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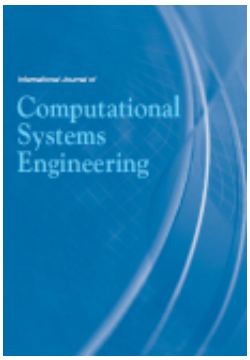

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Blockchain technology: a tool to solve the challenges of the education sector in developing countries

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Abstract: Education is getting diversified, challenged, and blended with the overwhelming advancement of modern technology, which can be resolved using blockchain technology (BT). The fourth industrial revolution (4IR) is changing our experiences teaching and learning. Delivering lectures, interacting between learners and educators, evaluating learning outcomes, and verifying educational credentials might be smoother, easier, faster, cheaper, and jollier than before. We have demonstrated that blockchain technology can contribute to the education provider tackling all those existing problems to create a comfortable learning environment for all, irrespective of their economic backgrounds and geographic location. How BT can contribute to improving education is one of our priorities of research in this study. Firstly, this study reviews recent inventions in BT. Secondly, we have gone through the connection between BT and education. Additionally, it discusses strategies around the world. Few models are arranged to enable the reader's mind to inventions in the realm of educationists.

Keywords: blockchain; 4IR; educators; learning outcome; blockchain in education; education; sustainable education; modern education; challenges of education.

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1 Introduction

1.1 Background

In 2008, a person or a group of persons (real identity not known) going by the name Satoshi Nakamoto proposed using blockchain technology for virtual currency. Nakamoto developed Bitcoin, a digital money based on the blockchain. This network stores and disseminates data using distributed ledger technology (DLT) and operates on a peer-to-peer model (Nakamoto and Bitcoin, 2008). Numerous alternative cryptocurrencies appeared on the market after Satoshi Nakamoto used blockchain technology to create Bitcoin. Essentially, blockchain is a shared ledger that records and verifies data records and data exchange etc. between parties. To put it simply, blockchain is a distributed database that records digital data transactions. The blockchain is a distributed ledger in which each user's transaction history is recorded in chronological order and could be altered by a consensus of all users (Sarmah, 2018). Private blockchains are exclusively utilised internally at a corporation or organisation, while public blockchains are available to the public. There are several different blockchains, but the one at the heart of Bitcoin's cryptocurrency is the most well-known. Various applications exist for DLTs tamper-proof transactions and its ability to maintain a clear and unambiguous register of information exchange (Ark, 2018).

To address the need for decentralisation and confidentiality of cycles common to ordinary people and organisations, the blockchain implements a large and global encoded dataset which is shared between many nodes and the integrity is preserved by mutual verification of connected nodes. This kind of decentralisation, confidentiality and verification puts an end to the corruption, manipulation, or monopolisation of data by different parties that interact with that data. An enormous, decentralised, encoded, and open book of records influences the veracity of the data and guarantee its moral correctness. Applications of this type of spectacular and general arrangement include the exchange of decryption forms of money, decentralised program distribution, and record keeping (Gomez, 2021).

At first, blockchain technology was mainly used for digital currency transactions, but now there is a growing body of research on the potential benefits of blockchain in other areas of applications, including medicine, education, urban planning, finance, insurance, and many more. Blockchain is finding more and more new area of application and helping to solve many challenges. One such area of application is supply chain sector. In their work Sreerakhi et al. (2022) showed how blockchain is successfully being implemented in supply chain and how this technology is helping solve different challenges. In another work Shakhbulatov et al. (2020) showed how blockchain is being applied in enhancing supply chain management. In their work Jabbar et al. (2022) showed how blockchain is successfully being used in intelligent transport systems. In another work Shammar et al. (2021) showed how blockchain is being successfully being integrated in security perspectives. The blockchain provides an almost impregnable and unhackable network for computer-based applications, therefore the trend has turned towards the secure and verified system (Sharples and Domingue, 2016).

Now, in education sector, the rapid development of distributed information and blockchain technology has prompted many organisations and people connected to this sector to reassess and re-examine several fundamental components of existing education, literacy, and training frameworks. With the introduction of this new systems and improvements, many previously held beliefs about things like trust, value, security, and character are being questioned. Because of the fast paced development of distributed computation and blockchain technologies, many of our long-standing standard processes of the educational institutions are being rethought and redesigned. When some new technology including blockchain is introduced into the classroom, it raises new questions such as the nature of ideas like trust, privacy, and identification, as well as a whole new set of technologies (Sharples and Domingue, 2016). The primary focus of blockchain research in the education sector is to find the ways in which the technology might facilitate the safe, reliable, and auditable dissemination of knowledge. The ledger then serves as a central repository for all of the related educational institutions to access and use in the course of their respective teaching, learning, and accrediting processes (Bhaskar et al., 2020). Researchers have discovered that blockchain technology is able to creates an educational setting where students may act as their own registrars and where third parties are not required to record or modify their grades. Education providers may also use blockchain technology, a decentralised data exchange, to issue, validate, and share certificates, which will assist to reduce the prevalence of certificate fraud (Agarwal et al., 2021).

The education industry has been highlighted as a revolutionary arena for new and upcoming technologies, a rising area where the credential is vital. Multiple studies have indicated that an appreciable number of candidates forged their academic credentials. It is not coincidental that we might benefit from avoiding certain potential arguments by introducing double-checking of this kind of data now (Sharma, 2018). The education industry process huge amount of student data and depend of proper handing of these data, and blockchain technology has the potential to make much of these relevant data like student enrolment, tuition paid, course completion, and even a student's diploma an integral part of their digital identity. Information security is improved by the immutability of these records. Rather than belonging to the institution where they were created, students should retain ownership of their academic records. Once a record is recorded on a blockchain, no user may change it. In the unlikely event that a record contains an error, a new record should be created to correct it, and both the incorrect and correct records will remain visible (Hance, 2021).

This whole chapter has been written with the aforementioned problems in mind, discussing them in light of existing solutions and anticipating future innovations that will further streamline the educational process. This chapter examines recent developments in this field of blockchain technology and outlines some of the methods that may be used to go surpassing the already active initiatives around the globe.

1.2 Aim of research

Studying blockchain's potential as a tool to address issues plaguing the global education system is fundamental to this study. In particularly, the specific objectives are to:

1 Classify the development of research areas concerning the blockchain.

2 Identify the various blockchain applications and categorise them.

3 Evaluate the practicality of blockchain technology.

4 Separate the current problems with contemporary education in underdeveloped countries from the challenges and opportunities of implementing blockchain technology in education.

5 Connect the dots between the discovered advantages and threats of blockchain implementation in education and the identified research topics.

1.3 Research question

RQ1 How can the educational system be integrated with blockchain technology?

RQ2 What are the implications of blockchain for the education systems of poor nations?

RQ3 What are the challenges to adopt blockchain technology for education system?

1.4 Methodology

In order to address the research objectives posed by the study, a thorough content analysis of the available literature has been conducted as a secondary data source. The purpose of content analysis is to identify recurring ideas, topics, and terminology within a body of qualitative data (typically text). Researchers may use content analysis to determine the frequency with which certain words, ideas, or concepts appear in a text, as well as their significance and interrelationships. Investigators may check articles for signs of prejudice or partiality by analysing the words and phrases used. This allows them to draw conclusions about the book's meaning, the author, the intended readers, and the historical and cultural context in which the piece was written (Harwood and Garry, 2003). Content analysis may be broken down into two broad categories: conceptual analysis and relationship analysis. Using this method, we may ascertain whether or not a text contains any ideas and how often they appear. By digging further into the interconnections between ideas in a text, relational analysis expands on the conceptual analysis. Results, conclusions, interpretations, and meanings may vary depending on the method used to analyse the data. Conceptual analysis was performed with content analysis in this study (Lacy et al., 2015).

Books, journal articles, essays, talks, newspaper headlines, lectures, media, historical records, and online forums are all mined for information for this study. The study used a process called content analysis, in which the text was dissected from several perspectives to reach its goal. The primary method used for this was a literature of previous research. A literature review is an approach of collecting, analysing, and interpreting the research that has been done on a certain subject, phenomena, or research issue (Snyder, 2019). Primary studies are the individual study projects that make up a systematic review, which is itself a subset of secondary research. Following the guidelines established by Petersen et al. (2008), we performed a search for applicable publications and compiled them into a literature review. Because this content analysis review set out to discover pre-existing research on blockchain technology, the review procedure was used as the study approach.

2 Blockchain: the associated issues with the technology features

2.1 Blockchain technology

Bitcoin, Ethereum, and other cryptocurrencies all use blockchain, a new kind of database technology. Blockchain prevents hacking and fraud by dispersing several, identical databases throughout a network. Bitcoin and other cryptocurrencies may be the most visible use of blockchain right now, but the technology has the potential to benefit a broad variety of industries. Blockchain may be thought of as a decentralised digital ledger that can be used to record and verify transactions of any sort. Non-fungible tokens and cryptocurrency transactions may both be recorded on a blockchain (Yli-Huumo et al., 2019). While this data may be stored in almost any database, blockchain is special because it is distributed. In contrast to centralised databases like Excel spreadsheets or bank ledgers, which are stored on a single server, blockchain databases are distributed throughout a network of computers. Nodes are the individual computers that make up a network (Sheth and Dattani, 2019).

2.2 How blockchain works

In many ways, blockchain technology is more important than the internet itself. There is no need for credibility or a governing body to facilitate the transfer of wealth (Yaga et al., 2019). So far, bit coin has been the ultimate example of workings of the blockchain technology. In this section we are explaining the inner workings of blockchain, or DLT,

using the workings of the Bitcoin implementation as an example in here:

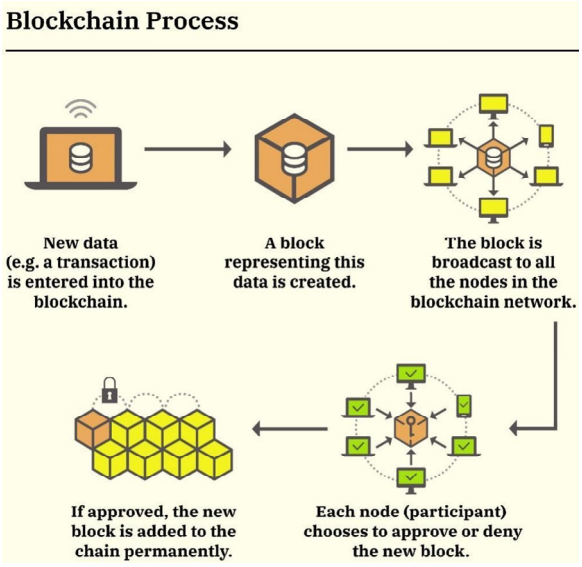
1 Bitcoin transactions are recorded and sent to a series of interconnected computers, or nodes, which verify and process the trades. These computers are interconnected through the internet and blockchain client process. The communication between nodes is secured using strong cryptographic processes.

2 Using complex mathematical procedures, hundreds of nodes in the network compete to verify the transaction. Bitcoin mining refers to this process. The miner who finishes a block first receives Bitcoin as payment for their efforts. These bonuses are paid for using freshly generated Bitcoin and shared network fees. Transaction volume will determine the range of transaction fees.

3 The transaction is added to the distributed ledger as a new block after the cryptographic confirmation of the purchase has been received. It is then up to the vast bulk of the network to approve the transaction.

4 A cryptographic fingerprint called a hash is used to link the block to all preceding block of Bitcoin transactions, and the transaction is finalised (Niranjanamurthy et al., 2019).

Figure 1 Steps of how blockchain works (see online version for colours)



Source: Fox (2017)

Although blockchain is a fairly new technology which created a huge buzz with the introduction of Bitcoin, it is already being used in everyday life along with Bitcoin and cryptocurrency. Blockchain technology has already entered into standard currencies and banking. Blockchain is also being used to execute transactions with fiat currencies such as the pound, the euro, and the eurozone's equivalent of the franc. If the payments can be confirmed and handled outside of typical business hours, this might be a speedier option than transferring money via a bank or financial institution. Blockchain technology can contribute to our everyday business by helping in keeping proper records of assets and asset transfers. Blockchain technology can be used to confirm ownership of other assets. As an example we can talk about keeping proper ownership record of digital artworks. This is a really hard task which blockchain technology can make very easy. Blockchain technology can be deployed to record the legal transfer of physical goods like titles to homes and cars. Another blockchain breakthrough is self-executing contracts generally termed – smart contracts. When certain criteria are satisfied, these electronic contracts are immediately put into action. For instance, a purchase for an item may be issued quickly if the sellers and buyers have completed all set requirements for a trade. Supply networks generate enormous volumes of data. Identifying issues, such as the manufacturer of low-quality items, may be challenging if data is stored in the conventional manner. Using blockchain to keep supply chain record can allow it easy to go back and check the supply chain. Also blockchain technology may be used to reduce voter fraud. In principle, blockchain voting would do away with the need to physically collect and validate paper ballots and would also enable voters to cast votes that are impossible to tamper with. Blockchain has the potential to drastically improve the ways in which academic collaboration and record keeping are handled. Since blockchain is a distributed ledger, it has the potential to greatly improve the sector by increasing openness and responsibility in technology. Let us take a look at how blockchain technology might impact classroom instruction (Lindman et al., 2017; Purohit, 2022).

3 Challenges of modern education

3.1 Challenges of traditional education system

The following challenges are accumulated by the information from on Stovall (2005) and Chiţiba (2012):

3.1.1 Less learning outcome

There are not enough learning outcome sets to blame for the collapse of the old school system. Most students seldom stop to consider why they are studying something or what they hope to gain from doing so. That begs the question, "why have we started this course now?" The fundamentals of beginning a chapter with questions regarding what I will gain from reading this chapter are never emphasised. The only time students read the chapter is just before an exam. Their main concern is doing well on the test. They consistently show a lack of study in what they should be learning.

3.1.2 Learning level is not the same

Those attending a class come from a wide variety of origins. It is likely that their parents' schooling experiences were unique. Parental academic attainment is not often high. While a handful of the students will be first-generation study-goers, the majority are third-generation students.

Thus, the third-generation student's parental participation in their child's schooling is superior to that of the first-generation learner.

3.1.3 Lack of skill-based education

When compared to more modern forms of education, the conventional one places more emphasis on imparting generalised information rather than practical training. Innovation, originality, and 'out of the box' thinking are often discussed in the business world. However, none of them are supported by the mainstream educational system. We live in a democracy where leadership can be changed, but our system of education is not built to foster growth over the course of years.

3.1.4 Non-availability of quality teachers

In conventional classrooms, teachers are of subpar quality. People often see teaching as a career of last resort. Teachers, even those who are formally trained in the field, often fail to pass on useful knowledge to their students. Commercial interests have penetrated the academic realm. Earning more money or landing a cushy job has replaced helping students learn as the main purpose of teaching.

3.2 Challenges of modern and digital education system

1 Sadly, few educational institutions have the technological wherewithal to provide digital textbooks and reading materials on a wide scale. Digital books demand fast internet, which is not widely available in the poor countries. However, developed countries like the US have no trouble with the huge data downloads that this entails (Gulati, 2008; Ronzhina et al., 2021).

2 It has never been the technology itself that has stood in the way of progress in this area, but rather the people who have been directly impacted. Everyone in the education system is mired in the past, from classroom instructors to school principals to librarians to parents. The difficulty comes from pushing students to accept digital learning as the norm (Mehdipour and Zerehkafi, 2013; Gulati, 2008).

3 The content of digitising educational materials extends much beyond the simple digitisation of textbooks and other materials already in existence. Dynamic and engaging curated content is essential for the success of digital learning in the classroom. Curating this kind of content is time-consuming and labour-intensive, which contributes to higher overall implementation costs (Khakpour, 2012).

4 The cost of implementing a virtual curriculum is not a fixed amount. As technology evolve, so too must the curriculum reflect these changes. Changes in technology may have profound effects on previously published content (Shutikova and Beshenkov, 2020; Ronzhina et al., 2021).

3.3 Challenges of education posed by rapid changes

A lot has changed in the way individuals work during the last 30 years. In modern, industrialised cultures, the practise of workers remaining at the same company for a quarter century is obsolete. As a result, today's schools and universities must equip their pupils to hold ten or more occupations before they are 50. Companies want to hire people who are not just knowledgeable in their fields, but also adaptable, mature, and fast learners (Oyedotun, 2020).

The whole structure of the economy is shifting. Globally, the information economy and the consumer economy are booming. The non-oil economy in Abu Dhabi is expected to increase by more than eight percent annually as the city continues its long-term transformation to a stable, high-value knowledge economy. The knowledge-based sectors of the future will demand people with strong communication, teamwork, and creative abilities. Each person must adopt a new way of thinking for globalisation to work. Fifty years ago, the globe seemed much larger than it is now. To appreciate the intricacies of other people's cultures, our pupils will need to be 'globally competent'. Information has also undergone profound changes in the modern era. Every two years, the total quantity of data on the globe doubles. Therefore, we will have to adjust our approach to this management. In ways we cannot foresee at the moment, students of tomorrow will need to understand how to filter, collect, and synthesise data (Nurhas et al., 2022).

4 Blockchain in education

4.1 Use of blockchain in education

During the epidemic, educational institutions jumped on the digitising bandwagon. As a result of the revolutionary nature of blockchain technology, this industry may see a dramatic shift. To begin, blockchain has the potential to drastically improve the ways in which academic collaboration and record keeping are handled. Since blockchain is a distributed ledger, it has the potential to greatly improve the sector by increasing openness and responsibility in technology. As the globe becomes more technologically sophisticated, the educational system stands to be shaken up. The education technology sector has benefited us for 20 years. It is safe to say that this trend has hastened the process of bringing schools up to date. Now is the moment for blockchain technology to greatly quicken the process. The distributed database of the blockchain, AI, and machine learning are gradually displacing textbooks (Maryville, 2021). Below, we highlight the applications and consequences of blockchain technology in the academic sector (Bhaskar et al., 2020; Rahardja et al., 2020).

Guustaaf et al. (2021), stated about the possible features of blockchain technology in education in a tabular format as

below where use cases are put in left column and features in right column.

Table 1 Use-cases of blockchain in education

Content library	*Decentralised and transaction rate*
Store personal data	Anonymity
E-certificate	Transaction rate
Scoring system	Smart contract
B2B approach	Smart contract
Token system	Consensus mechanism, smart contract and currency
Cooperative learning	Decentralised and smart contract
Job opportunities	Smart contract
Providing feedback services	Traceability

Source: Guustaaf et al. (2021)

4.1.1 Intelligent agreements for courses and assignments

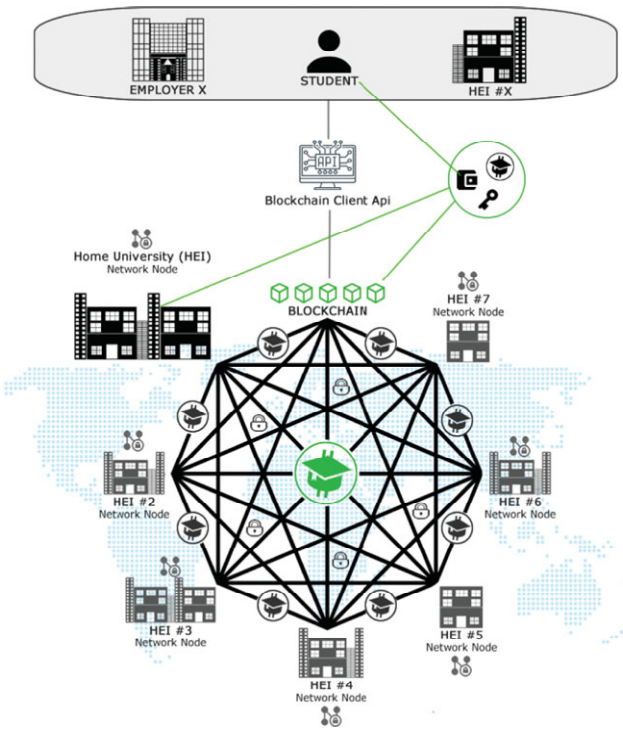
Agreements are often implemented on blockchains. This may help instructors create blockchain-based courses and lessons. After the requirements have been met, the class will be taught automatically and at the student's own speed. Students and instructors might sign a contract detailing assignment restrictions, due date, and grading deadline. (Guustaaf et al., 2021; Hameed et al., 2019; Kuvshinov et al., 2018).

4.1.2 Certifications, report cards, and documentation

The immutable ledger technology of blockchain produces a chronological record of recent occurrences. This might be useful for presenting student transcripts, producing a thorough report card, monitoring attendance, and informing students and stakeholders about their progress. Using blockchain, students may submit homework without concern of losing them. Additionally, students may obtain their degrees and certificates online, as opposed to on fragile paper. Digital degrees and certificates are favoured since they are hassle-free, well-organised, and uncomplicated (Guustaaf et al., 2021; Hameed et al., 2019; Kuvshinov et al., 2018). Almost all educational institutions use their own unique format to store student data. We can use blockchain technology to safeguard the security of academic degrees. By generating hash values for each block, the academic degree information may be kept up to date utilising blockchain technology. Blockchain technology and digital signatures are utilised to ensure the validity and reliability of academic degrees (Makani et al., 2022).

The figure described how the academic credit and grading system can be dealt between assessors, education network and students efficiently using blockchain network.

Figure 2 Proposed credit and grading platform (see online version for colours)



Source: Turkanović et al. (2018)

4.1.3 Streamlining the payments of fee

The procedure of paying student tuition is time-consuming and difficult. Students, parents, banks, organisations or government organisations for grants, lenders, and other university departments are involved. This process, however, can be expedited using blockchain technology, resulting in decreased administrative costs and maybe even cheaper tuition fees (Holotescu, 2018).

4.1.4 Universal admittance and lower expense

To encourage and facilitate lifelong learning, blockchain technology may facilitate the distribution of freely available, open educational content like books, lectures, and films in the public domain. Blockchain technology allows for the safe and low-cost public sharing of such assets. Additionally, blockchain enables teachers to assess their students' work on the blockchain, making it possible for students in far-flung regions to participate in digital versions of courses and exams (Hameed et al., 2019; Kuvshinov et al., 2018).

4.2 How blockchain can solve the challenges of education system

According to Wallace (2019) and Steiu (2020), below are some of the sectors of the education business where blockchain might have an influence and how it can tackle the issues of the education system:

- The purpose of higher education is dual in the field of research: first, to preserve information for future generations of students, and second, to increase current knowledge via research. Professors spend a great deal of time performing research work and publishing their results, expanding the boundaries of their disciplines and uncovering new areas of study that will lead us into the future. Moreover, the reach and effect of such articles may have an influence on academics' potential to seek large funding to cover future research. There is a strong incentive for authors to monitor the distribution of their works and take measures to discourage blatant theft.
- Researchers would be free to publish anything they choose, so long as they publish in a fashion that allows them to measure the reuse of their work (such as how frequently it is referenced or used as teaching materials), which is crucial since it may lead to recognition and further funding.
- While still in its infancy, blockchain in e-learning has been heralded as 'the ideal technology' for retooling an antiquated system.
- With the spotlight shining brighter than ever before, blockchain's distributed ledger keeps technology of transactions in near real-time and cannot be altered once they have been recorded. This is a great way to maintain tabs on kids' academic standing, show a full report card, and verify transcripts. Students who use blockchain to turn in their work cannot complain that their submission was misplaced.
- Smart contracts may also be used to emphasise responsibility. Teachers, administrators, and students at educational institutions will soon have access to smart contracts. To clarify the parameters of an assignment, the due date, and the grading schedule, for instance, students and professors might sign a digital agreement. It is possible that student loan debt may be settled via smart contracts.
- When applied to the problem of reducing the price of higher education, it has the potential to have a dramatic effect. Open educational materials are those that are in the digital realm and free to use and redistribute, and they might be made accessible to everyone via the use of blockchain technology, in addition to their potential utility in promoting lifelong learning. Blockchain technology makes it possible to safely and cheaply distribute these kinds of resources on a public network.
- Blockchain has the ability to change the education landscape because it can address these issues by providing new, less expensive means of teaching and by breaking the current link between schools and students (Bhaskar et al., 2020; Agarwal et al., 2021).

4.3 What are the current and possible limitations in adapting blockchain in education sector

Blockchain has a lot of promising applications, but it has not yet seen widespread adoption. More than half of the students polled by Gartner said they had no plans to use blockchain technology. The difficulties of putting into practice the technology might be to blame for much of the resistance (Alammary et al., 2019).

4.3.1 Security

Even while blockchain's security is a major selling point, it is not bullet-proof. Institutions need to be careful about what material they save and how they select to store it due to the sensitive nature of the information being kept on the blockchain (students' academic records and credentials). There may also be difficulties associated with meeting the requirements of federal and state privacy legislation. More stringent privacy safeguards may be required at universities, such as the use of private or private blockchain or the encryption of blockchain-stored data (Kosasi et al., 2022; Loukil et al., 2021; Mohammad and Vargas, 2022).

4.3.2 Scalability

Large amounts of student and alum data held by educational institutions might provide a scaling challenge for blockchain applications. More blocks are needed to accommodate more data, which slows down blockchain transactions since each one must be verified by the network's nodes. This may be a serious barrier to widespread implementation. A benefit of permissioned blockchain is that they can process more transactions per second than permissionless ones (Loukil et al., 2021; Raimundo and Rosário, 2021).

4.3.3 Adoption rate

Blockchain, like other technology before it, is only useful when enough universities and employers depend on it; students only gain from proprietorship of their diplomas if the schools or firms to which they are applying recognise their validity. Many job boards, like Upwork and Ziprecruiter, are actively encouraging blockchain-based credentials, and hundreds of colleges are now issuing and accepting them (Kosasi et al., 2022; Loukil et al., 2021; Raimundo and Rosário, 2021).

4.3.4 Cost

Adopting and deploying any new technology may be fairly expensive, despite the fact that it might lead to benefits in other areas. Investing in more computer resources or upgrading a current infrastructure may be expensive. Institutions may also need to spend time and money training school administrators to utilise the technology (Steiu, 2020; Lutfiani et al., 2021; Anand, 2022; Raimundo and Rosário, 2021). This is because many organisations may lack the

expertise and skills essential to handle student data on a public blockchain.

4.4 Context of models suggested for developing countries

Regarding the view from underdeveloped nations According to UNESCO's definition, open educational resources are those that are either freely available in the public domain or licensed in a way that allows for their reuse, modification, and redistribution by anyone. Open textbooks, courses, and curricula are only the beginning of what may be found in the realm of free and open educational materials. It is not limited to textbooks, though; software, podcasts, and movies may all serve the same purpose. They cut the price of educational materials for pupils by a significant content. Teachers and students have been given more control over their learning with the use of these tools since they have faster and easier access to more high-quality content. Taking this definition into account, blockchain may be thought of as a decentralised digital ledger as well as database operating on a network. Because the technology is decentralised, open educational materials (the 'blocks' in the 'chain') may be safely and efficiently shared across users on the internet. Blockchain technology can facilitate the worldwide distribution of free and open educational content. Blockchain was first developed for use in Bitcoin as a distributed ledger to record encrypted and verified financial transactions between users over a network (McGreal, 2021).

For example, look at the blockchain for education community of practice from the World Bank (COP). It is a hub for anyone interested in using blockchain for positive change in educational institutions. Members offer insights gained through their research and experimentation into the reality of making the most of connected technology. Educators and policymakers in charge of public school systems who are interested in enhancing their classrooms with technological resources are a key target demographic for this COP. This strategy may be adopted in underdeveloped countries with the help of the World Bank's EdTech Team, wherein participating organisations and Ministries of Education work together to conduct pilots and participate to accessible global public goods (World Bank, 2021).

5 Concluding remarks and way forward

The application of blockchain technology in education is still in its infancy which has been taken into consideration to identify specific gaps in research that must be helpful in future studies. This study aimed to perform a thorough review of blockchain implications in the education industry. For this purpose, this paper conducted a literature review based on content analysis covering theoretical and technical aspects. Our literature review enabled us to assess the benefits and drawbacks of using blockchain technology in educational arena, specially in underdeveloped nations. We have seen the general concepts of BT, its uses in different sectors, challenges, and way forward. Consequently, our research may assist future attempts to overcome the limitations of current solutions in the study of blockchain integration in education. It has the capacity to inspire tremendous future innovation. It will be feasible to implement blockchain technology in detail in future work. Moreover, the monetisation of all student affairs on a blockchain system will motivate students to participate in a range of activities, including sports, attendance, assignments, etc. as well as efficient models of such uses will be in use by future researchers and innovators. From our research we will suggest the followings to government and organisations to get the proper benefit while avoiding potential risks of blockchain applications in education:

1 While investing in better digital infrastructure is important, it's more important to invest in proper training of human resources. Governments should take this into account when introducing blockchain in education. Teachers and students must be properly trained on this new technology.

2 As a fairly new technology, blockchain needs time to mature in the education sector. Especially security of blockchain should properly be investigated before introducing more blockchain technologies in education.

3 Any change needs time, the organisations should introduce this technology in a slow and steady pace to give the human factor enough time and training to catch up.

4 Develop different blockchain based apps to securely save and transfer data as pilot projects to help involved human factor enough practice and training before introducing them on full scale.

5 Design fun to learn courses for students where students can interactively learn and get familiar with this technology.

Even though this innovation is still in its infancy and must be validated, it has the capacity to inspire a tremendous lot of future innovation. It will be feasible to discuss the educational uses of blockchain technology in detail in future work. Moreover, the monetisation of all student affairs on a blockchain system will motivate students to participate in a range of activities, including sports, attendance, assignments, etc. Moreover, efficient models of such uses will be in use by future researchers and innovators.

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Appendix

An overview of used references has been uphold in a tabular form partly for better understanding.

Table A1 Overview of references

Reference	*Key discussing points*	*Reference type*
Agarwal et al. (2021)	E-learning, teaching-learning, outcomes, classroom, environment, customised lecture plans, security, campus, etc.	Research paper, theoretical and analytical analysis
Alammary et al. (2019)	Blockchain in education, blockchain applications, educational technology, decentralised systems, etc.	Research paper, review paper
Anand (2022)	Blockchain in education, advantages, disadvantages, blockchain in university education, etc.	Internet resource, blog
Ark (2018)	Areas of blockchain application, blockchain in education, blockchain in governance, etc.	Newspaper, online resource
Bhaskar et al. (2020)	Education, blockchain, block chain in education, blockchain application, etc.	Research paper, theory and analytical analysis
Chiţiba (2012)	Globalisation traditional education institutions human capital lifelong learning pillars of education drivers and barriers academic preferences, etc.	Research paper, theoretical
Fox (2017)	Function of blockchain, working principle, key components, workflow, etc.	Online resource, technical
Gomez (2021)	Blockchain, applications of blockchain, blockchain in education, etc.	Online resource, theoretical

Table A1 Overview of references (continued)

Reference	*Key discussing points*	*Reference type*
Guustaaf et al. (2021)	Blockchain, education, digital certificate, technology	Research paper, technical
Hance (2021)	Blockchain, use of blockchain, blockchain in education	Online resource, blog
Harwood and Garry (2003)	Content analysis, qualitative, quantitative, reliability, sequential analysis, validity	Research paper, technical
Jabbar et al. (2022)	Blockchain, automotive communication, internet of vehicles, intelligent transport system, Bitcoin, Ethereum, smart contract, internet of things, security	Research paper, literature review
Lacy et al. (2015)	Content analysis, content sampling, reliability coefficient, algorithmic text analysis	Research paper, theoretical analysis
Lindman et al. (2017)	Issues related to design tech, environment, and organisation, blockchain technology, open source, digital platforms, services, research, digital payments, payment platform, risks, opportunities, etc.	Research paper, theoretical
Lutfiani et al. (2021)	Adoption of teaching and learning techniques along with evolution of technology, blockchain, Education 4.0, certificate, technology, etc.	Research paper, theoretical
Maryville (2021)	Blochchain, blockchain in education, opportunities of blockchain application, challenges, etc.	Online resource, blog
McGreal (2021)	Blockchain, blockchain in education, application of blockchain in education sector challenges, etc.	Online, blog/ interview
Nakamoto and Bitcoin (2008)	Blochchain, theory of blockchain, implementation of blockchain, working principles of blockchain, etc.	Research paper, theoretical and technical
Niranjanamurthy et al. (2019)	Bitcoin, digital money, crypto-currency, digitised decentralised public ledger, peer-to-peer network, central authority, Bitcoin, SWOT analysis, types of blockchain, advantages and disadvantages of blockchain, etc.	Research paper, analytical analysis

Table A1 Overview of references (continued)

Reference	*Key discussing points*	*Reference type*
Nurhas et al. (2021)	COVID-19 pandemic, digital transformation, higher education, challenges of digitalisation, rapid digitalisation	Research paper, theoretical analysis
Oyedotun (2020)	COVID-19, online teaching, undergraduate education, etc.	Research paper, theoretical analysis
Petersen et al. (2008)	Systematic mapping studies, systematic reviews, evidence-based software engineering, etc.	Research paper, technical and theoretical analysis
Purohit (2022)	E-learning, blockchain, blockchain in education, modern education, etc.	Online article, blog
Rahardja et al. (2020)	Higher education, Education 4.0, blockchain, etc.	Research paper, theoretical analysis
Ronzhina et al. (2021)	Digital transformation, digital economy, digital society, social digitalisation, technological changes, digitalisation in education, etc.	Research paper, theoretical analysis
Sarmah (2018)	Blockchain, cryptocurrency, Bitcoin, peer-to-peer network, decentralised ledger, nodes, token, etc.	Research paper, theoretical
Shakhbulatov et al. (2020)	Supply chains, stakeholders, peer-to-peer computing, supply chain management, smart contracts, distributed ledger, etc.	Research paper, survey
Sharma (2018)	Blockchain, blockchain in education, blockchain working principle, blockchain in modern education, etc.	Online resource, blog
Shammar et al. (2021)	Blockchains, internet of things, security, peer-to-peer computing, Bitcoin, information technology, object recognition, etc.	Research paper, theoretical analysis
Sharples and Domingue (2016)	Blockchain, reputation management, self-determined learning, e-portfolios, etc.	Research paper, theoretical
Sheth and Dattani (2019)	Blockchain, distributed ledger, hash, transaction cryptography, mining, etc.	Research paper, theoretical
Shutikova and Beshenkov (2020)	Digital technologies, digital educational environment, transformation, mass communications, media education, etc.	Research paper, theoretical

Table A1 Overview of references (continued)

Reference	*Key discussing points*	*Reference type*
Snyder (2019)	Systematic review, integrative review	Research paper, literature review
Sreerakhi et al. (2022)	Blockchain, distributed ledger, manufacturing supply chain, food supply chain, pharmaceutical supply chain, etc.	Research paper, survey
Steiu (2020)	Blockchain technologies, education sector, digitalisation, decentralisation, educational certifications, lifelong learning, data protection laws, general data protection, etc.	Research paper, theoretical
Stovall (2005)	Critical race theory, relationship, theory, practice, school-community relationships, African-American community organisers, urban schools, etc.	Research paper, theoretical
Turkanović et al. (2018)	Education, prototypes, Europe, Bitcoin, open source software, organisations, etc.	Research paper, analytical analysis
Wallace (2019)	Education, block chain, blockchain in education, etc.	Online, blog
Wegrzyn and Wang (2021)	Blockchain, types of blockchain, how blockchain works, application of blockchain, etc.	Online, blog
World Bank (2021)	Blockchain, blockchain in education, etc.	Online, blog, World Bank
Yaga et al. (2019)	Blockchain, blockchain technology overview, blockchain applications, etc.	Research paper, overview
Yli-Huumo et al. (2016)	Blockchain, decentralised, transaction, data management, technology, Bitcoin, cryptocurrency, etc.	Research paper, review