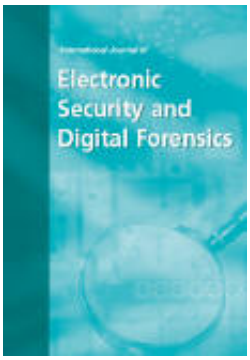

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Blockchain as an indispensable asset for educational institutions: a systematic review

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Abstract: Blockchain is eminently flourishing as an open distributed data structure to record digital transactions efficiently and permanently in cryptographically linked time-ordered sets of blocks. Integration of blockchain into education opens new possibilities by providing a secure platform to share student information, conduct evaluations and track the entire learning process. In this paper, research work on blockchain technology in the education sector is studied thoroughly and systematically organised into groups to get invaluable insight into the implementation of blockchain in education. It focuses on the perquisites of implementing blockchain technology in education as it significantly opens new possibilities for the education sector by providing a secure platform to share student information, conduct evaluations and track the entire learning process. In the education sector blockchain is showing conceptual breakthroughs, however, some administrative and technological concerns are to be addressed. We analysed research articles and found that data management and certificate verification have been two main research themes. This study provides an overview of blockchain applications in the education sector, as a contribution to already existing research work. The characteristics of blockchain used in the previous research are also examined and the research gaps are summarised.

Keywords: blockchain education; e-certification; information security; smart contracts; IPFS.

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1 Introduction

Blockchain is an open, distributed data structure (Christidis and Devetsikiotis, 2016) that records digital transactions efficiently and permanently in cryptographically linked time-ordered set of blocks. On the basis of privacy level, there are three types of blockchain (Yumna et al., 2019). *Public blockchain* is a transparent permission-less network, open for everyone to join consensus for validation of data and transactions. *Private blockchain* is a closed and partially decentralised permissioned network which is controlled by a set of rules designed by an organisation. *Consortium blockchain* is a closed decentralised hybrid network, which integrates the features of private and public blockchain.

Blockchain is an emerging technology which attracted attention with the introduction of Bitcoin (Nakamoto, 2008). Initially, it was only limited to cryptocurrency (Xu et al., 2019) but later on blockchain expanded its applications into various sectors (Syed et al., 2019; Karthika and Jaganathan, 2019), including education sector. Blockchain has also its applications in protecting intellectual property rights (Li et al., 2022) and cyber security in smart grid networks (Mishra, 2022). Blockchain in collaboration with RFID techniques can be used to resolve issues in supply chain management. Even though, the highest number of research articles on blockchain are being published in the field of computer science (Chen et al., 2018), education is still at early stages of utilising this technology. Most of the educational institutions use it to validate and share degree certificates (Grech and Camilleri, 2017).

Educational institutes are struggling with multiple challenges of certificate verification and degree fraud. It has become more difficult to differentiate between bogus certificates generated by skilled 'Degree Mills' and an authenticated degree certificate. Academic credentials being crucial for employment is the major reason people use fake certificates. Over the years, there has been increase in counterfeit certification. To solve this problem, institutions have adopted third party verification systems to check authenticity of certificates. However, this process is time consuming and costly. These issues can be solved transparently and without any intermediaries using blockchain. Blockchain technology can provide diverse assistance in providing authenticated immutable certificates that are easily verifiable. Apart from providing validation of educational certificates, blockchain technology can help manage academic credentials, track student progress, and protect intellectual property. Additionally, blockchain-based smart contracts could automate many of the administrative tasks associated with running a university or educational institution. Anticipating the potential of blockchain technology, educational sector employs different strategies to develop initiatives for the overall improvement (Bhutta et al., 2021). Researchers and academicians are intensely scrutinising various aspects of blockchain technology (Han et al., 2018) and with

increasing publication trend in the education sector, numerous applications have been developed.

The remainder of the paper is organised into following sections – Section 2 presents a structured review of the existing techniques developed for education system using blockchain technology. Finally, the paper is concluded along with some research gaps in Section 3.

2 Literature review

This segment of the paper gives an insight of the work that has been previously done on this topic. Section 2.1 reports the applications developed for degree verification; Section 2.2 provides a brief analysis of data management applications; Section 2.3 presents a study of applications of blockchain technology for student evaluation and exams; Section 2.4 gives an insight of research papers on credit transfer and admissions; Section 2.5 explains the previous work on blockchain applications for learning resources.

2.1 Degree verification

This category focuses on the study of blockchain technology assisting student degree validation. The applications developed in this category control the process of issuing and verifying of academic certificates.

A novel blockchain-based education record verification method, TUDocChain platform, proposed by Budhiraja and Rani (2019) ensures that students have authority of their official credentials. It is a method for sharing and authenticating certificates for universities where certificates can be exchanged officially or collected by students. TUDocChain offers a solution to issue, share and validate certificates and assures reliable authorisation using smart contracts. TUDoc uses Ethereum-based consortium blockchain with two smart contracts to manage user profiles and certificates deployed on Ethereum Virtual Machine. Similarly, a Hyperledger Fabric-based student instant verification system by Badyal et al. stores data in encrypted form (Badyal and Chowdhary, 2019). It aims to make recruitment easy and simple for students, recruiters and institutions. Students have to add a distinct code to their respective curriculum vitae (CV) and recruiters can verify student information scanning the code provided by students.

An Ethereum-based system, Unichain, offers secure access to academic certificates stored as electronic academic records (EARs) and controls access to EARs through time-based smart contracts (Daraghmi et al., 2019). Unichain is designed for reliable, interoperable, systematic access to EARs and solves the issues of fragmentation and isolation of data. Instead of using digital currency as rewards, a new incentive mechanism is included where a node that creates blocks is rewarded by adding an incentive to its degree. This decreases its chances to recreate the next block. Another application by Lizcano et al. (2020) proposed a model to annihilate the divergence between the academic world and enterprise/corporate world. It consists of four categories – trainer, student, verifier and employer. Students are trained for specific proficiency skills by the trainer and then the students have to solve a standard problem to exhibit their skills. Verifiers, a group of students and experts who already possess the proficient skills, have to solve the same problem to validate student's skills. Verified proficiency skills are added to the student's electronic CV that is accessible to employers.

Another blockchain-based academic record system is introduced with a reputation currency to check learning outcomes, wherein, performance-based rewards are given to students using a smart contract (Sharples and Domingue, 2016). The decentralised nature of blockchain, distributed consensus mechanism to add new information and the use of smart contracts are the elements that make blockchain technology suitable for educational institutions. Teachers or trusted experts can directly award certificates or badges to students. In addition to this, to avoid awarding bogus certificates, the awarding authority is publicly revealed.

Cerberus (Tariq et al., 2019), an online verification service proposed a solution for verification of credentials to decrease fraud. It is built on a permissioned Ethereum blockchain operated and maintained by a delegation of universities and spectators to collect transactions and add them to a block and ensure integrity after every process. Whenever a credit is issued to a student, the delegation verifies it before adding it to a block. A Quick Response code (QR code) is added to physical certificate of every student so that employers can scan the code to verify it. To revoke a degree, a revocation transaction is added to blockchain after being verified by the delegation. Scanning QR code validates information from Cerberus network in real time, if a revoked degree is scanned, the employer would be informed of the revocation of degree.

2.2 Data management

Main focus of majority of the applications is to issue, share and store student academic records. Data management applications collect and access university data, in order to support decision- making, automate rules and secure identity and data of students. To illustrate, an educational certificate infrastructure, educational certificate blockchain (ECBC), digitally manages educational certificates using Merkle-Patricia tree chain (MPT-CHAIN) to speed up block verification (Xu et al., 2017). To improve performance, ECBC supports high throughput and low latency with the help of consensus mechanism. Certificates are issued and revoked in the form of transactions and the data is stored in encrypted form to ensure privacy. The ECBC network consists of; Peer (school or regulator), Quorum (participant of consensus) and an Entity (student and employer). To speed up queries, MPT-chain, a tree structure that is a combination of features of Merkle tree and Patricia tree, is employed. Merkle root of MPT-chain assures accuracy of query results.

Another solution proposed for data privacy uses smart contracts to implement agreements on data rights and blockchain technology to provide security, integrity and authenticity of data (Forment et al., 2018). This paper evaluates privacy issues of learning analytics collecting sensitive student data and ensures data confidentiality using blockchain. DELICATE, an eight-point checklist of determination, explain, legitimate, consent, anonymise, technical aspects and external partner, is implemented using blockchain to cryptographically secure data and meta-data of student learning activities. Smart contracts are implemented to automate legal actions in case of detection of any data irregularity. The prototype designed is an independent software but interoperable with Moodle open source learning management system (LMS).

According to Filvà et al. (2018), learning analytics is used to present a solution for students to ensure privacy and control their data by automating rules. Analytical cycle collects data and stores it for a long time, aiming to increase learning and success opportunities. However, there is a level of distrust in terms of privacy and security that

can be solved with consensus mechanism of blockchain and use of smart contracts. Another application, blockchain enabled school information hub (SIH) implemented on hyperledger fabric aims to improve the process of record keeping and increases the accessibility of shared data (Bore et al., 2017). The proposed solution is based on challenges like budget allocation, learning environment and insufficient data of teachers and students. A generic model is developed that constitutes of lock in attribution, secure sharing, improve visibility and certificate of authority. The SIH is developed to store and manage data using transactions and the data is hash encrypted. It uses distributed smart contracts (chain-codes) to interact with distributed ledgers. To illustrate, creative higher education with learning objects (CHILO), a blockchain application is used to protect copyrights and ownership of e-books as well as any information obtained from students. It can be used to create a life-learning model for learners to communicate their ideas and compile learning outcomes into e-books (Hori et al., 2018). It is a blockchain-based decentralised learning system for creative higher education with learning objects, which produces e-books in electronic publication (EPUB) format using encapsulation. It is a flexible online learning environment with transactions in virtual currency and management of copyright information. A flexible life-long learning approach to support educational credential transfers between universities of different countries is proposed by Arndt and Guercio (2020). In higher education, students are continuously transferring universities and the delay by various levels of administration causes hardships for the students. This paper aims to empower students by implementing a transcript system for universities based on blockchain technology. Two models are being developed and evaluated, one using smart contracts and Neo4j graph database and other one BigchainDB which is a hybrid of blockchain and distributed database. Another application, educational records secure storage and sharing scheme (EduRSS) uses smart contracts to share educational records across institutions and a consortium blockchain combined with storage servers for data security (Li and Han, 2019). Original records are cryptographically encrypted and stored on off-chain servers. The proposed system constitutes of educational institutes, consortium blockchain, storage servers and framework service. Three smart contracts were developed using Truffle framework, for verification and storing data. Security analysis and impact of some common attacks were analysed like Sybil, hostage byte, collusion tamper and replay.

Similarly authors in reference (Ocheja et al., 2019) introduced blockchain of learning logs (BOLL), a system connecting learning records across institutions using smart contracts to keep track of learning achievements and manage access rights. It enables portability of learning records and provides consistency of data, distributed consensus, consistent processed transactions and facilitates transparent communication between stakeholders. A design-based research is adopted to propose a single public ledger for all institutions and smart contracts are developed for generation and managing of learning records. Identity of learner is not shared with different institutions, instead an address is shared and this address is used to track the student records on BOLL.

For instance, blockchain for education presents a solution in the form of smart contracts to securely generate, share and validate certificates where certificate lifecycle is managed using open badge extension (Gräther et al., 2018). There are three main tasks for certification using blockchain technology; identification of certification authorities, issuing of certificates to the learners and last one is for employers to verify the certificates. Learners protect privacy of certificates and control their access. Certificates are digitally represented in JavaScript Object Notation (JSON) format to be compatible

with Mozilla Open Badges. Interplanetary file system (IPFS) is used to hold data, and only IPFS address is placed on the blockchain not the whole data. In another example, a student focused approach of blockchain technology is used by Vidal et al. (2019) to manage and validate academic certificates using Blockcerts, where students have the authority to decide with whom the documents are shared. Blockcerts was developed by Massachusetts Institute of Technology (MIT) media lab and learning machine. It consists of cert tools, cert-issuer, cert-viewer and the Blockcerts wallet. Blockcerts provide command line interface for cert-tools and Application Programming Interface (API) for cert-issuer. The proposed architecture implements Blockcerts for University of Fernando Pessoa. The application considers three stakeholders - students, third party employers and University Fernando Pessoa (UFP) registration.

A decentralised application (DApp) developed on Ethereum blockchain is proposed by Mishra et al. (2021) to guarantee confidentiality and ensure secure authenticated sharing of student credentials. The architecture is presented in two stages; first stage for scalability and security while second stage for protection of privacy. Off-chain storage is used to make the system more scalable while reliability is increased by employing nine smart contracts for user, file, school, student, company, request, certificate authority, share file and fund raising. Government body allocates a unique identification associated with a lifelong account for every user. School is any educational institute that issues credentials to students and students can securely share their credentials in addition to control its access. Companies issue relevant credentials for an internship and can get access to credentials of a candidate for recruitment. Professor can view and issue credentials as pr the grades of students.

Ali et al. (2021) proposed three models of student information system, which are flexible for different sized organisations for issuing genuine electronic certificates. This model is primarily focused on data availability and consists of four types of nodes - administrator, student, faculty and guest. Administrator node deals with curriculum list, deadlines and block creation. Student node can read information or records of his course. Certificates are read for both students as well as faculty members. Faculty members can read or write their information and upload result or grades of students. Guest nodes can be any external third party interested in student information. Guest can read student credentials on student's approval and can access curriculum after getting permission of administrator. This paper also introduces three models for different size of organisations. *Model 1* is a private consensus network with all full nodes. Only stateful data is accepted by transactions while stateless data is stored outside the blockchain. *Model 2* is a semi-public permission consensus network consisting of both light-weight and full nodes. Both stateful and stateless data are accepted by transactions. This model is suitable for small and medium organisations. *Model 3*, suitable for big enterprises, is a permission less public consensus network. It includes guest and full nodes.

2.3 Student evaluation and exams

Automated examination and assessment systems are included in this category.

Duan et al. (2017) introduced a student's learning system to manage credits and strengthen online education and evaluation system. It aims to enhance professional capabilities of students and the results are stored for employment opportunities. An education blockchain technology is formulated for professional certification and graduation requirement index of university. The outcome of achieved values of the

course is formulated on the combination of qualitative and quantitative factors stored in a block, where from the achievements are transferred into capability index evaluation result. The learning outcome blockchain comprises of two side chains, student's ability chain and course chain. Proof of accreditation consensus mechanism is employed to evaluate student's achievements. An initiative by Mitchell et al. (2019), decentralised application for examination review (dAppER), is proposed to draft exam papers and evaluation procedures while assuring quality standards along with production of secure and verifiable documents. There are seven steps in the procedure to model an exam paper-initialisation, submit draft documents, internal moderation, submit moderated documents, external examiner, submit final documents and signing off. Key components of design system are module leader, module, internal moderator, external examiner, question paper, answer paper, head of department, assessment administrator and auditors.

The contribution by Zhao et al. (2019) introduces a professional skill evaluation system that uses k-means clustering to analyse student's professional ability and blockchain technology for the student data to be traceable and non-destructive. In addition to school course grades, student's ability evaluation considers academic as well as off-campus achievements to provide the student with employment related advice. Through data mining, student data is evaluated including academic performance, off campus practice, answer scores and other credits. Then the ability level is determined from evaluated data using clustering. Liu et al. (2018) proposed a Hyperledger-based education-industry cooperative system that uses certificate authority service to share information between universities and companies transparently in order to eliminate academic frauds and provide symmetry between student skills and enterprise requirements. Recruitment acts as a bridge between industry and educational institutions. The Hyperledger Fabric has three components – blockchain, chain code and membership. According to Liu et al. this prototype used Hyperledger Fabric to achieve convergence between Education and Industry. AngularJS is used for frontend interface and SpringBoot for backend service layer. Two kinds of organisations are simulated - one for educational institutions and second for other organisations. There are two peer nodes for each organisation and one node Hyperledger Fabric Orderer for service provider.

A blockchain-based education system of information management system (IMS) standard represent skills of a student through immutable and verifiable badges, predefined for each level of learning progress (Choi et al., 2019). Badges are awarded for performance assessment and a backpack is used to store and present badges. Badges are skill-based, flexible to changes and make education exciting. Network transparently verifies the paradigm to get a badge and the whole event is stored on blockchain from where the validity of the badge can be confirmed. This platform is suitable for location and time independent learning and distance learning. REpresentational State Transfer (REST) application interface to publish badges, is used to reduce financial expenditure. Each course consists of micro-learning units and on completion of every unit, a badge is added to the certificate of the student. For a degree with multiple micro learning units, the certificate is made up of digital badges for each course. This system can also be used for future career planning by analysing student information. It can also include royalty points to encourage students by rewarding them for participating in training programmes.

A double layer consortium blockchain model for student answer verification is developed by Shen and Xiao (2018), to create a transparent scoring process for online quiz system. Answers are unchangeable and protected by group signatures. Blockchain is combined with online examination and online quiz system to publicly verify answers of

the students and then the answers are stored on blockchain. A group contains an assembly of members and a manager to issue questions. Sub-chain nodes do not require to record complete history of answers, instead they've to record a summary. Only prime nodes store complete answer records.

Blockchain-Based Smart and Secured Scheme for Question Sharing (BSSSQS) utilises blockchain concept for smart education (Islam et al., 2018). A two-phase encrypted question paper (QSP), is stored along with smart contract that controls access to paper. This model consists of four units – question setter to submit questions before deadline, question cloud stores and modifies questions to compose a question paper, BSSSQS master selects question paper and sends it to all the minions, BSSSQS Minion possess processed question papers and the access to question papers is controlled by smart contract. Question paper is selected randomly along with a timestamp-based lock to prevent students from opening the paper before the assigned time.

2.4 Credit transfer and admissions

This category aims to eliminate any intermediary involved to handle credit transfers and exchange information between institutions using blockchain.

A paper by Bálint et al. (2019) proposed an automated bursary payment system, digital learning chain structure (DLCC) based on Bitcoin structure. The implementation of DLCC starts by signing a contract between students and faculty. The contract automatically generates an electronic grade book based on student results. If the student complies with the given standards, bursary is added to its account. DLCC consists of five elements. The definition of terms of contract for regularity of payment, electronic grade book to hold grades of students, gathering of information to keep updated information on Bitcoin, examination of terms in contracts to evaluate the information that has been collected and payment to transfer necessary amount to student's electronic wallet. Similarly, Turkanović et al. (2018) proposed EduCTX, a peer to peer global credit and grading platform, that stores student credits and enables credit transfer between higher education institutions. Based on European credit transfer system, this system is designed to manage, process and control student credits represented as ECTX tokens. An EduCTX wallet is assigned to every student to store ECTX tokens. Higher Educational Institute (HEI) assigned ECTX tokens to the student after course completion to his/her blockchain address. If a student's private key is lost, HEI can issue a new blockchain address on request after verifying the student records and appropriate ECTX tokens are transferred to the new address. The proposed system does not intend to change the existing system, it only aims to add automation and transparency for optimisation of administrative processes.

An electronic credit transfer scheme built on consortium Ark Blockchain Client platform is a collaborative educational framework for credit transfer between various higher education institutes and companies (Srivastava et al., 2018). A blockchain-based globally trusted framework for educational institutes is presented to collaborate with companies and other universities. The credits and academic certificates are verified and digitally transferred between organisations. On successful completion of the course, credits are assigned to students in the form of tokens. Mori and Miwa (2019) proposed in their paper a digital admission application system for universities to organise and manage documents, e-credentials and certificates with the help of smart contracts. All student data is encrypted and can be accessed only using tokens issued by the students, thus

preventing information leakage. The proposed system includes an input function to input information for tokens, an inquiry function to view articles in a token, registration function to register addresses in a smart contract, an issuing function to issue tokens and a transmitting function to send tokens. ERC 271, a smart contract standard is used for implantation of 'non-fungible tokens' to record the token transaction history.

2.5 Learning resources

The applications in this category provide a secure learning environment easily accessible to all students, faculty members and other authorities.

Table 1 Brief overview of publications on blockchain education

Title	*Contribution*	*Technique used*
A novel blockchain-based education records verification solution.	A method for sharing and authenticating official certificates for universities where certificates can be exchanged officially or collected by students.	Ethereum
TUDocChain – securing academic certificate digitally on blockchain (Budhiraja and Rani, 2019).	An Ethereum-based consortium blockchain system to issue, share and validate certificates that are stored on Interplanetary File System.	Ethereum
Alumnichain: blockchain-based records verification service (Badyal and Chowdhary, 2019).	A Hyperledger Fabric-based instant student verification system that stores data in encrypted form and recruiters can verify student information using a code provided by students.	Hyperledger
Unichain: a design of blockchain-based system for electronic academic records access and permission management (Daraghmi et al., 2019).	An Ethereum-based system that offers secure access to academic certificates stored as electronic academic records (EARs) and controls access to EARs through time-based smart contracts.	Ethereum
Blockchain-based approach to create a model of trust in open and ubiquitous higher education (Lizcano et al., 2020).	Annihilates the divergence between the academic world and enterprise or corporate world by adding verified proficiency skills to the student's electronic CV that is accessible to employers.	Ethereum
The blockchain and kudos: a distributed system for educational record, reputation and reward (Sharples and Domingue, 2016).	An academic records system with rewards as reputation currency that are established by institution to check learning outcomes, wherein, performance-based rewards are given to students using a smart contract.	Ethereum
Cerberus: A blockchain-based accreditation and degree verification system (Tariq et al., 2019).	An online verification service proposed as a solution for verification of credentials todecrease fraud. It is operated and maintained by a delegation of universities and spectators to collect transactions and add them to a block and ensure integrity after every process.	Ethereum

Table 1 Brief overview of publications on blockchain education (continued)

Title	*Contribution*	*Technique used*
ECBC: a high performance educational certificate blockchain with efficient query (Xu et al., 2017).	An educational certificate infrastructure, ECBC, digitally manages educational certificates using MPT- CHAIN to speed up block verification; supports high throughput and low latency	Ethereum
Learning analytics' privacy on the blockchain (Forment et al., 2018).	Evaluates privacy issues of Learning Analytics, collecting sensitive student data and ensures data confidentiality using blockchain technology.	Ethereum
Privacy and identity management in learning analytics processes with blockchain (Filvà et al., 2018).	Learning analytics is used to present a solution for students to ensure privacy and control their data by automating rules.	Ethereum
Towards blockchain-enabled school information hub (Bore et al., 2017).	Hyper ledger Fabric-based system to store and share data using hash-encrypted transactions.	Hyperledger
Learning system based on decentralised learning model using blockchain and SNS (Hori et al., 2018).	CHILO, a blockchain application to protect copyrights and ownership of e-books as well as any information obtained from students. It can be used to create a life-learning model for learners to communicate their ideas.	Hyperledger
Blockchain-based transcripts for mobile higher-education (Arndt and Guercio, 2020).	A flexible life-long learning approach that is flexible to support educational credential transfers between universities of different countries.	Ethereum
EduRSS – a blockchain-based secure educational records storage and sharing scheme (Li and Han, 2019).	A consortium blockchain combined with off- chain storage servers to store and share educational records across institutions.	Ethereum
Managing lifelong learning records through blockchain (Ocheja et al., 2019).	BOLL – blockchain of learning logs, a system connecting learning records across institutions using smart contract to keep track of learning achievements and manage access rights.	Ethereum
Blockchain for education: lifelong learning passport (Gräther et al., 2018).	Blockchain of learning logs, a system to connect learning records and keep track of learning achievements across institutions.	Ethereum
Privacy protected blockchain-based architecture and implementation for sharing of students' credentials (Mishra et al., 2021).	A DApp developed on Ethereum blockchain is proposed to guarantee confidentiality and to ensure secure and authenticated sharing of student credentials.	Ethereum
dAppER: decentralised application for examination review (Mitchell et al., 2019).	Permissioned blockchain to draft exam papers and evaluation procedures along with awarding secure and verifiable documents.	Hyperledger

Table 1 Brief overview of publications on blockchain education (continued)

Title	*Contribution*	*Technique used*
Design of student capability evaluation system merging blockchain technology (Zhao et al., 2019).	A professional skill evaluation system that uses k-means clustering to analyse student's professional ability and blockchain technology for the student data to be traceable and non-destructive.	Bitcoin
Education-industry cooperative system based on blockchain (Liu et al., 2018).	An Education-Industry cooperative system that uses certificate authority service to share information between universities and companies transparently in order to eliminate academic frauds and provide symmetry between student skills and enterprise requirements.	Hyperledger
Blockchain-based badge award with existence proof (Choi et al., 2019).	An education system of IMS standard, immutable and verifiable badges, predefined for each level of learning progress, represent skills of a student.	Ethereum
Connecting bitcoin blockchain with digital learning chain structure in education (Bálint et al., 2019).	An automated bursary payment system, DigitalLearning Chain Structure (DLCC) based on Bitcoin structure. The implementation of DLCC starts by signing a contract between students and faculty.	Bitcoin
EduCTX: a blockchain-based higher education credit platform (Turkanović et al., 2018).	Global credit and grading system to store student credits and enables credit transfer between higher education institutions.	Ark Blockchain
Digital university admission application system with study documents using smart contracts on blockchain (Mori and Miwa, 2019).	A digital admission application system for universities that organises and manages documents and e- credentials and certificates with the help of smart contracts. All student data is encrypted and can be accessed only using tokens issued by the students, thus preventing information leakage.	Ethereum

A blockchain-based integrated internet of things ubiquitous learning environment, a smart workspace proposed by Bdiwi et al. (2018) is equipped with sensors for secure information exchange to enhance interoperability challenges in education. Transaction complexity and cost is reduced by using blockchain. This architecture can provide reliable educational services and also improve management of data chain using smart contracts. It also creates efficient and secure decentralised network where IoT devices communicating with distributed ledgers can be traced. Data consistency with minimal errors is achieved with the help of consensus mechanism.

Guo et al. (2020) introduce a blockchain enabled digital rights management system with combination of private and public blockchain and three smart contracts for secure storage, protecting multimedia digital rights and verification of digital certificates. The proposed system has three types of nodes:

- *Learning users* include any user who wants to learn, *education authorities* include different educational institutions and *employers* or third parties for verifying learner's credentials. It also authenticates multimedia resources used in online education system that are divided into two parts.
- Material issued by education authorities and learner's achievements like presentation, homework, answer paper, etc.

This paper aims to review the techniques developed for educational sector using blockchain technology. TUDocChain, Alumnichain, Unichain and others have been designed to issue and validate certificates. ECBC, CHILO, EduRSS, BOLL and the rest are considered for storing and sharing of documents. EduCTX and similar others, fall under the category of techniques developed for student evaluation and exams. Rest other techniques are used to handle credit transfer and providing secure learning resources to students. Student-Centered iLearning Blockchain (SCi-B) is a learning model and assessment model that governs all activities through blockchain and gives assessment in the form of digital certificates (Anwar et al., 2022). Blockchain is considered best for reliable storage of records (Sunny et al., 2022). However, it is still affected by some immaturity problems (Mohammad and Vargas, 2022). Only limited blockchain-based projects have been implemented and very few have explained the effect of blockchain technology on administration and student learning outcomes (Ocheja et al., 2022). Most of the papers have been published for data management followed by degree verification. Rest of the areas have limited publications, that is the reason most of the institutions use this technology only for validation and sharing of credentials.

3 Conclusions and research gaps

Blockchain technology significantly opens new possibilities for education sector by providing secure platform to share student information, conduct evaluation and track entire learning process. Even though, blockchain technology in education is in its initial stage of development, it can bring evolution and innovations to this field. The decentralised and immutable features of blockchain are ideal for storing and sharing of sensitive data of educational institutes securely. Using blockchain technology in institutions ensures autonomy, security and data integrity.

The research articles and projects designed for education are limited but continuously evolving. To better evaluate and identify functionality of blockchain technology in education more research should be conducted in this field. After evaluating latest research papers, we found that blockchain is beneficial to educational institutions but it also has drawbacks. Since blockchain technology is expensive, it can't be directly used to store high volume data of educational institutes. Wrong entry of data can't be corrected because of the immutable nature of blockchain. Cost of implementing and adopting blockchain technology is high. Also, the lack of awareness of this technology is a reason many institutions hesitate to shift from traditional systems to blockchain technology. However, if full decentralisation is essential then blockchain technology is favourable.

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