Preface to 'EduQual': A Blockchain-based Platform to Securely Track&TraceEducational Qualifications

Dr. B. Chandrasekaram

Associate Professor, Department of Comuter Science,
National Sanskrit University, Tirupati

ABSTRACT

Blockchain is a technology that can generate trust and confidence in a trustless environment. Blockchain has already gained tremendous popularity across disciplines due to its incredible characteristics and features. As a decentralized and distributed ledger, Blockchain can immutably record information. Blockchain has a lot of opportunities in the domain of education. This paper presents a blockchain-based secure platform called 'EduQual' for recording the qualification details of candidates. Unlike the available frameworks reported in the literature, EduQual can securely track the qualification details across various education levels, starting from the secondary level.The same platform can be used for employment agencies and industries to verify the qualifications of candidates as part of the recruitment process. The proposed framework can prevent the usage of forged qualification documentsthat spoils the reputation and quality of education.EduQual can facilitate several benefits to the stakeholders, including improved trust and confidence,a high level of coordination; low cost; and high reliability.

Keywords: Blockchain, Education, Coordination, Bogus qualification, Recruitment

1. Introduction

Forgery of documents related to educational qualification is a severe issue spreading in society. This trend is triggering severe implications. The prevalence of bogus qualifications will negatively impact education stakeholders, including legitimate education institutions, students, employers, graduates, legislators, the government, and society(Garwe, 2015). While culprits manipulate academic documents for their benefits, actual beneficiaries lose their opportunity. According to Decoo (2002), fraudulent documents in the domain of academics can be of mainly five types. They include degree or diploma mills, fabricated or counterfeited documents, modified documents, produced in-house, and translations. Fraud in academic qualifications is being a prevalent issue in society.

There are several factors behind the increase in the number of fraudulent activities in education(Rodrigues, Franco, Scheid, Kanhere, & Stiller, 2020). One of the essential factors is the entry and survival of non-accredited institutions. While non-accredited institutes offer courses, candidates seeking bogus qualifications get an easy way to achieve it. Lack of governmental initiatives to restrict such institutions catalyzes such unauthorized practices. Earlier academic documentation wasutterly paper-based, but with the advancements in technology,authorities awarding the qualifications started adopting digital means to generate, deliver, and record essential documents. However, most of those means rely on centralized systems that are vulnerable to several security issues such as single point of failure, a chance for data manipulation, etc. Shortcomings of paper-based and digitized academic documents create means to tamper with the details.

Blockchain, the recently emerged distributed ledger technology, can replace the centralised systems by securing immutable data. Technically, blockchain can be defined as a shared, decentralized, and distributed database built on a peer-to-peer network keeping the transactions among the network participants safe and secure(Wamba, Kamdjoug, Bawack, & Keogh, 2020). With its incredible characteristics, blockchain turns data immutable.Applications of blockchain started from 2008 with the innovation of Bitcoin blockchain, but the education domain started finding the scope of blockchain in 2016 (Alnafrah & Mouselli, 2021; Nakamoto, 2008)

The applications of blockchain in education are already reported in the blockchain. Admittedly, most of them are conceptual in nature, while the rest propose frameworks for various applications. These applications include certificate verification, governance of examinations, evaluation of online courses, etc. However,out of the frameworks presented in the literature,a significant percentage addresses university/Higher Educational Institutions (HEIs) level applications of blockchain. None of these solutions can track or trace the entire educational background of the candidate. Addressing this gap, this paper presents a blockchain-based secure platform called EduQual for recording the qualification details of candidates. Unlike the available frameworks reported in the literature, EduQual can securely track and trace the qualification details across various educationlevels, starting from the secondary level. The same platform can be used for employment agencies and industries to verify the qualifications of candidates as part of the recruitment process. The proposed system can prevent the usage of forged qualification documents that spoils the reputation and quality of education.EduQual can facilitate several benefits to the stakeholders, including improved trust and confidence,a high level of coordination; low cost; and high reliability.

The remainder of this paper is structured as follows. Section 2 reviews the literature related to the applications of blockchain in education. Section 3 presents the existing way of managing the proof for qualifications and how recruiters

verify students' educational backgrounds. Section 4 explains the proposed blockchain-based secure platform called EduQual. Section 5 summarizes the paper with a note on the scope for future work.

2. Literature Review

Blockchain

Blockchain has a plethora of definitions from various perspectives. In simple terms, blockchain is a distributed database comprising records of transactions that are shared among participating parties. Blockchain ultimately makes the data incorruptible. Technically, blockchain is a decentralized, distributed, transmitted, and immutable database ledger that stores a registry of assets and transactions across a peer-to-peer (P2P) network(Wamba et al., 2020). Blockchain has a lot of applications in different domains, including supply chain management (Sunny, Undralla, & Pillai, 2020), education (Bhaskar, Tiwari, & Joshi, 2020), banking (Dashottar & Srivastava, 2021), real estate (Karamitsos, Papadaki, & Al Barghuthi, 2018), agriculture (Caro, Ali, Vecchio, & Giaffreda, 2018), and so on. The unique characteristics of blockchain make it feasible for all sorts of trust-related issues across domains. The core characteristics of blockchain include decentralization, immutability, trust, transparency, and consensus-driven network administration. The concept of blockchain got the world's attention with the invention of the peer to peer cash system called Bitcoin by the anonymous author/ group of authors Satoshi Nakamoto (Nakamoto, 2008).Existing technologies like finger print technology, RFID, IoT (Reyna, Martín, Chen, Soler, & Díaz, 2018), smart contract (Buterin, 2013; Kushwaha & Joshi, 2021), etc. can be integrated with blockchain technology to discovernovel application areas. Although blockchain is highly recognized as a technology that solves all the issues with trust deficit, there are specific occasions where it can be introduced to derive fruitful outputs (Peck, 2017; Wüst & Gervais, 2018). Blockchain has two major taxonomies. The most popular scheme of classification divides the networks into three; namely, public blockchain, private blockchain, and consortium blockchain. Further, based on the permissions, blockchain can be classified into permissioned blockchain and permissionless blockchain(Kolb, Abdelbaky, Katz, & Culler, 2020). Decentralization, persistency, anonymity, and auditability are the attributes of blockchain (Kaur, Nayyar, & Singh, 2020).

Blockchain in Education

The concept of Education 4.0 is gaining popularity across the world. Education 4.0 deals with innovation-based education and advanced digital technologies. Blockchain is one of the essential technologies in Education 4.0 that can potentially support the domain in terms of security and trust (Lutfiani et al., 2021).

Blockchain has a lot of applications in the education sector. The majority of the articles in the literature are qualitative, and they all explore these possible applications conceptually(Bhaskar et al., 2020). Blockchain technology can benefit education by safeguarding the students' data, minimizing costs, improving trust, and enabling transparency. Ultimately, blockchain builds a platform for document storage where the credentials and achievements of the candidates can be verified without the involvement of any third-party intermediaries. While implementing blockchains in universities can reduce administrative costs to a great extent. Blockchain makesthe important academic details immutablewith the principles of cryptography and keeps the data in chronological order through timestamping.In education, blockchain technology is mainly used to issue and verify educational certificates issued by various educational institutions. Apart from this, competence and learning outcomes management, evaluation of students' professional ability, securing collaborative learning environment, protecting learning objects, fee and credit transfer, obtaining digital guardianship consent, competitions management, students' interactions in e-learning, examination reviews, supporting lifelong learning, etc. are the core application categories of blockchain education domain (Alammary, Alhazmi, Almasri, & Gillani, 2019; G. Chen, Xu, Lu, & Chen, 2018).Among the applications presented under these categories, some are purely conceptual or prescriptive,while a few are descriptive researches that demonstrate the applicationsvia development of prototypes. Real implementations reported are very rare or almost nil. This can be due to the infancy of blockchain technology and the associated challenges and issues(Ma & Fang, 2020). Fedorova & Skobleva (2020)highlighted the applications of blockchain in education, specifically in the higher education segment.Various authors have already consolidated blockchain-based solutions crafted for the educational sector(Alnafrah & Mouselli, 2021; Guustaaf, Rahardja, Aini, Maharani, & Santoso, 2021).

Capece, Ghiron, and Pasquale (2020) compared the blockchain-based certificate issuing system developed by MIT, Blockcerts, with the conventional certificate issuing system at the University of Rome,"Tor Vergata". While the traditional issuing system remains expensive regarding resources, time and money, it was vulnerable to many other issues. Most importantly, if any third party such as a company or a consulting firm needs to verify the certificates of a candidate, this won't be possible with the current practice of issuing the certification. MIT's Blockcerts facilitates a secure environment for keeping instantly verifiable certificates. The system uses Bitcoin blockchain, where multiple certificates in an entire graduation session can be combined in a single transaction. The Blockcerts toolbox mainly contains three significant components called cert-tool, cert-issuer, and cert-viewer.

The evil and unauthorized political influence heavily influences the education sector in low-income countries. Highlighting this,Alnafrah and Mouselli (2021)explained the scope of blockchain technology and conceptualized a national level hybrid blockchain-based platform that can coordinate various stakeholders in the domain of education. They tested its feasibility in Syria and Sudan to know its cost benefits.

Chen et al. (2021) pinpointed the issueswith credits endorsement in cross-university course learning and proposed a blockchain-based solution using Hyperledger Fabric. In the proposed system, universities form a consortium and the credits obtained by students in the course and the hash value of the learning records are stored on the blockchain. The universities in the system jointly maintain data on the blockchain. One university can verify the homework and final examination of students to check students' actual ability, thus recognizing the credits from other universities. At the same time, to protect students' privacy, the essential data of students are encrypted for transmission.

Hsu, Tu, and Chiu(2022) considered the combination of blockchain and facial recognition technology to develop an e-diploma system. Most systems can only guarantee that the diploma is authentic and not a forgery, but they cannot confirmwhether the diploma holder and the issueraregenuine. In this study, cryptography and biometrics are used to strengthen the connection between the diploma and the recipient. The blockchain deployment framework proposed in this work is composed of educational authorities and institutions to make the identity of the diploma issuer credible. In addition, the Hyperledger Fabric application channel is also used to realize access control among organizations in the consortium. The proposed system usesthe feature called channels in Hyperledge fabric to enable access restrictions.

To simplify the interactions between the Higher Education Commission and Universities,Khan et al.(2021)proposed a certain degree attestation and verification traceability architecture. Deenmahomed, Didier, and Sungkur (2021) designed and implemented an examination, transcript and certificate system using blockchain. It is meant to provide a completely transparent and practical examination and awards system that can replace the traditional one in place. What has also been proposed in this study is a novel light blockchain system composed of several modules, which have been built from scratch.

While analyzing the works mentioned above, it is evident that the applications of blockchain in education revolve around the higher education segment. The stakeholders will be only able to verify the qualifications in the HEI level. Although these frameworks can be independently implemented by the organizations in different levels of education, it cannot bring the benefits of a single standardized platform where all the educational qualification related details of a candidate can be recorded. In view of this research gap, this paper presents a blockchain-based platform that records and preserves the qualification related details and proofs of a candidate from the secondary level of education.

3. Present System

Figure 1 illustrates the existing system of awarding qualifications, starting from the secondary level of education—responsible organizations administrating the academic activities at different levels of education issue certificate proofs for the candidates. To qualify, candidates need to meet specific minimum requirements (examinations/ interviews/etc.). Especially in developing countries, certificate proofs are mainly paper-based, and they are on the way to digitizing academic documents.

Digitized academic documents are recorded and maintained using centralized systems. There will be paper-based and digital-based issues associated with the existing system. Alnafrah and Mouselli (2021) suggested that paper-based academic documents are constantly exposed to the risk of tampering, verification challenge, human resource demand, and single point of failure. While organizations utilize digital platforms to manage academic documents, there is always the requirement of third parties. There will be issues in exchanging the documents across other universities due to security concerns and other technical challenges. Irrespective of the mode of issuing the certificate, as a significant drawback, the certificates issued by various organizations is not securely compiled anywhere. Organizations awarding the qualifications remain independent to each other.
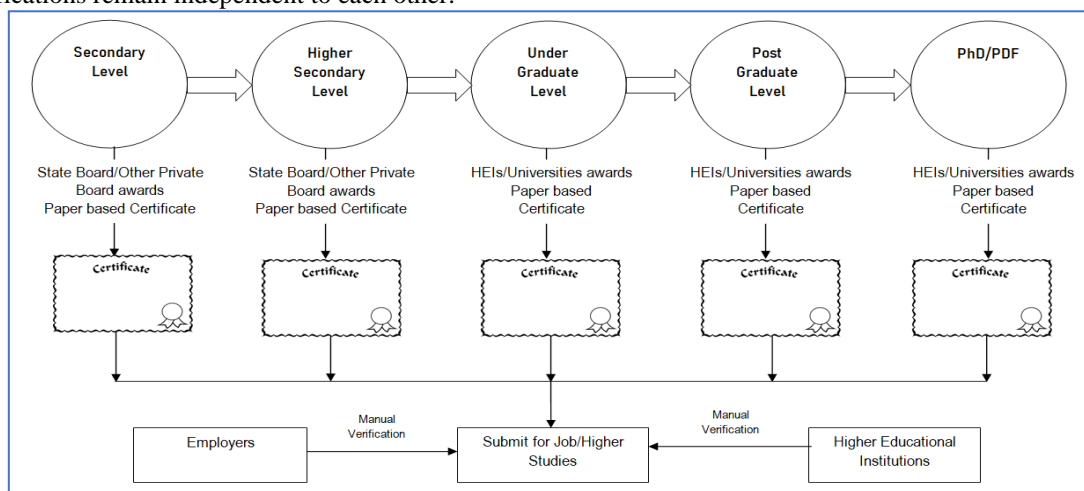

Figure 2: Present System

This will weaken the possibilities for coordination and interoperability among the stakeholders at different levels of education. On the other side, candidates need to submit the proofs of academic qualifications to the stakeholders for job

requirements and higher studies. Notably, employers and higher educational institutions need to verify each of the proofs manually or approach other third-party consultancy firms before they consider the candidate.

If a candidate loses their paper-based academic documents in the present scenario, they need to approach the organizations to get duplicate copies. This process requires time and money. In some other cases, external parties cannot directly verify the qualifications of the candidates; instead, candidates need to consult the concerned authorities to get the same direction.

4. Proposed EduQual Platform

The platform integrates the various stakeholders in the education sector, including secondary and higher secondary boards, higher education institutions and universities, employment agencies, various other employers, students, and other government monitoring agencies. The framework of the proposed EduQual is given in Figure 2.

The network of the EduQual system is a consortium blockchain. The access restrictions in the network can be coded in the form of smart contracts and deployed by the government body. This framework mainly covers four different levels of education -secondary level, higher secondary level, undergraduate level and postgraduate level. Private or state-level boards primarily handle the secondary and higher secondary level of education, and HEIs manage other levels.

This system is conceptualized with the assumption that the secondary level is the basic level of education. Candidate registration to EduQual starts when they enrol for the secondary level public examination. Once registered, the candidate gets a profile for updating the details of their educational qualification. Details and proof for capabilities will be uploaded and edited by the organizations corresponding to the various levels of education. For example, undergraduate, postgraduate, doctoral, or post-doctoral level qualifications will be uploaded and updated by the private universities or other HEIs.

The digital certificates proving the qualifications can be kept in decentralized storage systems and the corresponding hash values (identity) can be recorded in the blockchain. Framework presented in Figure 2 includes Inter Planetary File System (IPFS) decentralized storage system.
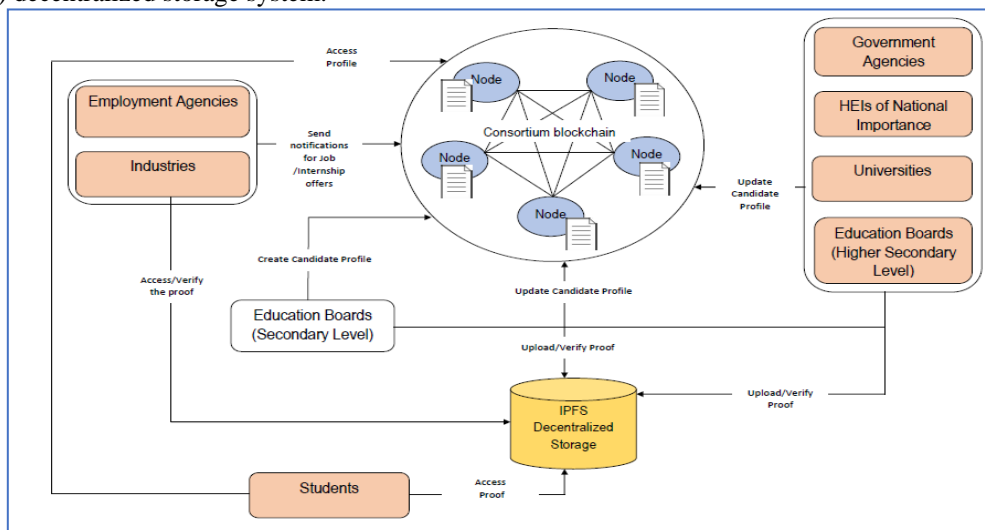

Figure 2: Framework of the proposed EduQual

Employers and employment agencies participating in the network can access and verify the qualifications of candidates at any point in time using their ID. With the help of smart contracts, they can send internship or job offers into their profiles. This can be used as proof of job experience. On the other side, candidates can always access their profiles to view their qualifications and experience.

For the productivefunctioning of the proposed system, government bodies should keenly monitor the activities ongoing in the network. At most, care is to be taken while adding an entity to the consortium. The credibility of the entities can be checked thoroughly before adding to the network.

Benefits of the proposed EduQual

Trust and Confidence

Blockchain can enable trust in a trustless environment as a technology that immutably keeps the documents. However, the level of confidence generated by the blockchain always depends on how they are designed and developed. In the light of this, (De Filippi, Mannan, & Reijers, 2020) addressed blockchain as 'confidence machine' questioning the title 'trust generating machine'(Kumar & Sharma, 2019). While blockchain gets proposed for the sphere of education, stakeholders can use the academic proofs with confidence and trust.

High Level of Coordination

As depicted in Figure 2, the network participants of EduQual can avail a high level of coordination among themselves with the transparency offered by the blockchain architecture. The candidates' profiles are visible to all the members of the network. While one entity updates the candidate's educational qualifications, it instantly gets updated in the candidate profile and broadcasted to the entire network. In short, the proposed framework of EduQualhelps the stakeholders to trace and track the qualification details of the candidates.

Low Cost

While the proposed system comes into the picture, it can reduce the expenses in creating, accessing, and verifying academic documents. The governance of blockchain is purely based on consensus among the participants, and it eliminates the third-party intermediaries. As depicted in Figure 1, certificates rely on individual organizations in the present scenario. It will be challenging for other stakeholders to verify the proofs of qualification, as it requires consultation with the issuing organizations/authority (Capece et al., 2020).

High Reliability

Although many organizations use digital facilities to issue and verify academic documents, they all are subjected to vulnerabilities (single point of failure, information manipulation, information leakage, etc.). The maintenance of a conventional centralized database is difficult and expensive. In this sense, services with centralized information systems are not reliable. An adequately framed blockchain is free from all these issues and is highly reliable.

Implications of the proposed EduQual

A secure qualification tracking system like EduQual can significantly affect the economy and society. Most importantly, this can avoid forged or counterfeited academic qualifications. Forged academic qualifications will take over a lot of opportunities for eligible candidates. Blockchain is highly immutable in nature hence no one can edit or delete the information that isalready approved and recorded. While ineligible candidates unethically acquire positions and benefits via creating or manipulating their own academic qualifications, this can bring unexpected societal issues. For instance, while an unskilled medical student takes the position of a doctor, it can negatively impact public health.

Employers are investing a lot of money for effectively conducting their recruitment processes, wherein verification of candidates and screening is a crucial part. As of now, companies are doing this either directly or through consulting firms. A system like EduQual can aid the employers to avoid the costly qualification verification process. This will save a lot of time and effort. Recruitment/employment agencies can avail the same benefits.

Like any other digital data management platform, EduQual can erase the issues with traditional paper-based records. Paper-based proofs such as certificate or mark list are difficult to carry, easy to lose, easy to forge, and other security issues.Although centralized digital systems for managing academic documents are abundantly available, designed, and developed by various firms, they are all subjected to vulnerabilities. There are incidents wherein confidential qualifications details are leaked/ damaged. EduQual can erase all the issues with centralized digital solutions.

EduQual can standardize the process of updating and maintaining the academic qualification details of candidates. In the absence of such a system, organizations representing different levels of education need to frame independent systems.

The proposed system is not free from limitations. The major end is related with the morality of the organizationsawarding qualifications. If the organizations are not acting ethically, still there are loop holes for ineligible candidates to avail the benefits and opportunities deserved by right candidates. Also, there are issues with identity of the candidates. To overcome this, advanced mechanisms and technologies can be incorporated with the framework. Integration of blockchain with fingerprint done by (Hsu et al., 2022) is an example

5. Conclusions and Scope for Future Work

Blockchain, a technology that keeps the record immutably, has many applications in the educational sector, but they are not yet fully discovered. The blockchain-based systems proposed in this domain are exclusively for generating, issuing, and verifying certificates. Other blockchain applications like conducting of examinations and evaluation, cross-university learning systems, etc., underline the unceasing possibilities of this technology. Widening the scope of blockchain in the education sector, this paper presents a secure platform called EduQual for recording the qualification details of a candidate across various education levels starting from the secondary level. The system can sequentially record all the qualification related information from level to level, and members can trace and verify these details in real-time. The system can be realized with a consortium blockchain. Registered employers and other employment agencies can verify the profile of the candidates using their ID. As an additional feature, employers can send job offers to the candidates' profile, and thus job experiences can be added to the profile.

The proposed system is in its conceptual phase, requiring more additions and refinements. EduQual, in its functional form, can be implemented on a national level to standardize the way of keeping educational qualification details. However, it is a fact that for the practical implementation of such a system, many barriers and challenges are to be tackled. Setting up infrastructure would be the most challenging constraint. Although it is tough to overcome these

issues, the implementation can be planned in different phases to make it smoother. In the next step of this work, a working prototype can be developed to check the technical feasibility of the solution. Development of smart contracts for

References

Alammary, A., Alhazmi, S., Almasri, M., & Gillani, S. (2019). Blockchain-based applications in education: A systematic review. *Applied Sciences*, *9*(12), 2400.

Alnafrah, I., & Mousselli, S. (2021). Revitalizing blockchain technology potentials for smooth academic records management and verification in low-income countries. *International Journal of Educational Development*, *85*, 102460.

Ayub Khan, A., Laghari, A. A., Shaikh, A. A., Bourouis, S., Mamlouk, A. M., & Alshazly, H. (2021). Educational Blockchain: A Secure Degree Attestation and Verification Traceability Architecture for Higher Education Commission. *Applied Sciences*, *11*(22), 10917.

Bhaskar, P., Tiwari, C. K., & Joshi, A. (2020). Blockchain in education management: present and future applications. *Interactive Technology and Smart Education*.

Buterin, V. (2013). A next generation smart contract & decentralized application platform. Ethereum Foundation.

Capece, G., Ghiron, N. L., & Pasquale, F. (2020). Blockchain Technology: Redefining Trust for Digital Certificates. *Sustainability*, *12*(21), 8952.

Caro, M. P., Ali, M. S., Vecchio, M., & Giaffreda, R. (2018). Blockchain-based traceability in Agri-Food supply chain management: A practical implementation. In *2018 IoT Vertical and Topical Summit on Agriculture - Tuscany, IOT Tuscany 2018* (pp. 1–4). IEEE. https://doi.org/10.1109/IOT-TUSCANY.2018.8373021

Chen, C. L., Wang, T., Tsaur, W. J., Weng, W., Deng, Y.-Y., & Cui, J. (2021). Based on Consortium Blockchain to Design a Credit Verifiable Cross University Course Learning System. *Security and Communication Networks*.

Chen, G., Xu, B., Lu, M., & Chen, N.-S. (2018). Exploring blockchain technology and its potential applications for education. *Smart Learning Environments*, *5*(1), 1–0.

Dashottar, S., & Srivastava, V. (2021). Corporate banking—risk management, regulatory and reporting framework in India: A blockchain application-based approach. *Journal of Banking Regulation*, *22*(1), 39–51. https://doi.org/10.1057/s41261-020-00127-z

De Filippi, P., Mannan, M., & Reijers, W. (2020). Blockchain as a confidence machine: The problem of trust & challenges of governance. *Technology in Society*, *62*, 101284.

Deenmahomed, H. A., Didier, M. M., & Sungkur, R. K. (2021). The future of university education: Examination, transcript, and certificate system using blockchain. *Computer Applications in Engineering Education*.

Fedorova, E. P., & Skobleva, E. I. (2020). Application of Blockchain Technology in Higher Education. *European Journal of Contemporary Education*, *9*(3), 552–571.

Garwe, E. C. (2015). Qualification, award and recognition fraud in higher education in Zimbabwe. *Journal of Studies in Education*, *5*(2), 119–135.

Guustaaf, E., Rahardja, U., Aini, Q., Maharani, H. W., & Santoso, N. A. (2021). Blockchain-based Education Project. *Aptisi Transactions on Management (ATM)*, *5*(1), 46–61.

Hsu, C.-S., Tu, S.-F., & Chiu, P.-C. (2022). Design of an e-diploma system based on consortium blockchain and facial recognition. *Education and Information Technologies*, 1–25.

Karamitsos, I., Papadaki, M., & Al Barghuthi, N. (2018). Design of the blockchain smart contract: a use case for real estate. *Journal of Information Security*, *9*(3), 177–190. https://doi.org/DOI: 10.4236/jis.2018.93013

Kaur, A., Nayyar, A., & Singh, P. (2020). Blockchain: A path to the future. In *Cryptocurrencies and Blockchain Technology Applications* (pp. 25–42).

Kolb, J., Abdelbaky, M., Katz, R. H., & Culler, D. E. (2020). Core concepts, challenges, and future directions in blockchain: A centralized tutorial. *ACM Computing Surveys*, *53*(1), 1–39. https://doi.org/10.1145/3366370

Kumar, K., & Sharma, A. (2019). E-voting in India using blockchain and it's modus operandi. In *Journal of Computational and Theoretical Nanoscience* (Vol. 16, pp. 3774–3777). American Scientific Publishers. https://doi.org/10.1166/jctn.2019.8249

Kushwaha, S. S., & Joshi, S. (2021). An overview of blockchain-based smart contract. *Computer Networks and Inventive Communication Technologies*, 899–906.

Lutfiani, N., Aini, Q., Rahardja, U., Wijayanti, L., Nabila, E. A., & Ali, M. I. (2021). Transformation of blockchain and opportunities for education 4.0. *International Journal of Education and Learning*, *3*(3), 222–231.

Ma, Y., & Fang, Y. (2020). Current status, issues, and challenges of blockchain applications in education. *International Journal of Emerging Technologies in Learning (IJET)*, *15*(12), 20–31.

Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system.

Peck, M. E. (2017). Blockchain world-Do you need a blockchain? This chart will tell you if the technology can solve your problem. *IEEE Spectrum*, *54*(10), 38–60.

Reyna, A., Martín, C., Chen, J., Soler, E., & Díaz, M. (2018). On blockchain and its integration with IoT . Challenges and opportunities. *Future Generation Computer Systems*, *88*(2018), 173–190. https://doi.org/10.1016/j.future.2018.05.046

Rodrigues, B., Franco, M. F., Scheid, E., Kanhere, S. S., & Stiller, B. (2020). A technology-driven overview on blockchain-based academic certificate handling. In *In Blockchain Technology Applications in Education* (pp. 197–223). IGI Global.

Sunny, J., Undralla, N., & Pillai, V. M. (2020). Supply chain transparency through blockchain-based traceability: An overview with demonstration. *Computers & Industrial Engineering*, *150*(2020), 106895. https://doi.org/https://doi.org/10.1016/j.cie.2020.106895

Wamba, S. F., Kamdjoug, J. R. K., Bawack, R. E., & Keogh, J. G. (2020). Bitcoin, Blockchain and Fintech: a systematic review and case studies in the supply chain. *Production Planning and Control*, *31*(2–3), 115–142. https://doi.org/10.1080/09537287.2019.1631460

Wüst, K., & Gervais, A. (2018). Do you Need a Blockchain? In *2018 Crypto Valley Conference on Blockchain Technology (CVCBT)*.