study," in *World Conference on Information Systems and Technologies*, 2020, pp. 253–262.

[29] R. A. Mishra, A. Kalla, A. Braeken, and M. Liyanage, "Privacy Protected Blockchain Based Architecture and Implementation for Sharing of Students' Credentials," *Inf. Process. Manag.*, vol. 58, no. 3, p. 102512, 2021.

[30] S. Mahankali and S. Chaudhary, "Blockchain in education: a comprehensive approach–utility, use cases, and implementation in a university," in *Blockchain Technology Applications in Education*, IGI Global, 2020, pp. 267–293.

[31] G. Caldarelli and J. Ellul, "Trusted Academic Transcripts on the Blockchain: A Systematic Literature Review," *Appl. Sci.*, vol. 11, no. 4, p. 1842, 2021.