

A Survey on Blockchain-based Applications in Education

Nadeem Abdullah Malibari
Saudi Arabian Airlines, Jeddah, SAUDI ARABIA
nmalibari@gmail.com

Abstract—Researchers and practitioners continue to draw varied interest on blockchain (BC) technology. The concept is generally attributed to its outstanding features such as decentralization, reliability, security and data veracity. However, even with the growing interest, a lot has to be done concerning the modern state of knowledge and practice in relation to the use of BC technology in education. Therefore, this survey presents a review of the existing studies on BC-based learning applications. The survey is centered on three major themes: learning applications that have been made using BC technology, the contribution and merits of blockchain technology to the education sector, and the problems experienced while integrating BC technology in learning. An intensive discussion is presented as well as a comprehensive result analysis of each theme. The survey also highlights the key areas in education that stand to benefit from the incorporation of the blockchain technology.

Keywords—Blockchain, technology, education, challenges, applications

I. INTRODUCTION

The deployment of blockchain technology in the education sector is still in the initial stages. At the moment, educational institutions using this technology are very few. Most of the existing solutions use blockchain as a secure platform for validating and sharing personal student data and academic certificates as well as learning databases of educational organizations. Recent studies propose online identity authentication systems that use blockchain to implement cloud education cooperation. For time authentication on transactions to be realized, blockchain technology is adopted to give proof of data content authenticity thus maintaining system reliability. To validate the effectiveness of the BC-based applications in education, several case studies have been conducted at Chou University in Japan. Moreover, BC ledgers and cloud computing are also being used to enhance computer science education. A modern decentralized P2P cloud model is also recommended using Bitcoin and Torrent models to put together proof-of-concept platforms to support education service providers.

II. BACKGROUND

In the year 2008, Blockchain was first introduced as an emerging technology. The primary function of Blockchain was the registration of transactions of the bitcoin cryptocurrency as a peer-to-peer ledger. The tool would help facilitate direct transactions thus eliminating third-party intermediaries. For the goal to be realized, the design of blockchain was such that it

encompassed a decentralized network of peer nodes. A copy of the transactions ledger is stored in every node of the network. Each node is also tasked with the function of writing an entry to its ledger after an approval is received from other network nodes, transmitting any transaction made by its user to other network nodes, and ensuring that the ledger it holds is the same as the ones across the network always.

As the popularity of Bitcoin continues to increase, practitioners and researchers continue to uncover the huge potential of this essential technology. Blockchain's special abilities like trustworthiness, immutability, and precision have been understood to be valuable not only in cryptocurrencies but also in many different fields such as education. Researchers believe that the technology has a lot to offer in the education sector that could potentially transform the world. According to [1], the role of educational institutions in opening up more learning opportunities for students while acting as certification agents could be weakened by blockchain.

Despite the increasing number of publications in the last few years on the integration of BC technology in learning, limited surveys have been carried out on the topic. Therefore, this paper provides a timely survey by analyzing credible, peer-reviewed sources exploring how BC technology is being used in education. The survey mainly targets managers, academicians, researchers, and policy-makers with the core focus being the interest to amass knowledge on the advances made in blockchain technology and its impact on the education sector.

III. METHODOLOGY

To conduct this survey, a search of the relevant articles was done. Currently, most of the published literature can be accessed from electronic resources retrieved from electronic databases like IEEE Xplore and ProQuest. The search was then preceded by screening of the articles found for inclusion and for a decision regarding the articles to be considered for review and analysis to be made. Consequently, the appraisal of articles was then done after making sure that the relevant journals meet the minimum quality standards for inclusion. The selected sources contained useful information associated with the application of BC technology to education. The information from these articles was then extracted and used as the raw material in this survey for analysis, comparison, and discussion.

IV. DISCUSSION

A. Educational Applications Developed With Blockchain Technology

Even though several blockchain-based applications are available for use in the education sector, only a few of these can be accessed by the public. As [1] describes, some of the applications related to certificates management. These kinds of applications handle all forms of academic credentials, students, transcripts, students' certificates as well as any other form of achievement certificate. Most applications rely on blockchain technology for the issuance of digital certificates. Furthermore, most of the applications that issue these credentials have relied greatly on the increased trust level and privacy assurance of BC technology.

The author recommended a blockchain certification system which is rewarded for utilizing the school certification agent. Using the application will avail a means through which employers or providers of higher education providers will issue official certificates with high level of information privacy. This could enable students to share their official documents directly with anyone upon request. Similarly, [13] used the decentralized feature of BC technology to offer new BC-based education documents to verify and issue official certificates or transcripts. However, there are stipulated rules and conditions that allow only certified institutions to access and change the information kept in the system.

Great attention to applications that focused on proficiency and learning outcomes management is shown in [2]. Some blockchain applications can be developed to enhance student's learning objectives and facilitate them to attain competencies in education. This would enrich the education sector and enhance the learning process. Owing to high blockchain efficiency, some applications can be made to evaluate and measure students' performance using quantitative and qualitative factors. For example, the authors in [3] developed a system to trace students' performance for their multi-learning activities. Williams also developed another system for students' learning atmosphere. The system offers direct support and valuable feedback to students to help them apply a wide range of skills, problem-solving, and critical thinking through better communication and collaboration.

Authors in [4] emphasize about applications related to securing a shared-learning atmosphere. The main focus of the authors is on the capabilities of the technology in enhancing the learning setting. The use of blockchain avails a decentralized network. The concept makes it possible for multiple users such as students, department members, and authorities to access it with high security and veracity. They presented the Ubiquitous learning (U-learning) system which utilizes BC technology to give students an enhanced learning atmosphere featured with an increased security level. Therefore, efficient student-teacher communication is enabled through an interactive multimedia system on the U-learning platform. The authors also highlighted the essence of using the technology to realize a School Information Hub (SIH) to improve the learning environment in schools. If this is done, then school systems

will have an efficient tool for collecting, analyzing, and compiling reports thus helping to make informed decisions.

Concerning fees and credit transfer, some blockchain applications with special characteristics for credential records or fees transfer in learning organizations or universities have been developed. Normally, educational institutions depend on intermediaries to handle and approve credit or fees transfer. Fortunately, due on its high security and trust level, blockchain technology can be used as an efficient mode of transfer and eliminate the need for an intermediary. As described in [5], the EduCTX system that facilitates the transfer procedure using tokens. The tokens used can assume any digital form for educational units including courses, diplomas and certificates. Additionally, every learning institution carries out the secure transfers using their unique EduCTX address.

B. Results

A majority of applications have been developed with a core focus on the management of certificates. Three of the sources presented applications for handling, storing, issuing and sharing students' academic certificates. On the other hand, two sources discussed blockchain applications based on their storage and sharing capabilities as well as the education results that students have scored. One source detailed applications that can be utilized by organizations to assess student's professional skills and ability based on their educational performance. Furthermore, three sources focused on applications concerned with collaborative learning atmosphere while applications relating to privacy and security were discussed in five sources.

TABLE I. APPLICATIONS IDENTIFIED IN THE SURVEYED JOURNALS

Application Category	Sources
Certificates management	Nespor (2018), Bandara et al. (2018)
Competencies and learning outcomes management	Williams (2018)
Evaluating students' professional capabilities	Licano (2019)
Securing a collaborative learning atmosphere	Bdiwi et al. (2018), Bore et al. (2017)
Fees and credit transfer	Holbl et al. (2018)

C. Blockchain Technology Benefits to Education

BC technology has a great potential to bring numerous advantages to education. Some of these advantages include low cost, increased safety, students enhancement, enhanced data access management, promoting accountability and integrity, boosting trust, supporting learners, identity authentication, improving students' records efficiency, career decisions, and enhancing interactivity among learners. As [4] authors argue, using blockchain guarantees safety, data confidentiality, and transactions exchange among the parties involved. The journal describes a consensus protocol used for maintaining the transactions' order and lowering the risk of transactions that were not secured. The concept would enable all the parties involved to confirm the contents of the ledger. Using the cryptographic hashes and signatures also ensures transactions' reliability. The best thing about

blockchain technology is that it relies on protecting the data itself and confirming its authentication.

Authors in [5] illustrate how BC technology helps to lower storage costs, transaction associated costs, and the cost of maintaining and managing education records. The expenses associated with the traditional idea of storing information on cloud can be reduced significantly by using private/public networks accessible from any location. Generally, additional costs are incurred in processing and verifying academic certificates which could be reduced significantly by using blockchain technology which also helps to enhance the student assessment process. The authors in [6] used the technology to evaluate students' learning achievements depending on how they realized their learning objectives. Each block was furnished with qualitative and quantitative data such as scores, learning outcome, name of the student and the course, weight for each course, and the graduation condition indicator. After evaluating the achievement of learning outcomes, like minded entities can capitalize on this data and communicate accordingly.

In addition, [7] emphasize the blockchain benefit of controlling and restricting stored records access. The blockchain system used in this regard restricted access to academic credentials by limiting access to specific groups. Thus, only certified institutions could access and change the information stored based on the stipulated rules. Similarly, [8] point out that blockchain enhances accountability and transparency in the education sector since all educational and school records are stored in one place where they are easily accessible. The SIH system was selected in this case to carry out the function of collecting and storing reports and records

for a give school. The system was beneficial since it helped realize enhanced intelligibility of the mutual information and elasticity of data analysis, correlation, and distribution.

The validity of digital certificates is well assured while using blockchain technology because it helps to secure the identity of users. According to [9], a digital syllabus was kept in a BC. After making the book, a private key will be used by all authorized parties to sign in. Consequently, there is need to ensure that the content developed cannot be tampered. In this case, the course syllabus is secured using the cryptographic hash. Thus, the hash and the key availed to every institution are an integral component that confirm that the data is genuine.

D. Results

The reviewed journals detailed several benefits that come with the adoption of blockchain technology in education. Three sources identified security as a major benefit through enhanced data privacy, protection, and integrity. One source emphasized on the benefit of using blockchain in education to facilitate a controlled access for student data. The third benefit capitalizes on the need to promote transparency and accountability as discussed in four sources. According to two sources, the integration of blockchain technology would help realize significant cost reductions. The nature of the blockchain can help to lower the unnecessary cost linked to data storage and transactions. Moreover, one source [5] showed that BC technology can promote evaluation of the students' performances and their learning outcomes. Lastly, one source indicated that interoperability, students' interactivity, and learner's career decisions are enhanced due to the adoption of BC in the education field.

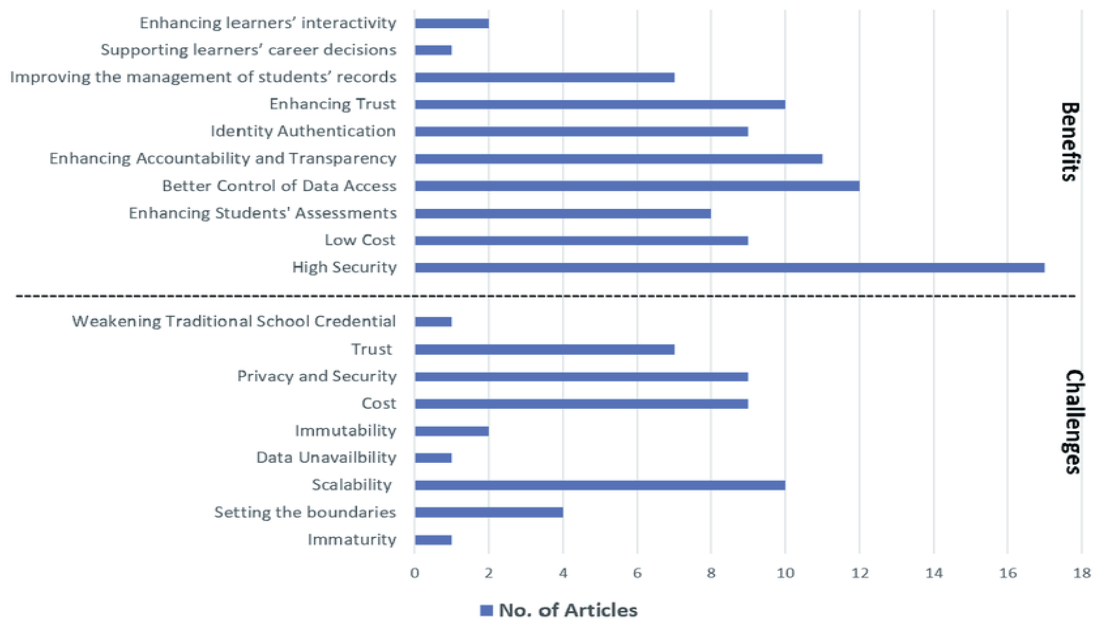


Fig. 1. Benefits and challenges of adopting blockchain technology in education

E. Challenges of Integrating Blockchain Technology in Education

Even though BC has shown that it has a high potential for revamping the education sector, there are many issues that must be considered before deployment and active use in the field. According to [10], the technology is highly secure but not immune to the possible threat of malicious attacks. It is not easy to avail a system that is both secure and assures users of privacy. The issue is graver when it puts careers on the line by authorizing academic testimonials and certificates online. To enhance confidentiality, numerous BC systems employ private and public keys. Nonetheless, the privacy of transactions cannot be assured since the data for each of the public keys is visible to the public. Thus, one can link the transactions made to a specific user and ultimately reveal their information. Furthermore, a security challenge also comes about from storing and securing private keys for all members' the regular data updates makes the situation worse by creating loopholes for data breach.

The slow speed challenge in blockchain transactions (blockchain's scalability problem), which can be encountered in education systems using BC technology is discussed in detail in [11] and [6]. The increasing volume of records and transactions potentially slows down the big size blocks' transaction speeds. As the number of users increase, so does the size of the blocks on the blockchain. Educational systems have a daunting task of collecting, storing, and maintaining student data to keep track with the changes especially when they transfer to different schools. The concept further increases the size of the blocks. A lot of time is also wasted through the peer-to-peer verification on each transaction. This is a major challenge that have slowed down the process to only realize 3-7 transactions per second. Ziliqa has been proposed as a solution to some of these issues. Ziliqa is a new blockchain platform founded on a technique of sharing so that the big blockchain network can be broken down into multi-shards for parallel authentication of transactions.

Furthermore, [12] describes how the immutability feature in blockchain technology is a challenge. This feature makes it hard to make data changes unless all parties give consent to change the ledger content. The authors describe how this immutability feature can be a challenge for government departments that demands their citizens' data for law and order. Besides, the immutability characteristic of systems with defined policies makes it hard for governments to effect changes. The notion could potentially lead to even bigger problems in situations where an ex-external examiner or an ex-employee makes an unauthorized delete. This is because of the irreversible and immutable nature of such data that limits modifications.

According to [1], blockchain technology is decentralized while education systems are centralized. Thus, introducing the technology to education system would disrupt it to a large extent. Like in blockchain, having a ledger that constantly aggregates can influence the traditional school credential's value. As one of the remarkable innovation in the modern times, blockchain technology is expected to take a considerable period

of time for large-scale adoption. This is due to the existing challenges associated with technology adoption in the education sector.

F. Results

Based on the survey from different sources, four main challenges were highlighted. The first of these is related to blockchain scalability. Three journals; [2], [11] and [13] recorded that when the amount of transactions in the BC network increases, then the size of blocks also increases. Consequently, the latency of the transactions also increases. The second challenge highlighted in [11] stems from the idea of lessening the value of school credentials in the traditional setup. According to [11], the technology can allow students to act as their lifelong registrar of educational accomplishments. In this regard, the role of education institutions as certification agents can be destabilized.

The third challenge relates to the immutable feature of the technology. According to [13] and [14], immutability is the main limitation that will hinder the integration of BC technology into the education sector. These journals explained that educational institutions would have a hard time applying up-to-date information storage laws or amend inaccurate data. The final challenge which is highlighted in [4], [8] and [6] is related to the privacy and security of blockchain technology. A discussion of the different types of security and privacy issues like data breaches and malicious attacks which are likely to be encountered when using blockchain is presented.

V. CONCLUSION

The integration of BC technology into the education sector is still in its formative stages. The selection criteria for the journals used in this survey was based on their applicability, benefits, and challenges. First of all, the survey showed that blockchain technology is mostly utilized to issues and verification of academic certificates, evaluation of students' professional capabilities, and to share student competencies and academic achievements. However, numerous blockchain applications keep emerging each day. Secondly, it shows that blockchain several benefits could be realized by incorporating blockchain technology in education. These include a secure platform for sharing students' data, enhanced transparency and trust, and significant cost reductions. Thirdly, the survey also highlighted the challenges that could come up with the adoption of BC technology to education. Policymakers, managers, and other stakeholders are advised to consider challenges associated with cost, confidentiality, security, scalability, and availability before introducing the BC technology in the education sector. Nevertheless, blockchain technology has a lot more to offer and there is no doubt that it can offer many more advantages to all educational areas globally.

Blockchain is now used in many applications in different fields. An application of Blockchain for managing Hajj permits is discussed in [15]. A number of related issues like privacy, security, dealing with recent applications in technology are discussed in [16-24].

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