Use of Blockchain in Education: A Systematic Literature Review

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Abstract. Blockchain technology enables the formation of a distributed record of a digital event in decentralized manner where data and related transactions are not under the control of any third party. This technology was early used for value transfer but now it has vast range of applications in different fields such as healthcare, banking, internet of things and many others. In the field of education, it also provides numerous opportunities for decentralized management of records in educational institutions in an interoperability manner. The main objective of this research is to highlight the existing issues related to the educational institutes and to find suitable blockchain features that could resolve them. We have adopted a systematic literature review approach for the identification and the extraction of relevant information from the shortlisted studies. This study describes existing issues in three aspects physical, digital and financial. The results of the analysis shows that the manipulation risk, difficulty in verification and exchanging record between institutions are the major issues faced by the educational institutions. This study, then explores blockchain features including decentralization, traceability and consensus mechanism that can be used to address the issues related to the educational institution. Finally, due to unique and underlying technology, it has still some technical challenges and boundaries along with immutability feature, disclosure of personal privacy and scalability issue also discussed in this study.

Keywords: Blockchain · Education · Systematic review

1 Introduction

The blockchain first showed up in 2008 when Satoshi Nakamoto published "Bitcoin: A Peer-to-Peer Electronic Cash System". Proposed system was based on cryptographic proof instead of reliance, enabling any two parties to execute transactions without the requirement for a trusted third party. This proposal solved the double-spending problem [1] and was the first application of blockchain.

Versatile features of blockchain such as transparent, information exchange in a decentralized manner, smart contracts, speed of transaction etc., can help improve variety of applications. The wide and promising scope of blockchain technology provides better assistance in the education field to students and other entities of

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educational institutions, i.e., in credentials and certification [6, 7, 17], verified and authenticate record [13], helps recruiters in the recruitment process [19], maintenance of records [13, 19, 23] and ease of accessing these records [18]. Taking everything into consideration, the scope of blockchain technology is not limited to above-mentioned applications but also opens the door for university administration for managing their finance and accounting department by simply putting all the dues and charges of campus in it [6].

This review is about how the blockchain supports the education field and show its worth. This paper highlights some of the existing issues in the education field which can be fixed by blockchain features. But there are still some shortcomings including disclosure of personal privacy [2, 11], protection of private and public keys [18, 23] and scalability issues [2, 7, 10, 12, 13, 24]. We can mold this technology by fixing these shortcoming to have fruitful benefits.

The rest of the paper is structured as follows. Section 2 is about related research and explores the blockchain features. In Sect. 3, research methodology, research questions, and search strategy is discussed. Section 4 discovers the result of research questions. Section 5 presents applications of blockchain in education. Section 6 is about the various threats to validity. Lastly, Sect. 7 concludes the assumptions and constraints of our review and also present the future directions.

2 Literature Review

This section presents some core concepts and theories from existing research related to the blockchain and its several practical implementations in the education field. It also makes a comparison between the existing secondary studies.

2.1 Blockchain

Blockchain is a distributed setup that allows the formulation of distributed digital record of transactions, shared among the nodes of the network instead of being stored on a central server [4]. Current blockchain frameworks are categorized into three types: public or permission less blockchain, private or permission blockchain and consortium blockchain [2, 18].

2.2 Features of Blockchain

Blockchain technology has the following major features.

Decentralized: Blockchain is a decentralized shared public ledger in which all nodes are connected to each other in a mesh network where all the data and decision making is placed and distributed among various nodes [1, 3, 6, 12].

Traceability: Blockchain traceability feature promotes the audibility of an event as it stores information in blocks which are secured by uni-directional cryptographic hash function [19]. Complete chain of blocks is maintained by mining pools, which provide cloud based websites for exploring the blocks [3].

Consensus mechanism: Consensus mechanism refers to the mutual approval of all the nodes associated to the blockchain network [7]. Thus, it does not rely on mediators. Proof-of-work (POW), proof-of-stake (POS), delegated-proof-of-stake (DPOS) are some techniques of consensus mechanism [6].
Immutability: In blockchain, data is stored in ledger form and if there is any modification by external nodes, the hash key values would be changed because these keys are cryptographically linked with previous and preceding blocks and modification in data will interrupt the continuance of the keys [7, 18, 19, 23].
Smart contract: Smart contract is a self-executing computer program, running on a blockchain distributed network [7].
Currency: The blockchain technology has a property of cryptocurrency, which is a type of digital or virtual currency that guarantees the end-to-end transaction making it protected and trustworthy. The formation of this currency is generated by different mining algorithms [19]. Thus, the joined form of blockchain and cryptocurrency can be used in several aspects such as dealings of finance and accounting.

The abovementioned, identified features will be used to classify the primary studies together to conduct this review.

2.3 Use of Blockchain in Education

There is no denying the importance of education for the development and advancement of a country. Therefore, it is always been a struggle to find innovative technologies such as blockchain, to assist in the education field. The most noticeable advantages are seen in the form of data storage management [7, 11–13, 17, 21]. Others benefits are observed in data security [11, 19, 21], system trust [11, 13, 19, 23], Global ubiquitous database [13, 18, 19, 23], formative evaluation [19, 21] and some have got benefit in payments using smart contract [7, 17, 19, 23]. There has been numerous initiatives undertaken by the educational institutions that are using blockchain technology to store the data of their students and faculties. For the very first time, the University of Nicosia used the blockchain technology to manage the record of students, i.e. certificates that they received from MOOC platforms [7, 9, 19]. Massachusetts Institute of Technology (MIT) has developed a learning machine technology based on blockchain technology and they have formed a wallet for their students containing the educational records of a student [7, 19, 23]. Holberton school is also applying blockchain technology to save the educational record of students, i.e. their credential, learning behavior and activities in class [18, 19].

Table 1. Compared secondary studies

	Existing issues in education (aspects)			Blockchain features	Challenges and issues to BC implementation
	Physical	Digital	Financial		
[7]	✓	✓	✗	✓	✓
[8]	✗	✗	✓	✓	✓

2.4 Compared Secondary Studies

Blockchain is the fastest growing domain and provides a great research value from the last few years. However, while looking for secondary studies, we found only two studies that discuss research trends. Firstly, we found a report that was published by European Commission and we identified that it has only focused on physical and digital aspect. Second, a qualitative analysis was found that discussed the perceptions of distributed ledger technology by financial professionals with fiduciary responsibilities at select institutions of higher education. Table 1 enlists the attributes of these secondary studies with respect to the classification of its context.

3 Research Methodology

A Systematic Literature Review is defined as a method of gathering, identifying and interpreting all available research in order to answer a specific research question [5]. We have performed a systematic literature review by following the guidelines provided by Barbara Kitchenham to search for relevant studies. Steps of the guidelines are discussed in the following subsections.

3.1 Need of Conducting SLR

Table 1 presents the attributes of secondary studies in accordance with the classification of this study. By examining the existing secondary studies, it is identified that there are some gaps that have not been discussed yet and need to be filled for further practical implications. For example, Grech et al. [7] has mainly focused on paper certificate and digital certificate whereas, Harpool [8] has purely focused on financial aspect discussing the perceptions of distributed ledger technology by financial professionals. Moreover, both have used the qualitative research method using case studies, interviews, observations and literature reviews. No single study was found that covers all the aspects of existing issues in educational institutions and used a quantitative research method approach exploring the existing primary studies. Hence, we conducted this systematic literature review to achieve our goals and used a quantitative research approach.

3.2 Motivation and Research Question

The first phase of this systematic research is to define the research questions. Hence, following are the focused research questions:

RQ1: What are issues pertaining to area? (**Aim:** to illustrate the issues faced by the current educational domain that can be solved by blockchain.)
RQ2: What are the Blockchain features used to solve the identified issues? (**Aim:** to search out the blockchain features that precisely resolve the issues of the current education system.)
RQ3: What are the unaddressed issues? (**Aim:** to highlight the unresolved issues that could be fixed in future.)

3.3 Search Strategy

We used the tag-based approach to search for related papers in keyword form. On Google Scholar, these keywords i.e. "blockchain", "education", and "review" were searched. All the papers (ignoring the publication year and quality) that were published from start to up to date were collected and downloaded. We explored different papers, reports, and articles published in different journals and conferences.

3.4 Inclusion and Exclusion Criteria

After setting the research questions, all the primary studies were scrutinized to find appropriate data related to our context. For inclusion, 12 primary studies were tagged for data extraction and the remaining were excluded because they were out of our context and we figured out that these studies were specifically on "blockchain" instead of "blockchain in education". Table 2 presents the papers with corresponding ID.

Table 2. Paper ID with corresponding reference

#	Paper title	Year	ID
1	ECBC: a high-performance educational certificate blockchain with efficient query	2017	[11]
2	An introduction to the blockchain and its implications for libraries and medicine	2017	[12]
3	The blockchain and kudos: a distributed system for educational record, reputation, and reward	2016	[13]
4	Disciplina: blockchain for education	2018	[14]
5	The emerging trend of blockchain for validating degree apprenticeship certification in cyber security education	2018	[15]
6	Blockchain for education : lifelong learning passport	2018	[16]
7	Trustless education? A blockchain system for university grades	2017	[17]
8	EduCTX: a blockchain-based higher education credit platform	2018	[18]
9	Exploring blockchain technology and its potential application for education	2018	[19]
10	Higher education in an age of innovation, disruption, and anxiety	2018	[20]
11	Towards blockchain-enabled school information hub	2017	[21]
12	The case for a data bank: an institution to govern healthcare and education	2017	[22]

3.5 Data Extraction

After shortlisting the studies that were to be included in our SLR, the tagged primary studies were then proceeded to data extraction process. In this phase, the relevant data was extracted from the selected primary studies primarily focusing on existing issues in educational institution and to find blockchain features that exceptionally resolve them. Issues and features were covered in 12 primary studies [11–16, 18–22], whereas, unaddressed issues in 10 [2, 7, 10–13, 18, 19, 23, 24].

3.6 Publication Trend

Although research in blockchain was started with the invention of bitcoin in 2008. From then, there has seen a rapid advancement and adoption. However, the very first paper that covered both blockchain and its application in the field of education was found to be published in 2016. In 2017, 5 papers were found, whereas, till March 2018, 6 papers covered area under observation.

4 Results

This section is divided into three subsections. The first section classifies the common issues in the education system. The second subsection identifies the blockchain features that resolve the issues of the current education system and the third subsection highlights the unsettled issues that could be fixed in future.

4.1 RQ1: What are the Issues Pertaining to the Area?

The objective of this Research Question is to identify the common issues faced by educational institutions. To make this discussion more convenient and clear, these issues are divided into three aspects: physical, digital and financial. The detail is as follows.

Physical Aspect: Physical aspect includes the attributes that are characterized by some physical activity or manner done by people. It contains the issues that are caused by manual activity or physical handling of the educational records.

Manipulation Risk: There is a series of human involvement in the creation of physical records i.e., taking and scoring the exams where the exams are paper-based. Manipulation attack happens when these academic records are created by an unauthorized body, i.e., they can do alteration in the marks of a student which can cause the social evil favoritism. The existing mechanism to secure academic record such as degree and transcript are reproducible [21] and hard to differentiate from the original record. Hence, these are more prone to manipulation attack [11].

Difficult to Verify: It is difficult to verify the student's record in manual system [20]. This problem is especially faced by third world countries which do not maintain a centralized record of all the universities. [7, 16]. On the contrary, an applicant face resistance from the institute because it's an additional burden. So, document verification in those universities, where records are maintained manually, becomes difficult [11, 14, 16, 18, 21].

Demand Human Resource: In traditional education system, there is always need a human resource for students as well as for the institution. For example, in case of a student, he could lose his academic certificate. In this situation, he has to write many applications for the issuance of the certificate and has to go through a costly and time-consuming process. On the other side, the institution needs to verify this application

through various steps e.g. check and match the previous record of a student and also has to maintain a physical record of students for a long period of time [7, 16, 18].

Single Point Failure: The record of a student in the educational institution is centralized and organized by a single entity. Even if some kind of distributed architecture is used within its boundaries, it can still be directly shared by a group of non-trusted parties. Conventional educational records are maintained at a certain place which become a single point of failure. This means, if, because of unforeseen reason, physical records are burnt, the recovery becomes impossible [7, 21].

Digital Aspect: Digital aspect refers to any record or activity that is stored or performed electronically or online. Issues related to digital aspect are given below.

Third Party Approval is Needed: The grading on academic record is produced by a teacher for a student. However, the evidence of the record either digital or physical is generated by a third party [7]. This gives power to the third party to produce a fake academic record [12].

Security Breach: Similar to single failure point of physical records, digital records are accessed from a centralized source which can lead to the changes in the data either intentionally, accidentally or other illegal means by third party. This means if source is compromised, then all digital data can be lost [7, 11, 15].

Difficult to Exchange Record Between Institutions: Record exchanging is very sophisticated and time-consuming process. In some cases, it becomes impossible. For example, if a student wants to migrate from one institution to another, it is difficult to exchange record. The students also face difficulty when they apply for admission as they have to submit all their educational records [18, 21]. No global standard system exists which can offer such services to all the universities [7, 18].

Financial Aspect: Word "finance" refers to the study and management of money. In financial aspect, issues that are related to money and budget are highlighted.

Middleman Commission: Universities conduct several of transactions every month with students, employees, vendors, suppliers and government agencies. There are chances of corruption by higher authorities. It can only be stopped if decentralized auditing is integrated into the financial system of the institutions [21].

Proof of Performance In educational institutions, there is no well-defined structure for monitoring and evaluating the activities of students and teachers [21]. Also, students and teachers feel demotivated when the rewards are not given to them for their hard work. Rewards must be given to them when they show good performance and there must be a proof and record to encourage and motivate them [17, 19, 22] (Table 3).

Table 3. Issues vs features

Issues		Blockchain features				
		Decentalized	Traceability	Consensus mechanism	Smart contract	Currency
Physical	Manipulation risk	✓	✓	✓		
	Difficult to verify	✓				
	Demand human resource	✓			✓	
	Single point failure	✓				
Digital aspect	Third party approval required			✓		
	Security breach		✓			
	Difficult to exchange record between institutions	✓				
Financial	Middleman commission				✓	
	Proof of performance				✓	✓

4.2 RQ2: Blockchain Features Used to Solve the Identified Issue

Blockchain features were discussed in Sect. 2 and this section highlights how these features can help address issues identified in previous section.

Decentralized: Decentralization attributes to a distributed network maintaining redundant records. Decentralization can help reduce:

Manipulation Risk: By making it difficult for an attacker to alter blockchain record maintained by number of nodes. This is difficult as compared to a single node which maintain all records as done in today's centralized system [21].

Difficult to Verify: By providing an open source and distributed platform which contains a multiple copies of transactions and distributes them across all the nodes in the network [11, 18, 21].

Demand Human Resource: By reducing the administrative load in different cases, i.e., in verification or migration case, which minimizes the cost and effort of traditional manual work. For example, if a student is migrating from one institution to another, then the faculty of the desired university can easily verify the record of a student from the blockchain database [18, 21]. It also provides a facility for employers to read and verify a certificate during a hiring process on a single application instead by asking the issuing institution [16].

Single Point Failure: By keeping a copy of data on each node. If any node gets offline, the data will not lost as it is maintained on a redundant network [7].

Difficult to Exchange Record Between Institutions: By helping the institutions to exchange information openly through the open source blockchain in an easy and convenient manner, e.g., in migration case and for further study case [18].

Traceability: Traceability refers to the ability of tracking and reaching out to everything back to its root. Traceability can solve the following issues.

Manipulation Risk: Can be reduced by traceability feature in a way that if someone tries to make illegal transaction or changes in the blockchain, then it can be tracked back by obtaining the block information linked by hash keys from the chronicle blockchain. Thus, any modification or fraudulent activity can be detected immediately against a particular instance [21].

Security Breach: by making a model of proof-of-existence and possession [15]. Blockchain technology creates a digital signature for every transaction which impossible to recreate as compared to electronic signature [7].

Smart Contract: Smart contract is a self-executing computer program under some conditions that is distributed across the blockchain nodes. Smart contract can resolve:

Proof of Performance: By making the real-time payments under the smart contract, hence, payments can be automatically executed via smart contract and real-time rewards could be given to students and teachers on the basis of their performance [13, 19].

Demand Human Resource: By automating human operations into smart contract, such as internal audits, student promotion to new class once the fee is paid etc., [21].

Middleman Commission: By automating the middle man operation into smart contracts, such as, degree verification can be implemented between different blockchain platforms etc., [21]. Systems will charge minimal fee for the contract execution, while making the whole process transparent.

Consensus Mechanism: Consensus Mechanism refers to the mutual approval of all the nodes associated to the blockchain network. Consensus mechanism can facilitate in solving the following issues:

Manipulation Risk: As the data is summed up in blockchain through a different consensus mechanism and so, is not handled by a single entity. There are fewer chances of fraud and mistakes because every new incoming transaction is verified by the other nodes of the network.

Third Party Approval is Needed: Can be solved as the blockchain framework works on consensus mechanism without any intermediary. Instead of using central authority to manage transactions, blockchain allow governance protocol, which work as smart contract.

Currency: Cryptocurrency is a type of digital or virtual currency that uses strong cryptographic techniques and generated by different mining algorithms. It could be used to solve the following issues:

Proof of Performance: By introducing an educational currency, the reward could be given in the form of cryptocurrency through a smart contract to the best-performing students and teachers [17, 19]. This kind of money could be stored in the education wallet and exchangeable with other currencies [13, 17].

4.3 RQ3: What are the Unaddressed Issues?

Although blockchain technology has a great potential to resolve issues in the education field by its tremendous feature, still research is in its infancy. So, it brings challenges and risks while its implementation. This research question highlights some unaddressed issues that could be resolved in the future.

Immutability Feature: In blockchain, once data has been placed on it, it cannot be changed or modified. This immutable feature can affect its useful functioning as it does not allow any change or modification which is often required [19]. Appropriately implementation of blockchain technology significantly improves these criteria, allowing fewer unwanted side effects.

Who Will Give the Approval of the First Network Node? At the beginning, some institution has to be the first network node and that time there will be no existing node to verify it, such an attribute can be seen as a security risk. However, we expect that with the increase in numbers of nodes, such security concerns will be minimized [18].

Disclosure of Personal Privacy: As it is open source and transparent technology, the record or personal information about the students can be accessed or shared without the willingness of students [2, 11, 23].

Scalability Issue: Blockchain has to scale for improving network transactions per second [2, 7, 10, 12, 13, 24], hence, areas such as "side chains" is being explored.

5 Applications of Blockchain in Education

After having the distinguish benefits of blockchain in education, demand for it has become global. Currently, various applications have been running on blockchain and others are in processing stage. Echolink is a global standard blockchain platform that stores verified credentials, skills and work experience in a hashed and unalterable way. All information is entered by the authoritative institutions and thus provides a trustworthiness of such information. **Echolink** recognized a partnership with Microsoft to offer blockchain application cloud service on Azure [25].

Another application **Disciplina** projected by Teach Me Please is a multifunction blockchain platform creates and stores verified personal profiles related to academic and professional career. It helps recruiting services by providing digital CV of student generated during the educational career, accompanied by the authenticity proofs [14]. An application named **Open certificates** developed by Attorneys, assigns block-proof to the educational certificates using Ethereum smart contracts. They have declared their partnership with educational institutions of Singapore [7].

6 Threats to Validity

To summarize the existing evidence related to the use of blockchain in the education field, we tried to gather as many related primary studies as possible for the extraction of knowledge. As the related research was in the exploratory stages, therefore, little peer-reviewed literature was found in this area. As our extraction scenario was based on the perception of the defined research questions, so there might be chances that the reader can identify some attributes that we did not consider and can be helpful in the future. Also, most of the work was on the features and innovative applications; less was on its limitations. Finally, there might be some work done that we could not refer in our paper during the period of publication, as the researchers are continuously focusing to fix the problems in educational institutes through blockchain.

7 Conclusion

In this study, we decided to map all possible relevant primary studies by using a systematic literature approach. By exploring and examining all the features of blockchain, we have presented the suitable solutions to deal education related problems in a precise way. Since this technology is in initial experimental stages, so, it still has to go through an evolutionary process. In future, it is believed that a better review could be written as the world is moving towards innovation and the people are becoming more technology oriented.

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