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EDITED BY
Antigoni Parmaxi,
Cyprus University of Technology,
Cyprus

REVIEWED BY
Víctor Gayoso Martínez,
Spanish National Research Council (CSIC), Spain
Ying Hsun Lai,
National Taitung University, Taiwan

*CORRESPONDENCE
Nasser Alshareef
nm.alshareef@mu.edu.sa

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Investment opportunity of blockchain technology in the education sector of Saudi Arabia: A systematic literature review

Nasser Alshareef*

College of Business Administration, Majmaah University, Al Majma'ah, Saudi Arabia

The primary objective of this research is to explore the literature on blockchain technology and its investment opportunity in the education sector. Studies on the investment opportunities of blockchain technology in education have remained limited and little is known about the existing state of knowledge and practice of blockchain technology in the education sector of Saudi Arabia, especially for its sustainable development. In this study, the author tried to synthesise literature on blockchain technology to understand the difficulties and prospects of this technology in Saudi Arabia. A total of 15 empirical studies from 2017 to 2020 were reviewed. The descriptive and thematic analysis identified four types of challenges of blockchain technology in the education sector. They include leaking privacy and security, processing cost, setting the boundaries, and weakening school credentials. The review also revealed several opportunities for adopting blockchain technology such as certifying identity authentication, improving learning assessment, maintaining student records, enhancing trust, and reducing costs. Implications and recommendations related to education for sustainable development are provided accordingly.

KEYWORDS

blockchain technology, blockchain in education, blockchain investment opportunity, Saudi Arabia, systematic literature review, education for sustainable development (ESD)

Introduction

The concept of blockchain was first proposed and introduced back in 2008 through the application of Bitcoin, a cryptocurrency (Nakamoto, 2008). This technology has gained significant interest in the last few years from many sectors, including academia (Ghazawneh, 2019). Although cryptocurrency is the most well-known blockchain application (Beck et al., 2016), blockchain technology has been increasingly used in a variety of applications and industries beyond cryptocurrencies (Zheng et al., 2018),

including banking (Tapscott and Tapscott, 2016), insurance (Underwood, 2016; Lorenz et al., 2018), health care (Swan, 2015; Ekblaw et al., 2016), public service (Akins et al., 2014), security service (Noyes, 2016), and education (Sharples and Domingue, 2016).

Blockchain is defined as a series of blocks that hold transaction data for a specific period (Nakamoto, 2008; Beck et al., 2018). This technology delivers a single truth to all network members by disclosing all transactions and reduces transaction uncertainty, insecurity, and ambiguity (Beck et al., 2016; Naerland et al., 2017; Catalini and Gans, 2018). Procedurally, blockchain technology works based on a decentralised database of transactions, which is spread evenly across decentralised nodes (Glaser, 2017). It is a cryptography-based data structure that uses a consensus process to assure database consistency and prevents retrospective manipulations when transactions are validated (Underwood, 2016; Beck et al., 2018).

Typically, there are public and private blockchains (Buterin, 2014; Peters and Panayi, 2016; Zheng et al., 2018). The nodes can read data from a public blockchain and propose new transactions whereas the nodes can only read data from a private blockchain and submit new transactions after the data are pre-registered by a central authority (Beck et al., 2018). In a blockchain, transaction validation is either permissioned or permissionless. All nodes in a permissionless blockchain can read, submit, and validate transactions, but for a permissioned blockchain, only authorised nodes can read, submit, and validate transactions (Peters and Panayi, 2016). **Table 1** shows blockchain typology based on its access to transactions and access to transaction validation.

Blockchain was initially created to facilitate the transfer of cryptocurrency Bitcoin in the form of digital tokens; it was not intended for any other application (Nakamoto, 2008). Following that, Ethereum was launched, allowing blockchains to construct and design numerous types of transactions through executable pieces of software known as "smart contracts" (Buterin, 2014). With that, blockchain technology can be implemented in many areas and industries. In terms of its relationship to sustainable development, the advent and development of blockchain technology, which has the potential to become a compelling disruptive breakthrough, should worry higher education. Additionally, blockchain technology now addresses the problems that higher education and society as a whole are currently facing. The benefits of decentralised open data, a lack of forgeries, safe data storage, and decreased transaction costs associated with data monitoring, control, and verification are all advantages of blockchain technology (Alahmari et al., 2019; Fedorova and Skobleva, 2020; Chivu et al., 2022).

TABLE 1 Blockchain typology (Beck et al., 2018).

Access to transaction	Access to transaction validation	
	Permissioned	***Permissionless***
Public	Transactions can be read and submitted by any nodes, but they can only be validated by authorised nodes.	Transactions can be read, submitted, and validated by any node.
Private	Transactions can only be read, submitted, and validated by authorised nodes.	Not applicable.

Study background

Technology development in the Middle East

Saudi Arabia is one of the Gulf countries in the Middle East region. Alphabetically, the rest include Bahrain, Iraq, Kuwait, Oman, Qatar, and United Arab Emirates. This region is

TABLE 2 Adapted query strings for the systematic literature search.

Databases	Query strings
ACM Digital Library	(blockchain + investment), (blockchain + education), (blockchain + Saudi Arabia)
IEEE Xplore	((blockchain) AND investment), ((blockchain) AND education), ((blockchain) AND Saudi Arabia)
ScienceDirect	blockchain AND investment, blockchain AND education, blockchain AND Saudi Arabia
Taylor & Francis Online	[All: blockchain] AND [All: investment], [All: blockchain] AND [All: education], [All: blockchain] AND Saudi Arabia]
SAGE Journals	[All blockchain] AND [All investment], [All blockchain] AND [All education], [All blockchain] AND Saudi Arabia]
ProQuest	blockchain AND investment, blockchain AND education, blockchain AND Saudi Arabia
Springer	blockchain AND investment, blockchain AND education, blockchain AND Saudi Arabia
Web of Science	TOPIC: (blockchain) AND TOPIC: (investment), TOPIC: (blockchain) AND TOPIC: (education), TOPIC: (blockchain) AND TOPIC: (Saudi Arabia)
Scopus	(TITLE-ABS-KEY (blockchain) AND TITLE-ABS-KEY (investment)), (TITLE-ABS-KEY (blockchain) AND TITLE-ABS-KEY (education)), (TITLE-ABS-KEY (blockchain) AND TITLE-ABS-KEY (Saudi Arabia))

distinguished by its religious, linguistic, and social homogeneity. When it comes to technological development and adoption, Middle East countries have their own set of socioeconomic factors. These traits either help or hinder the adoption and growth of information technology in the region (Jafar, 2004). This is because the Middle East region encompasses both impoverished and underdeveloped economies with enormous populations, such as Egypt. There are also rich and sparsely populated countries like United Arab Emirates, Kuwait, Qatar, and Saudi Arabia.

The Middle East region is also known for its volatile and unpredictable environments (Aghimien, 2016; Niazi and Hassan, 2016). Only a few Middle Eastern countries inspire business investments, particularly in technology—for instance, Jordan is one of the safest and most attractive destinations for such investments (Moideenkutty et al., 2016; Sharma et al., 2017). The unique regional context of the Middle East region presents a challenge for the current study to investigate the opportunities associated with blockchain technology, especially in the education sector of Saudi Arabia which experiences continuous socio-economic transformation and sustainable development.

The body of knowledge on the problems and potentials of technological acceptance, implementation, and development in the Middle East region is quickly expanding. Certain studies explored the Arab world's pioneering government systems (Pons, 2004; AlAwadhi and Morris, 2012), especially in Dubai and Jordan (Awan, 2008). Other studies looked into e-banking adoption and implementation in Oman (Khalfan and Alshawaf, 2004), Lebanon (Hammoud et al., 2018), and Jordan (AbuShanab and Pearson, 2007). Furthermore, several other studies focused on computing in the Middle East (Goodman and Green, 1998); the culture of Arab and information technology transfer (Hill et al., 1998; Straub et al., 2001); the efficacy of information systems in countries like Egypt (Khalil and Elkordy, 1999; Seliem et al., 2003) and Saudi Arabia (Al-Khaldi and Wallace, 1999); and the applicability of technology acceptance in the Arab world (Al-Gahtani, 2001), such as Kuwait (Almutairi, 2007). A few other studies explored specific topics on health information technology in the Middle East (Bennett et al., 2015) and internet fraud in Saudi Arabia (Algarni, 2013).

Although blockchain technology offers enormous potential for building the future of Internet infrastructure and smart transactions or contracts, the technology also encounters several technical (Beck et al., 2018) and social hurdles (Zheng et al., 2018). A substantial body of literature revealed the challenges of blockchain at various levels, which include obstacles for enterprises (Hamida et al., 2017), business process management (Mendling et al., 2017), logistics and supply chain (Hackius and Petersen, 2017), and educational systems (Grech and Camilleri, 2017; Chen et al., 2018).

At the same time, only a few studies explored the societal issues and potentials presented by blockchains such as the benefits of blockchain technologies to the developing world's population (Kshetri and Voas, 2018), the emergence of blockchain as a tool to alleviate poverty in the Global South (Kshetri, 2017), and global blockchain initiatives, such as Sweden, Denmark, Malta, United States, United Kingdom, China, and Australia (Ojo and Adebayo, 2017; Jun, 2018).

On the other hand, there is a growing body of literature on the adoption, implementation, and development of blockchain technology in Middle Eastern countries (Jafar, 2004). Prior studies covered the instigation of e-government systems (Pons, 2004; Awan, 2008; AlAwadhi and Morris, 2012), the adoption and implementation of e-banking systems (Khalfan and Alshawaf, 2004; AbuShanab and Pearson, 2007; Hammoud et al., 2018), computing and information technology transfer (Goodman and Green, 1998; Hill et al., 1998; Straub et al., 2001), and the effectiveness of information systems in the regions (Al-Khaldi and Wallace, 1999; Khalil and Elkordy, 1999; Seliem et al., 2003).

More importantly, education has the potential to play a vital role in the future realisation of a vision of sustainability that integrates economic well-being with respect for cultural variety, the Earth, and its resources (Little and Green, 2009). This is recognised at the second World Summit on Sustainable Development in Johannesburg in 2002 (UNESCO, 2007). Following that, the United Nations General Assembly passed Resolution 57/254, designating the years 2005–2014 as the International Decade for Education for Sustainable Development (ESD). The overall goal of the ESD is to integrate values, activities, and principles that are inherently linked to sustainable development into all forms of education and learning, as well as to help usher in a change in attitudes, behaviours, and values that will ensure a more sustainable future in terms of social, environmental, and economic terms.

Education for Sustainable Development (ESD) is essentially a demand for a shift in how we educate our children and ourselves to ensure a long-term future. While governments and stakeholders are already interpreting this appeal in a variety of ways, UNESCO describes ESD as a development project with four goals and four thrusts. The goals are to facilitate ESD stakeholders' networking, linkages, exchange, and interaction; foster improved teaching and learning in education for sustainable development; assist countries in making progress towards and achieving the Millennium Development Goals through ESD efforts; and provide countries with new opportunities to incorporate ESD into education reform efforts (UNESCO, 2007, p. 6).

Nonetheless, only a few studies explored the role of blockchain technology in the education sector of Saudi Arabia. Thus, the current study focused on the difficulties and prospects of blockchain technology in the education sector for its sustainable development. With that, a substantial literature search related to the investment opportunity of blockchain technology in the education sector of Saudi Arabia was

conducted. But it is crucial to keep in mind that the use of blockchain in education is still a relatively new topic, which has an impact on the quantity and calibre of the study done on it.

Although the amount of research on blockchain's potential applications in education has grown recently, it is still dispersed, and no thorough investigation of the topic has yet been conducted (Chivu et al., 2022). The blockchain technology of today might not be sufficiently advanced to scale for all use cases. This is especially concerning for use scenarios involving educational platforms such as blockchain record-keeping or digital asset use cases. Many of the most significant blockchain-in-education projects have yet to be extensively studied and recorded due to the relative youth of blockchain investigation in the education sector. Hence, this study implies that investigating the role of blockchain-related education for sustainable development is considered timely and important.

Overall, this article is organised into several sub-topics. It begins with an overview of related literature and a conceptual discussion on blockchain technology. This is followed by a description of the methodology, which includes defining the research questions, searching for relevant articles, inclusion and exclusion of articles, data extraction, and data analysis. The findings are then presented in the form of a related literature review, followed by a discussion with respect to the research questions. Areas for future research and limitations of the study are discussed accordingly. Finally, the analysis of challenges and opportunities of blockchain technology in the education sector of Saudi Arabia are outlined as key conclusions.

Educational literature review on blockchain technology

Since its emergence in 2008, blockchain technology has developed into several stages, namely Blockchain 1.0, Blockchain 2.0, and Blockchain 3.0 (Gatteschi et al., 2018). The first stage, which was designed to ease simple monetary transactions, was utilised for cryptocurrencies. Following that, the second stage was introduced for properties and smart contracts. Prior to being registered in the blockchain, these smart contracts would impose precise rules and criteria that must be followed. The registration process can be completed without the involvement of a third party. The third stage involves the development of many applications of blockchains in numerous sectors, including but not limited to government, education, health, and science.

Meanwhile, the application of blockchain in the education sector is still in its infancy. Only a few educational institutions use blockchain technology to validate and share academic certifications and/or learning outcomes of students (Chen et al., 2018). Therefore, blockchain technology has so much more to offer and has the potential to transform the education sector and its sustainable development. Nespor (2019) believed that blockchain potentially erodes the central position of educational institutions as certification agencies, giving students more responsibilities to study. Despite the growing number of studies on the application of blockchain in the education sector in recent years, findings are still fragmented. A systematic review on this subject, especially within the context of Saudi Arabia, has remained scarce. This type of review is deemed critical, especially in providing a current state-of-the-art overview of the topic and informing evidence-based practices.

As a result, by studying the use of blockchain technology in the education sector and its sustainable development, the current study offered novel contributions to the literature on educational technology. The main target audiences of this study are those who are interested in learning about this developing technology and its significant impact on the education sector such as managers, policymakers, academics, and researchers. The remaining sections of this paper are organised in the following manner. The subsequent section describes the systematic review techniques used in this study. The review's findings are presented in Section "Research methodology," and Section "Descriptive results" further discusses the results in detail. Section "Discussion and analysis" presents areas for future research. The limitations of the review are discussed in Section "Future research agenda." Finally, Section "Conclusion and limitations" concludes the overall review.

Research methodology

There was extensive literature available on blockchain technology. In this systematic literature review, this study adopted the guidelines established by Okoli and Schabram (2010). The established guidelines for conducting a systematic review consist of the following eight steps, which are further discussed in the next subsections:

1. **Identify the review's goal and research questions.** This step is required to ensure a clear systematic review for readers. Furthermore, well-formulated research questions can improve the effectiveness of a systematic review and reduces the time and cost of locating relevant publications.
2. **Create a detailed review protocol and instruct all reviewers on how to follow the protocol.** A protocol is a detailed strategy that outlines the stages and procedures to be followed during the evaluation. This phase is critical to ensure that reviewers understand and follow the specific protocol.
3. **Search for relevant articles.** Relying on electronic resources is now the most common way to look for

relevant literature. Most of the published studies are available in electronic databases, such as IEEE Xplore and ProQuest. However, to successfully search these databases, reviewers must learn how to use Boolean operators correctly.

4. **Screen articles for inclusion.** In this step, reviewers decide which articles should be accepted for review and which articles should be rejected. They must also clarify the practical grounds for the exclusion of each article.
5. **Examine the articles for quality.** In this stage, reviewers must decide which articles are of sufficient quality to be included in the systematic review. By doing this step, reviewers accomplish two goals. First, a quality appraisal removes any publications that do not satisfy the reviewers' criteria in a systematic review, with a minimum quality level for inclusion. Second, a systematic review requires some forms of quality assessment, as the quality of the review is largely determined by the quality of the articles included.
6. **Extract data from articles.** Reviewers must extract the necessary data from each article in a methodical manner after they identify all articles for the review. Reviewers use the data as the starting point for the synthesis stage. The type of data to be extracted is determined by the research questions created early in the review process.
7. **Analyse the extracted data.** This process, which is also known as data synthesis, entails gathering, organising, comparing, and debating the data extracted from the gathered articles. The approach used in this step varies, depending on whether the approach is used in the studies (e.g., qualitative, quantitative, or mixed-methods approach). All qualitative, quantitative, and mixed-methods studies can be analysed qualitatively, but only quantitative studies can be examined quantitatively.
8. **Write the systematic review.** The standard guidelines for writing a systematic review should be applied in this step. The systematic review should be presented in sufficient detail, such that the results may be replicated independently.

A systematic literature review (SLR) focuses on existing publications and employs a systematic approach to synthesise the data. It is a high-objectivity review of an existing body of literature that follows a clear and reproducible technique in searching, assessing, and synthesising it. In line with added that a systematic literature reviews provide high-quality evidence and are the most efficient approach for locating and assessing large amounts of information. Hence, this study employed the SLR method to meet the objectives of the study.

Defining the research questions

The following research questions were developed based on the objectives of the study:

1. What are the types of educational applications in Saudi Arabia that are built using blockchain technology?
2. What are the benefits of blockchain technology for the education and sustainable development sector of Saudi Arabia?
3. What are the challenges of implementing blockchain technology in the education sector of Saudi Arabia?
4. What are the types of blockchain technologies that can be invested in the education sector of Saudi Arabia for its sustainable development?

Searching for relevant articles

In this systematic review, nine significant scientific databases were examined to identify relevant publications on the topic under study: (1) ACM Digital Library, (2) IEEE Xplore, (3) ScienceDirect, (4) Taylor & Francis Online, (5) SAGE Journals, (6) ProQuest, (7) Springer, (8) Web of Science, and (9) Scopus. These nine databases were used because these databases are notable for indexing high-impact, high-quality educational and information technology content. For this systematic review, the most recent literature search took place at the end of June 2021.

For the execution of the search for relevant articles in the listed databases, the following specific terms were used: "Blockchain AND Investment," "Blockchain AND Education," and "Blockchain and Saudi Arabia." However, as each database has its unique search syntax, query strings were created for each database separately. **Table 2** presents the adapted query strings.

Inclusion and exclusion of articles

For this step, the titles and abstracts of the obtained articles were assessed using the predefined criteria for the purpose of inclusion and exclusion of articles. First, there were four criteria for the exclusion of articles in this study: (1) non-English article; (2) no online full text; (3) it does not present a blockchain application in education; and (4) the application is not practical (in the forms of opinions or viewpoints). The remaining articles were imported into EndNote, and the duplicates were removed. Finally, the full text of each article was evaluated to ensure that the article had all data needed for this systematic review.

A quality assessment was conducted for this systematic review. The quality of the review was ensured by relying on

these scientific databases as the primary source for locating relevant publications. Only peer-reviewed articles published by prominent publishers were included in the systematic review. With that, the study was able to include articles of excellent quality for review.

Data extraction

Data from the included articles were then extracted using a data extraction form. The form was specifically created for this systematic review and tested on a group of four publications. Table 3 lists all 11 points considered for data extraction.

Data analysis

Once the data from the articles were extracted, data analysis was carried out. With respect to the research questions, key themes were used to analyse the extracted data. The themes included application, benefits, problems, and future application areas. Additionally, several subthemes of each key theme were developed.

Descriptive results

Systematic review process

From the above-mentioned nine scientific databases, a total of 1,342 articles were found: (1) 53 articles from ACM Digital Library; (2) 270 articles from IEEE Xplore; (3) 60 articles from ScienceDirect; (4) 23 articles from Taylor & Francis Online; (5) 64 articles from SAGE Journals; (6) 76 articles from ProQuest; (7) 87 articles from Springer; (8) 354 articles from Web of Science; and (9) 355 articles from Scopus.

TABLE 3 Form of data extraction items.

Data items	Descriptions
Title	The title of the article
Author(s)	The name(s) of author(s)
Type	For example, conference, workshop, or journal
Date	The year in which the article was published
Country	Home country of author(s)
Aim of the application	The objective(s) of the application as stated by the authors
Implementation of the application	A summary of the application's implementation
Benefits	Potential or actual benefits of the application
Challenges	Potential or actual challenges of using the application
Future areas	Areas of future research
Comments	The remark about the quality of the article

Based on the title and abstract, the initial screening resulted in the elimination of 1,118 articles. Most of these articles were excluded because these studies did not demonstrate blockchain-based educational applications. In the second stage, another 175 articles were omitted due to the impractical nature of the applications (in the form of opinions or viewpoints). Finally, the remaining 49 articles were examined, and 29 duplicated articles were excluded. As a result, only 20 articles remained and were used for further analysis in this systematic review.

Following that, five more articles were removed during the full-text reading. These articles were eliminated because these articles did not provide sufficient data related to the topic under study. Conclusively, 15 articles were found to be suitable for this systematic review and were included for data extraction. Figure 1 shows the flowchart of the systematic review process in the search and extraction of relevant articles for the study.

Literature review matrix

A total of 15 articles were included in the systematic review. The articles are listed according to the year of publication, as follows: (1) Grech and Camilleri (2017); (2) Hamida et al. (2017); (3) Ojo and Adebayo (2017); (4) AlSubaei (2019); (5) Chen et al. (2018); (6) Kshetri and Voas (2018); (7) Zheng et al. (2018); (8) Al-Otaibi et al. (2019); (9) Ghazawneh (2019); (10) Khan et al. (2019); (11) Alam and Benaida (2020); (12) Anisiuba (2020); (13) Asiri (2020); (14) Fedorova and Skobleva (2020); and (15) Ma and Fang (2020) (**Table 4**).

Distribution of articles by year of publication

Figure 2 shows the distribution of articles by year of publication. All included articles for review were published during the recent 5 years. In general, there was no significant increase in the number of publications. In 2017, only three articles were published, and the number of articles slightly increased in 2018 and 2020. The number of articles remained the same in 2019. Overall, the distribution of articles by year of publication is as follows: three articles (20%) in 2017; four articles (27%) in 2018; three articles (20%) in 2019; and five articles (33%) in 2020.

It is worth noting that three other articles were included in this systematic review, but not presented in Figure 2 as these articles were published in the first 6 months of 2021 when the data collection for the study was concluded. This is because it does not reflect an accurate picture of the entire year 2021.

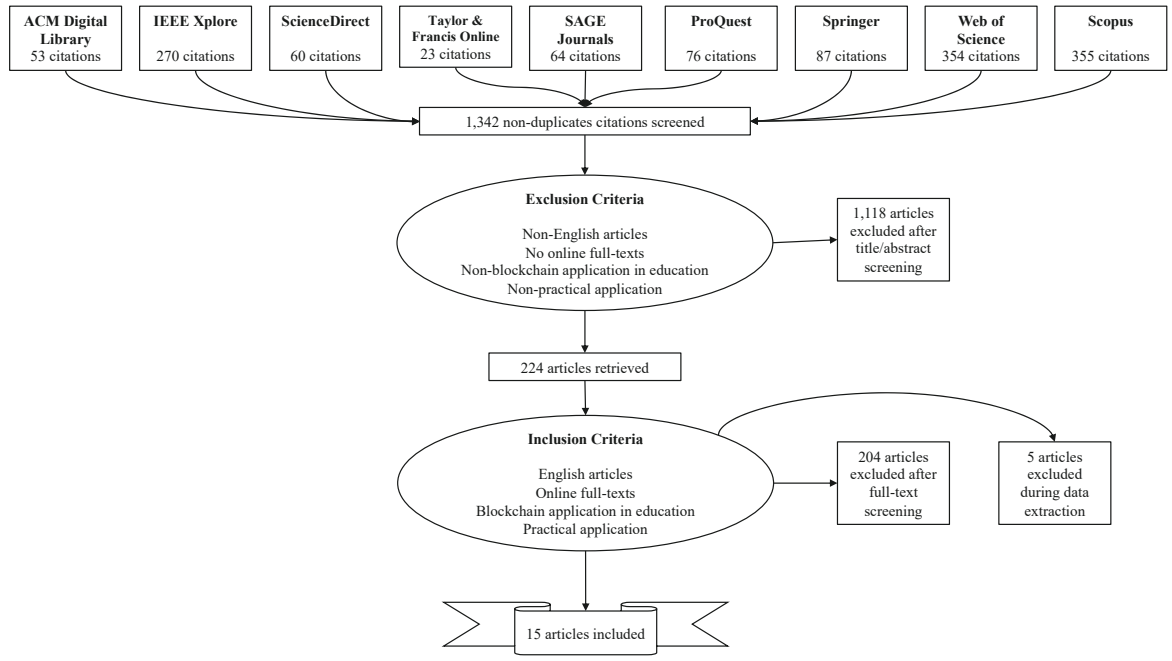

FIGURE 1
Flowchart of the systematic review process.

Publication venue

Figure 3 depicts the distribution of articles by publication venue. Out of 15 articles, eight articles (53%) were published in journals, and three articles (20%) were published in conference proceedings. The remaining articles were published in books (n = 2, 13%), policy papers (n = 1, 7%), and dissertations (n = 1, 7%).

Applications of blockchain technology in education

Previous studies revealed the development of several blockchain applications in education. For this systematic review, these applications were categorised into seven categories: (1) managing educational certificates; (2) handling financial transactions; (3) designing smart contracts; (4) establishing blockchain ecosystems; (5) creating an LMS; (6) transforming students' records; and (7) tracking learning performance. **Table 5** presents the seven applications of blockchain technology in education.

As presented in **Table 5**, some classifications of the articles fall into different categories. The gathered articles revealed that most of the applications were geared towards the category of managing educational certificates. For instance, Grech and Camilleri (2017) reported ways of verifying students' diplomas and professional certificates. Chen et al. (2018) and Kshetri and Voas (2018) used blockchain technology for academic degree management. Furthermore, Ma and Fang (2020) described certificate management in higher learning institutions. Similarly, Fedorova and Skobleva (2020) explained diploma certificates, while Asiri (2020) discussed the distribution of educational certificates.

In terms of handling financial transactions using blockchain technology, Grech and Camilleri (2017) noted student payment, while Kshetri and Voas (2018) focused on students' financial transactions. Besides that, Alam and Benaida (2020) included student loans in the application of blockchain technology in the educational sector. Furthermore, Hamida et al. (2017), Ojo and Adebayo (2017), Zheng et al. (2018), and Al-Otaibi et al. (2019) also promoted the use of smart contracts in the management of higher education institutions.

Apart from that, blockchain technology can be used to establish blockchain ecosystems (Ojo and Adebayo, 2017; Zheng et al., 2018; Ghazawneh, 2019) and create an LMS (Khan et al., 2019; Alam and Benaida, 2020; Fedorova and Skobleva, 2020; Ma and Fang, 2020). These applications include but are not limited to teaching educational courses, massive open online courses, teaching and learning platforms, and the online educational market. Finally, blockchain technology in the educational sector can be used to transform students' records (Ma and Fang, 2020) and track their learning performance (Chen et al., 2018; Anisiuba, 2020) such as learning record keeper,

TABLE 4 An overview of literature review matrix.

Sources	Descriptions
Grech and Camilleri, 2017	*Publication Type*: Policy report *Research Objective*: Focusing on the potential of blockchain technology in the education sector, this study introduced the essential principles of blockchain. The study demonstrated how the technology has the potential to both disrupt and empower learners. Based on the present state of technological development and deployment, the study proposed eight scenarios for the use of blockchain in the education sector. *Research Method*: Qualitative methods using literature review, desk research, and interviews *Key Findings*: Blockchain applications in the education sector are still in their infancy, but they are gradually gaining traction. However, it is important to note that blockchain has the potential to disrupt the student information system market and weaken the grip that present competitors have on the sector. Although many of the uses of blockchain technology are still to be envisaged, the study believed that the following areas in the education sector are most likely to be impacted by blockchain adoption in the near future: The end of a paper-based certificate system will be hastened by blockchain technology. Users can use blockchain technology to automatically check the authenticity of certificates against the blockchain without having to contact the organisation that originally issued them. The ability of blockchain technology to develop data management structures that give users more ownership and control over their own data might greatly reduce data management costs and liability risk as a result of data management concerns for educational institutions. Some institutions are likely to employ blockchain-based cryptocurrencies to facilitate payments.
Hamida et al., 2017	*Publication Type*: Conference paper *Research Objective*: The study examined enterprise Blockchains in-depth, including their key components, technologies, and applications. The obstacles and opportunities for research were also highlighted. *Research Method:* Qualitative method using literature search *Key Findings*: In the near future, blockchain technology will represent a huge paradigm shift in how business apps are built, managed, consumed, and marketed. The study examined the technical aspects of this technology and gave a taxonomy of applications and cases. Finally, the study discussed the significant difficulties that must be overcome before reaching mass-market adoption, such as governance, audit, scalability, incentives, data privacy, security, and data analytics.
Ojo and Adebayo, 2017	*Publication Type*: Book chapter *Research Objective*: The study provided a brief history of the new technology and examined the major blockchain-related efforts of Digital 5 (D5) countries. The book chapter ended with policymakers' recommendations on emergent governance concerns that need to be investigated to fully realise the potential of blockchain technology in public administration and government. *Research Method*: Qualitative method using cases studies *Key Findings*: The book chapter explicitly addressed the paucity of research materials on the implementation of blockchain and distributed ledger technologies in the government domain. Several projects in the D5 countries were explored, where the government took on diverse roles in blockchain initiatives. Although several of these projects showed considerable promise, the majority of them are still in the early stages of implementation. At the same time, a variety of legal, regulatory, ethical, and technical constraints must be overcome to fully exploit the potentials of blockchain and distributed ledger technology in the government.
AlSubaei, 2019	*Publication Type*: Policy paper *Research Objective*: This study compared the current trends in blockchain adoption in the Gulf states to provide light on the use of blockchain technology in these Gulf nations. This study also examined the ability of Gulf institutions to keep up with the changes and advances brought about by blockchain adoption. *Research Method*: Qualitative method using literature review *Key Findings*: Many Gulf state institutions still lack public plans for putting blockchain technology into practice. They must continue to investigate and keep up with international blockchain usage in their sectors. Gulf states should undertake the following to encourage blockchain usage even more: Define how blockchain systems work on a practical level and why blockchain adoption can improve developmental, innovative, and competitive capabilities while reducing and simplifying operational procedures Encourage all public and private sector entities to collaborate on studying the development-specific benefits gained from using the technology and its capabilities and systems to lay the foundation for the blockchain transformation, particularly among countries that have yet to establish a national committee or strategy for utilising the technology
Chen et al., 2018	*Publication Type*: Research paper *Research Objective*: The study focused on the possible educational uses of blockchain technology and looked at how the technology can be utilised to tackle specific educational issues. The features and benefits of blockchain technology were first explained in the article, which was followed by an examination of some of the current blockchain applications for education. Some novel applications of blockchain technology as well as the advantages and drawbacks of adopting blockchain technology in education were offered. *Research Method*: Qualitative method using literature review *Key Findings*: Decentralisation, traceability, immutability, and monetary qualities are all features of blockchain. It is essentially a distributed ledger technology that uses cryptography techniques and distributed consensus algorithms. Its currency features can lead to a slew of new educational uses. Blockchain technology, for example, can boost student motivation by recognising that "learning is earning." In a nutshell, blockchain offers significant potential for both learners and teachers in terms of instructional design, behaviour recording and analysis, and formative evaluation. At the same time, it presents researchers, developers, and educators with both obstacles and opportunities.
Kshetri and Voas, 2018	*Publication Type*: Research paper *Research Objective*: Blockchain has the potential to benefit a substantial section of the developing world's population. The study explored and evaluated the potential role of blockchain in addressing fundamental institutional issues in the developing world. *Research Method*: Qualitative method using literature review *Key Findings*: Blockchain contributes a good impact on developing countries: technology can help minimise fraud and corruption while increasing legal property rights and allowing the world's poorest to start businesses. It can also speed up financial transactions and ensure that aid can be given with lower risks of theft and fraud.

(Continued)

TABLE 4 (Continued)

Sources	Descriptions
Zheng et al., 2018	*Publication Type*: Research paper *Research Objective*: Although several prior studies focused on various applications of blockchain technology, the study noted that there is yet to be a complete review of the technology from both technological and application standpoints. To close this gap, the study conducted a comprehensive blockchain technology survey. In particular, the study explained the blockchain taxonomy, explored common blockchain consensus algorithms, reviewed blockchain applications, and discussed technical obstacles as well as recent progress in addressing the challenges. Furthermore, this study discussed the future directions of blockchain technology. *Research Method*: Qualitative method using survey analysis *Key Findings*: Due to its decentralised infrastructure and peer-to-peer nature, blockchain is highly regarded and approved. Bitcoin, on the other hand, protects the process of blockchain in many ways. However, blockchain can be used in a multitude of sectors, apart from Bitcoin. With its main qualities of decentralisation, persistency, anonymity, and auditability, blockchain has proved its potential to revolutionise traditional industries.
Al-Otaibi et al., 2019	*Publication Type*: Research paper *Research Objective*: The study reviewed blockchain research during the last 4 years, from 2015 to 2018. The consequences of this new blockchain technology in the Kingdom of Saudi Arabia were discussed. The study also presented recommendations for future blockchain technology research in Saudi Arabia. *Research Method*: Qualitative method using literature review *Key Findings*: Overall, blockchain technology is undoubtedly recognised. The study covered all facets of the blockchain's structure as well as the mechanics that make it works. The forms of blockchain were also discussed in terms of some of the consensus algorithms utilised in blockchain, which were separated into two categories: evidence-based consensus and voting-based consensus. Based on the properties of the blockchain and peer-to-peer decentralisation, the study addressed how to implement and develop blockchain in the Kingdom of Saudi Arabia based on the two most important applications of blockchain, namely Bitcoin and smart contracts. This decentralised feature was highlighted as a huge and fantastic power to conduct various operations for a large number of users. It is exactly what the study intended to provide for processing in KSA institutions.
Ghazawneh, 2019	*Publication Type*: Conference paper *Research Objective*: The study synthesised blockchain technology and IT using a multiple case study of 21 enterprises from six different Middle Eastern nations to understand the difficulties and prospects of that technology in the Middle East region. *Research Method*: Qualitative case study and literature review *Key Findings*: The study identified four types of difficulties and opportunities: fine-tune challenges, alienation challenges, sprint opportunities, and act on opportunities, as well as four elements that influence them: regulation, education, teamwork, and culture. The study contributed to the IT literature in the Middle East region by extending and complementing previous blockchain studies.
Khan et al., 2019	*Publication Type*: Research paper *Research Objective*: The study aimed to shed light on the database distribution and security challenges of a learning management system (LMS). The study explained the fundamental principles underpinning the practices and legislations to determine their provision and limitations for privacy and security, as well as the more stringent security measures that a distributed database system should consider over a centralised system in LMS. *Research Method*: Qualitative literature review analysis *Key Findings*: Blockchain technology, according to the study, is an investigation of distribution data handling and drive, a new form of decentralised application. It enables highly secure data transfer in LMS.
Alam and Benaida, 2020	*Publication Type*: Research paper *Research Objective*: The study aimed to link an educational system that incorporates blockchain to the internet of things (IoT) or keep things cryptographically secure on the Internet. This study combined its upgraded blockchain and IoT technologies to provide an efficient online interaction system for students, professors, employers, developers, facilitators, and accreditors. This defined framework served as a wonderful estimate of extensive investigation. *Research Method*: Qualitative literature review analysis *Key Findings*: This study linked blockchain and IoT to the educational system by making use of blockchain and IoT technologies. For the educational system, the study proposed a mix of IoT and blockchain. To record the transactions, blockchain was employed to establish a hyper-distributed public authentic ledger.
Anisiuba, 2020	*Publication Type*: Conference paper *Research Objective*: Through qualitative surveys and analysis, this study aimed to investigate Blockchain technology and its potential for sustainable growth in the educational sector. *Research Method*: Qualitative survey and analysis *Key Findings*: Blockchain technology has moved much beyond the abovementioned usefulness and has evolved into a new manner of solving problems in the fields of record-keeping, verification, tracking, and information aggregation. The technology is extremely useful in the education sector because it allows for secure data storage on a blockchain network, which can drastically minimise risks and information-sharing. In the educational sector, blockchain technology solves several difficulties, such as an insecure system, manual document filing that takes time and sometimes results in duplication of information, inaccurate information-sharing, and vulnerability to identity mismanagement and theft. The technology also helps to make data more accessible in real-time than a centralised database and reduces the cost of data hosting infrastructure.
Asiri, 2020	*Publication Type*: Master's thesis *Research Objective*: This study aimed to explore how alternative technologies can help Florida Institute of Technology students and faculty deal with their problems, as well as whether they support the introduction of blockchain technology. This study explored the difficulties of using Blockchain technology to issue and verify academic records, certificates, and diplomas for students and teachers at the Florida Institute of Technology. *Research Method*: Mixed methods of survey and interview *Key Findings*: Institutions may find it challenging to adopt blockchain technology, which incurs additional expenditures, but it offers additional security for the students' documents. Even if the long-term persistence features of blockchain technology remain unknown based on many years of experience, which can limit user trust, the study discovered that the majority of potential users are optimistic about the potential of the technology.

(Continued)

TABLE 4 (Continued)

Sources	Descriptions
Fedorova and Skobleva, 2020	*Publication Type*: Research paper *Research Objective*: This study provided a critical examination of blockchain technology's uses in education, focusing on its applicability prospects and limitations, as well as the repercussions of its influence on educational development. The study examined real-world applications of this technology, using the Massachusetts Institute of Technology (MIT) as an example. Blockchain technology was used by MIT to secure and validate the certificates issued. *Research Method*: Qualitative systematic review *Key Findings*: Based on the findings of research and projects related to blockchain technology in higher education, it is deemed feasible to infer that this new technology is gaining traction and dominating the educational landscape. Its application transforms the concept of student-professor contact, making education more accessible and individualised. A personal plan targeted at lifelong education has become necessary in recent years, and blockchain technology provides the resources needed to make this a reality. At the same time, blockchain technology has the potential to create inequalities in access to online and offline schooling. It is worth noting that most colleges that have created educational blockchain technologies are still using them as a supplement to the traditional modes of instruction.
Ma and Fang, 2020	*Publication Type*: Research paper *Research Objective*: This study provided a brief overview of the most common blockchain approaches and characteristics. Following that, recent blockchain applications in education were extensively discussed, with a focus on learning record keeper, certificate issuing and management, and a decentralised education ecosystem. Finally, a discussion of technical and non-technical difficulties was presented. *Research Method*: Qualitative literature review *Key Findings*: Blockchain is thought to have significant potential to bring a wide range of benefits to educational development due to its unique properties of decentralisation and security. Its use in education is still relatively young, but it is growing rapidly. It is envisaged that this study provided an in-depth look at the potential of blockchain in expanding the education and development of new application platforms.

evaluation of learning outcomes, and learning performance tracking.

Benefits of blockchain technology in education

The selected articles revealed five different benefits that blockchain technology provides for the education sector. Figure 4 shows the benefits of adopting blockchain technology in the education sector. The *first* advantage is associated with authentication, which was mentioned in eight articles (53%) as a key benefit of incorporating blockchain technology into education. According to these articles, blockchain technology can be highly valuable in certifying students' identities and their digital certificates. The *second* important advantage of blockchain in the education sector is that it allows for more control over student evaluations. Seven articles (47%) stressed the benefit in which blockchain technology can improve the way students' learning outcomes and performance are assessed.

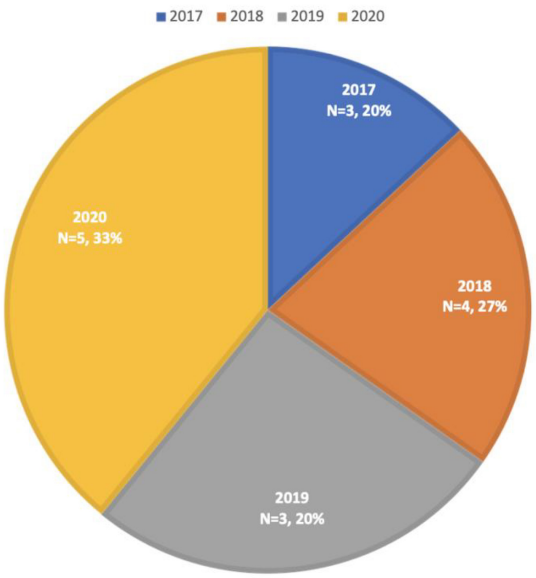

FIGURE 2
Distribution of articles by year of publication.

Furthermore, improving the efficiency of data sharing and maintenance of student records is the *third* benefit, which was reported in five articles (33%). Enhancing trust is the *fourth* benefit that blockchain technology can offer to the education sector. Five articles (33%) described that blockchain technology can build confidence among all parties involved and make communication easier. Finally, the *fifth* advantage of using blockchain in education is that it reduces costs. This benefit was mentioned in three articles (20%), which described that blockchain technology can naturally assist in eliminating the excessive costs connected with data transactions and storage.

Challenges of blockchain technology in education

The reviewed articles emphasised four main challenges of adopting blockchain technology in education, which are depicted in Figure 5. The *first* challenge is related to the privacy and security of blockchain. Nine articles (60%) highlighted malicious attacks and data leaking, which are the most common examples of security and privacy risks that potentially arise when blockchain technology is used. The expense of

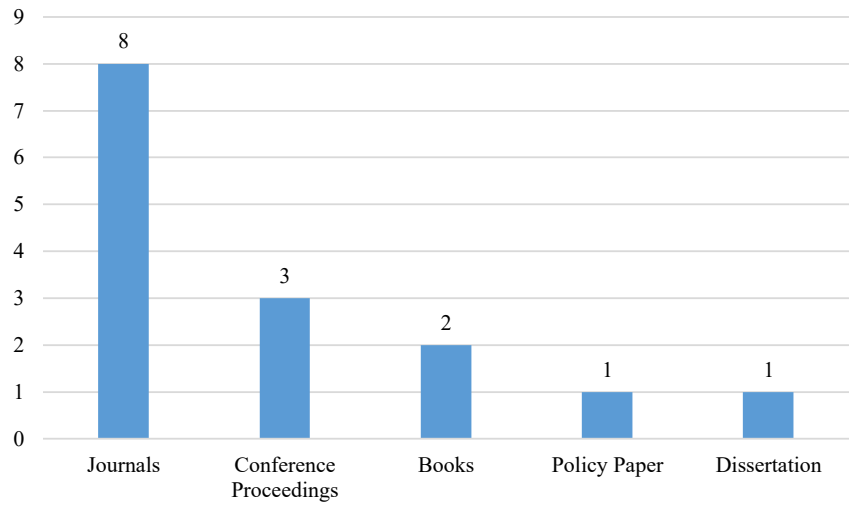

FIGURE 3
Distribution of articles by publication venue.

implementing blockchain technology in education is the *second* main challenge. Seven articles (47%) addressed this issue from various perspectives, including the cost of processing power, the cost of altering current infrastructure, the cost of time due to slow-moving transactions, and the cost of managing a large amount of data.

TABLE 5 The seven applications of blockchain technology in education.

No.	Categories of applications	Articles
1	Managing educational certificates	Grech and Camilleri, 2017; Chen et al., 2018; Kshetri and Voas, 2018; Asiri, 2020; Fedorova and Skobleva, 2020; Ma and Fang, 2020
2	Handling financial transactions	Grech and Camilleri, 2017; Kshetri and Voas, 2018; Alam and Benaida, 2020
3	Designing smart contracts	Hamida et al., 2017; Ojo and Adebayo, 2017; Zheng et al., 2018; Al-Otaibi et al., 2019
4	Establishing blockchain ecosystems	Ojo and Adebayo, 2017; Zheng et al., 2018; Ghazawneh, 2019
5	Creating an LMS	Khan et al., 2019; Alam and Benaida, 2020; Fedorova and Skobleva, 2020; Ma and Fang, 2020
6	Transforming students' records	Ma and Fang, 2020; Anisiuba, 2020
7	Tracking learning performance	Chen et al., 2018; Anisiuba, 2020

Additionally, setting the boundaries of blockchain technology adoption is the *third* main challenge, which was mentioned in four articles (27%). These studies highlighted that educational institutions may have difficulty deciding which data and services should be made available over the blockchain network. Lastly, the *fourth* challenge is related to the weakening of the significance of traditional school credentials. According to one of the studies (7%), blockchain technology allows students to function as their own registrar of educational achievements; thereby, undermining the central role of educational institutions as certification agents.

Discussion and analysis

As shown in this systematic review, the publication trend reflects the increased interest in the implementation of blockchain technology in the education sector. Nevertheless, considering the small number of gathered studies, more studies in this area are significantly required. Generally, the systematic review of 15 studies proved to be beneficial in answering all four research questions. The details of the discussion are presented in the following subsections.

What are the types of educational applications in Saudi Arabia that are built using blockchain technology?

Recently, a growing number of blockchain-based educational applications have been developed in Saudi Arabia. However, only a few applications have been released to the

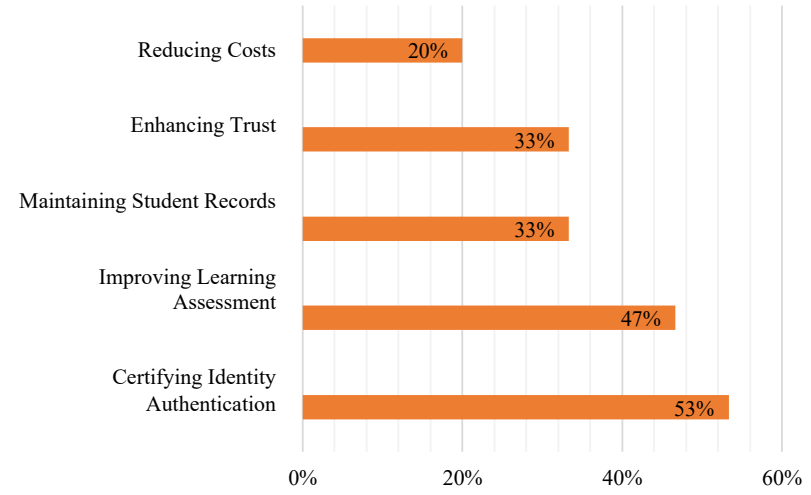

FIGURE 4
Benefits of adopting blockchain technology in education.

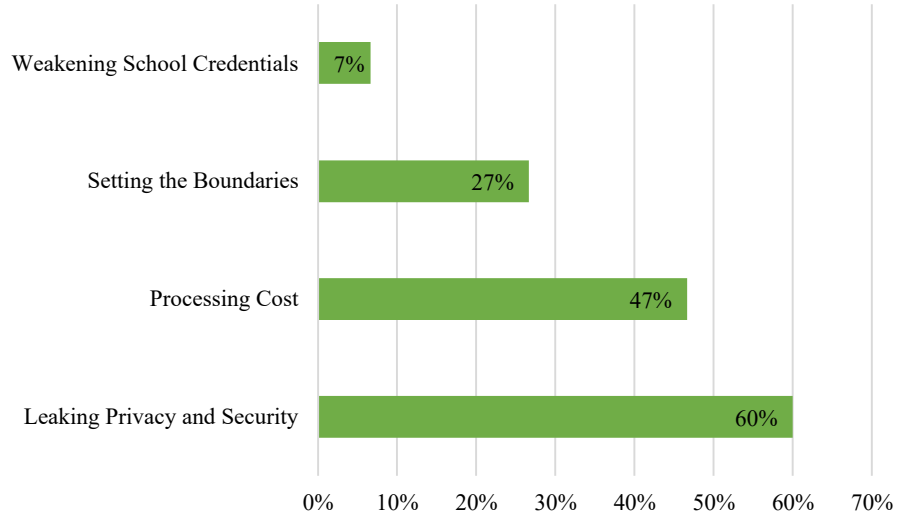

FIGURE 5
Challenges of adopting blockchain technology in education.

public (Hamida et al., 2017; Al-Otaibi et al., 2019; AlSubaei, 2019; Ghazawneh, 2019; Anisiuba, 2020; Asiri, 2020). As mentioned in the previous part of this systematic review, these applications are divided into seven different categories: (1) managing educational certificates; (2) handling financial transactions; (3) designing smart contracts; (4) establishing blockchain ecosystems; (5) creating an LMS; (6) transforming students' records; and (7) tracking learning performance. Each category focuses on different aspects of trust, privacy, or security in educational settings.

The *first* category focuses on certain certificate management-related applications. This category includes all types of academic credentials, transcripts, academic certificates, and other achievement records (Kshetri and Voas, 2018; Khan et al., 2019; Fedorova and Skobleva, 2020). Currently, blockchain has been used in many applications in the education sector to create digital certificates. Such high levels of trust and secrecy afforded by blockchain technology have improved the majority of these applications. Almost similarly, Nespor (2019) proposed a blockchain certification platform that rewards institutions for acting as certifying agents. This programme would allow higher education institutions or employers to issue official certificates to students while maintaining a high level of data protection. As a result, students can present certificates to anyone who needs the official documents. Likewise, Han et al. (2018) utilised the

decentralised nature of blockchain technology in the creation of new blockchain-based education records to check and provide authentic transcripts or certificates. Individuals may have access to their personal data records. Nevertheless, only certified organisations, under certain conditions and criteria, are allowed to access and edit the system's stored data.

Handling financial transactions falls into the *second* category. Considering the great security and trust of blockchain, it contains certain applications with similar qualities to transfer credential data or fees across institutions, corporations, or even universities (Chen et al., 2018; Zheng et al., 2018; Ma and Fang, 2020). Typically, educational institutions entrust the handling and approval of credit or fee transfers to a third party or intermediary. Due to its high-security level, blockchain may be utilised as an efficient way to share information and eliminate the need for third or intermediary parties. Similarly, the EduCTX system (Hölbl et al., 2018) used tokens to facilitate the transfer procedure. For learning units like certificates, courses, and diplomas, these tokens can take any digital form. Therefore, to ensure a secure transfer process, each educational institution has its own EduCTX address.

The *third* category of using the blockchain involves designing smart contracts, which is related to copyright management and ownership rights (Grech and Camilleri, 2017; Ojo and Adebayo, 2017; Fedorova and Skobleva, 2020). In line with that, Hori et al. (2018) explored the use of a decentralised learning system called "CHiLO" to preserve the copyrights and ownerships of e-books. Furthermore, protecting learning objects is another category that underlines the need of using the blockchain application to safeguard any new information or learning objects collected from students or faculty members. Furthermore, Sychov and Chirtsov (2018), for example, created a unified bank of learning elements that includes the electronic educational environment (EEE). As a resource protection approach is required due to the large number of resources available, the study deployed a legal blockchain method to preserve essential scientific resources.

The *fourth* category involves establishing blockchain ecosystems. For example, blockchain technology has been useful in boosting the components of lifelong learning, such as skills, knowledge, and efficiency (Ojo and Adebayo, 2017; Kshetri and Voas, 2018; Fedorova and Skobleva, 2020). In line with this, Mikroyannidis et al. (2018) discussed how blockchain technology has influenced real-world learning and presented an ecosystem that places learners at the centre of the learning process and data. The study also specifically noted how blockchain technology can be used to establish accreditation, tutoring, and ePortfolios within this lifelong learning ecosystem. By giving learners the entire control and ownership over their learning processes, the suggested model can help them create an effective strategy for their educational journey based on their desired career path.

Creating an LMS is the *fifth* category of application that embraces blockchain technology to solve various challenges related to students' interactivity in an e-learning environment (Khan et al., 2019). In this sense, Zhong et al. (2018) proposed a potential application based on the blockchain approach. This application was created to increase student involvement in the classroom. Based on specified regulations deployed on the blockchain network, top-ranked learners are awarded in the form of virtual money.

The *sixth* category is related to students' professionalism with the specific aim of transforming students' records (Zheng et al., 2018; AlSubaei, 2019; Asiri, 2020). In a different study, Liu et al. (2018) used blockchain technology to create a link between educational institutions and employment firms, allowing them to share all required information about recruiting and industry requirements. Similarly, Zhao et al. (2019) built a blockchain-based application software to evaluate students' professional talents based on their academic achievements and performances, which could subsequently be shared with any interested industry. Based on the blockchain's clustering algorithm, the evaluation system was created to measure and analyse students' talents.

Finally, the *seventh* category focuses on tracking learning performance. Building certain blockchain applications have received more attention to improve learning objectives and increase competency attainment within the educational scope (Grech and Camilleri, 2017; Al-Otaibi et al., 2019; Ghazawneh, 2019). This would serve to improve the learning process and broaden the scope of instructions. Several applications can measure and evaluate the performance of students based on qualitative and quantitative metrics due to the great efficiency of the blockchain. For example, Farah et al. (2018) developed a method to track students' multi-learning activity performance. The developed method accumulates all traces for each activity into a block on its own. This learning block is known as self-descriptive, as it contains all metadata for a variety of activities. Through this application, a high level of self-efficiency is achieved. Almost similarly, Williams (2019) offered a learning environment for students through another application. The system provides immediate or direct assistance as well as useful feedback. The study designed the system to improve the learning process by encouraging critical thinking and problem-solving, as well as better teamwork and communication.

What are the benefits of blockchain technology for the education and sustainable development sector of Saudi Arabia?

Education and sustainable development in Saudi Arabia can benefit greatly from blockchain technology in the following five areas: certifying identity authentication, improving learning

assessment, maintaining student records, enhancing trust, and reducing costs.

First, blockchain technology ensures the validity of digital certificates as well as the users' identities (Chen et al., 2018; Khan et al., 2019; Asiri, 2020). In line with that, Bandara et al. (2018) explained that the digital syllabus is stored in a blockchain. The constructed blocks are signed with a private key by the authorised university. Following that, a cryptographic hash of the course curriculum is issued to verify that the materials cannot be tampered with. The hash and key that belong to the originating institution are used by the university to authenticate the legitimacy of the data.

Second, improving learning assessment is one of the main features and benefits of the blockchain (Zheng et al., 2018; Fedorova and Skobleva, 2020; Ma and Fang, 2020). Many other studies support this assumption. Arenas and Fernandez (2018), for instance, presented an excellent example of how a permissioned blockchain platform can be utilised to limit access to academic credentials to only the intended participants. In line with that, Han et al. (2018) believed that only accredited organisations with certain permissions can access and modify the data stored on the blockchain platform. Furthermore, employing blockchain technology improves both accountability and transparency. Keeping all educational or school records in a single location, where they can be easily accessed, improves the accountability and openness of the application. Additionally, Bore et al. (2017) used the School Information Hub (SIH) system, which is built on a blockchain, to gather and store school reports and records. This technology was said to have aided in increasing the transparency of shared data as well as the flexibility of analysing, correlating, and disseminating the data.

Third, another significant advantage of blockchain technology is that it improves the efficiency of maintaining student records. The use of blockchain in education reduces the possibility of trade errors between intended parties (Ojo and Adebayo, 2017; Al-Otaibi et al., 2019; Anisiuba, 2020). Blockchain technology uses a single ledger to share data quicker and more efficiently. Due to its flexibility and openness, blockchain increases the effectiveness of handling digital records and certificates. Almost similarly, Gresch et al. (2018) presented "UZHBC," a blockchain system at the University of Zurich, which handles the degrees while taking into account many stakeholder requirements. Furthermore, educational institutions, students, and employment agencies can achieve efficiency and transparency in advising recommendations by exchanging student information using the blockchain system (Liu et al., 2018).

Fourth, another benefit of blockchain technology is the ability to enhance trust. Only trustworthy parties can add blocks to the network, and only trusted parties can access the network (Grech and Camilleri, 2017; Kshetri and Voas, 2018; Asiri, 2020). Trust is a major challenge when one is required to interact with officials from several places. By deploying secure and dependable blockchain-based solutions, universities and other educational institutions can create a trustworthy community. In another study, Turkanoviæ et al. (2018) introduced EduCTX, a blockchain-based platform for credit and grading. It sends tokens to trusted third parties. These tokens are based on the number of completed credits in the students' records, resulting in the development of a worldwide trusted and unified system for higher education organisations.

Finally, the use of blockchain to minimise expenses in the education sector can be rather beneficial. Storage fees associated with transaction charges and the cost of administering and maintaining educational records are all included in the total expenses (Zheng et al., 2018; Khan et al., 2019; Ma and Fang, 2020). The cost of typical cloud-based storage is considerably reduced when a public or private distributed network that can be accessed from anywhere is employed. In this sense, according to Han et al. (2018), verifying and processing academic certifications generally incur additional costs, which can be lowered using blockchain. Furthermore, using blockchain technology in the classroom can improve student evaluations. Duan et al. (2017) used blockchain to quantify learning performance based on the students' learning outcomes. Grades, course name, learning outcome name, course weight, and graduation requirement indicators are all contained in each block. Other universities or institutions can obtain the information and communicate accordingly after assessing the learning outcome successes.

What are the challenges of implementing blockchain technology in the education sector in Saudi Arabia?

Although blockchain has demonstrated its potential in the education sector, there are several issues to consider before this technology can be implemented. This systematic review divided the challenges into four fundamental categories: leaking privacy and security, processing cost, setting the boundaries, and weakening school credentials.

First, blockchain technology is known for its security, but the possibility of malicious attacks cannot be eliminated (Zheng et al., 2018; Ma and Fang, 2020). On the other hand, other studies showed that it is extremely difficult to offer security while maintaining privacy (Arenas and Fernandez, 2018; Han et al., 2018). This issue becomes even more critical when one's job is in jeopardy (online authorisation of educational credentials and certificates). Many blockchain architectures utilise public and private keys to maintain anonymity. However, as the data of each public key is publicly viewable (Farah et al., 2018), blockchain cannot guarantee transactional privacy. As a result, those transactions can be linked, and personal information would be revealed. The proper storage and safeguarding of all members' private keys are also part of the security issues that

should be resolved amicably (Turkanoviæ et al., 2018). Data leaking is a security issue that occurs because of frequent data modifications, which should be taken into account (Gilda and Mehrotra, 2018).

Second, blockchain is a new technology that must be integrated with the existing systems. The costs of acceptance and execution, on the other hand, can be rather expensive (Al-Otaibi et al., 2019; AlSubaei, 2019; Anisiuba, 2020). Apart from the installation cost, many blockchain solutions have substantial transaction or processing costs (Farah et al., 2018). As previously stated, the costs of managing and storing such large amounts of student data would increase with the size of block size in tandem with the number of users (Han et al., 2018). It is difficult to incorporate this technology into conventional education systems without regulating the development and operational costs (Bore et al., 2017; Purdon and Erturk, 2017).

Third, there is also a lack of clarity in setting the boundaries. It is plausible that some businesses do not want to use blockchain technology for their operations (Ojo and Adebayo, 2017; Ghazawneh, 2019; Fedorova and Skobleva, 2020). Without articulating the possible benefits of blockchain in the existing systems, a major hurdle will be established (Sharples and Domingue, 2016). It is also crucial to determine who sets the boundaries on the extent of an institution requiring technology transfer and the number of blockchain processes the institution should implement (Turkanoviæ et al., 2018). Early regulatory compliance partnership between the government or higher education and the private sector can set the pace for blockchain implementation in the education sector.

Fourth, decentralised blockchain technology can affect the centralised character of any educational system's process (Al-Otaibi et al., 2019; AlSubaei, 2019; Asiri, 2020). The availability of a continuously aggregating ledger, such as blockchain, can influence the value of a conventional school diploma (Nespor, 2019). Since blockchain technology is one of the most significant advancements in recent history, it will most likely take a long time for the technology to gain widespread acceptance because there are several issues related to blockchain adoption that must be addressed before the technology can be used in the education sector.

What are the types of blockchain technologies that can be invested in the education and sustainable development sector of Saudi Arabia?

Blockchain technology can be used in the education and sustainable development sector in a variety of novel ways, even beyond diploma management and success evaluation (Grech and Camilleri, 2017; Hamida et al., 2017; Ojo and Adebayo, 2017). It has significant potential for both learners and teachers in terms of formative evaluation, learning activity design and implementation, and keeping track of the entire learning process (Chen et al., 2018; Kshetri and Voas, 2018; AlSubaei, 2019). This section discusses some investment opportunities of blockchain technology in the sphere of education.

Blockchain can be used in educational contracts and transactions. For example, a smart contract running on the Ethereum blockchain network is simply a computer programme that simulates a genuine contract (such as economic transactions, employment, etc.). It can help with contract negotiations, contract terms, contract execution, and contract fulfilment verification. The programme can digitally identify the unique and precise identity of parties in a transaction (contract subjects) and codify the rights and obligations of both parties (contract terms) (Zheng et al., 2018; Ghazawneh, 2019). This presents a good opportunity for an organisation to invest in this programme.

For a typical transaction, for instance, the smart contract not only saves "third party costs" but also drastically increases transaction security and reliability. Another example is in the case of automobile installation. Rather than taking out a bank loan, the buyer can directly negotiate with the seller, avoiding any additional processing fees. The code is then performed, and the smart contract will be cancelled if the buyer breaks the rules. The smart contract outperforms the regular contract in terms of executive power and fairness (Khan et al., 2019; Anisiuba, 2020). As a result, several educational challenges can be resolved if teachers and students carry out teaching and learning activities based on a smart contract.

Blockchain can be used to inspire students through the concept of "learning is earning" (Sharples and Domingue, 2016) due to its currency property. This presents a good opportunity to invest in blockchain technology for the education sector considering that there are certain negative subjective or objective factors affecting students' poor learning outcomes, such as the lack of desire and financial pressure. In educational settings, a smart contract between teachers and students can be used. Instructors can issue students real-time prizes with a few simple clicks. As for the reward, students receive an amount of digital money based on the smart contract (Asiri, 2020; Fedorova and Skobleva, 2020; Ma and Fang, 2020). In this sense, money can be kept in their digital wallet, which can be spent for tuition, and even swapped for actual money.

Another good investment opportunity in blockchain technology involves educational evaluation. Evaluation can be a challenge in the educational system. For example, formative assessment has long been supported, but it is still not fully adopted because it is difficult to follow every detail of teaching and learning. This problem can be solved by using blockchain and smart contracts. Due to the immutability, traceability, and trustworthiness of blockchain, all the stored data are more particular, authentic, and anti-theft (Hamida et al., 2017; Kshetri and Voas, 2018; AlSubaei, 2019). In line with that, collaborative learning can be recognised as a good technique

to implement constructivist instruction and develop students' ability to collaborate with others.

Furthermore, collaborative learning is frequently coupled with the issue of free-riding, which makes impartial appraisal difficult. This can be addressed using blockchain technology. Students can individually submit their work to the learning platform via a unique account, where a smart contract reviews their performance and records the results in blocks. All collaborative behaviours are recorded in blocks as evidence for evaluation (Al-Otaibi et al., 2019; Khan et al., 2019; Anisiuba, 2020). In this case, decentralisation is a feature of a public blockchain. This implies that the distributed ledger assures that most nodes are consistent. Students' opinions are considered as nodes in the blockchain network, which would be evaluated accordingly. As a result, blockchain can assure fair evaluation.

On a similar note, teachers have reported that the sophisticated and artistic nature of education and sustainable development makes it difficult to evaluate students' learning outcomes. The old method based on student input is one-sided, lacks subjectivity, and is not very beneficial for teachers' professional development. Based on the blockchain network and smart contracts, a new assessment system can be built (Grech and Camilleri, 2017; Asiri, 2020; Ma and Fang, 2020). First, teachers must submit pre-planned instructional activities to schools, as part of a smart contract. All instructional actions are recorded in the blockchain network during the teaching process. The smart contract ensures consistent instructional design and practice, which are the key signal for evaluating instructions. Furthermore, a smart contract between teachers and schools, as well as a smart contract between teachers and students can be checked and reinforced by one another. Teachers who meet the requirements are rewarded with digital currency. It serves as a compliment and a source of encouragement for teachers.

In terms of student development, an academic supervisor is directly accountable for the supervision of each student. The academic supervisor is responsible for supporting students in developing study plans and keeping track of their research efforts and progress. However, as these concerns are not examined and supervised in practice, it is difficult to recognise problems if any unfavourable event takes place. If smart contracts and blockchain technology are applied in this sector, the situation will be different. A smart contract platform keeps track of all information and records them in the blockchain ledger such as the number of times a supervisor meets the students in the previous semester, the number of times the supervisor reviews the thesis (in the draft and final forms), or any advice provided in terms of students' course choices and research design (Ojo and Adebayo, 2017; Zheng et al., 2018; Fedorova and Skobleva, 2020). The behaviours of both academic supervisors and their respective students can be recorded in the blockchain ledger due to the traceability and immutability of blockchain technology. This cutting-edge programme can safeguard the interests of both parties.

Overall, blockchain can be utilised to create a balance that can be used to assess the learning process and outcomes. It is trustworthy and equal evidence of value for all. Due to its decentralisation and immutability, blockchain can theoretically solve problems of information asymmetry and trust among strangers. As knowledge and value are disclosed and maintained jointly, blockchain technology can ensure authenticity. It provides a secure platform for talent acquisition or investment. Users who are more knowledgeable about digital currencies have a better probability of gaining appreciation and investment. Everything that a learner has ever learnt is recorded in a blockchain ledger. Employers make use of information to match applicants with the job that fits their qualifications. Employers who seek competent employees, on the other hand, can make use of the blockchain ledger. This significantly reduces the likelihood of investment bias and failure. In a nutshell, blockchain serves the interests of both parties.

Future research agenda

This systematic review addressed a variety of potential solutions that blockchain technology can offer for the education sector and its sustainable development. Nevertheless, blockchain technology has so much more to offer and can help students in a variety of ways.

First, collaborations and partnerships among educational institutions are primary areas that would significantly benefit from blockchain technology. As previously stated, some educational institutions have tested and deemed blockchain as a safe and dependable ledger to record students' academic achievements. This covers not just the certifications that students receive, but also the many learning outcomes and skills that they acquire. A future study in this area can investigate how blockchain can be utilised to help educational institutions collaborate and interact more effectively. Educational institutions can utilise smart contracts to store and communicate academic information of their students, such as an academic transcript, a programme description, major and minor requirements, and academic probation. Students can then enrol in classes at any of the partner schools. Joint academic programmes can also be offered by these educational institutions. Students can gain more flexibility as they are provided with access to the full range of academic programmes available at other institutions. The use of these shared infrastructures, services, and academic programmes can also assist educational institutions in lowering operating expenses. This can be posited as an avenue for educators to build students' understanding of the sustainable development of their education (Campbell and Speldewinde, 2022).

Second, another area of blockchain technology is job-driven education. Job-driven education focuses on providing education

and training programmes that match the current and future hiring needs and lead to employment for students. Blockchain has the potential to make this form of education for sustainable development more accessible through sustainability pedagogies (Nousheen and Kalsoom, 2022). Businesses can also make use of blockchain to exchange the required skills and competencies. All data are to be checked regularly by educational institutions, which can then be utilised to create training programmes tailored to the needs of businesses. Students can utilise the blockchain to store their abilities and competencies as an aggregating ledger. Recruiting firms can scan the blockchain and assess candidates based on their abilities while recommending specific training programmes. Therefore, a course on education for sustainable development (ESD) should be a part of the education programmes.

Third, the use of blockchain technology in authenticating and increasing the quality of online education is another key area for future research. Although online education offers many benefits, such as cost savings, accessibility, and flexibility, it also has several disadvantages. The certification and inadequate quality are at the top of the list of disadvantages. Many educational organisations claim to be certified and provide high-quality online courses—this is an issue that blockchain can solve. It can be used as a decentralised platform to safely and reliably transmit information between students, educational institutions, and accreditation organisations. Through blockchain, information on online courses, online programmes, instructors, and accreditations can be stored by educational institutions. After completing a course, students can share their ratings of the courses and teachers. Other students can then use these ratings to assess the quality of the courses and academic programmes. The accreditation information offered by educational institutions can also be verified by accrediting authorities. Students can make use of the information to locate certified online programmes that can provide them with the certification they require. Hence, to fully realise the return of the humanistic value of education for sustainable development (ESD), education should pay greater attention to the humanisation of purpose, the contextualisation of material, the experience of the process, and the rationalisation of technology (Zhang and Zeng, 2022).

Conclusion and limitations

The use of blockchain technology in the education sector of Saudi Arabia is still in its early stages. As a result, a systematic review of the current blockchain research in the education sector was undertaken. To date, this was the first review on blockchain technology in the education sector. The study contained 15 publications, which were divided into four categories: applications, benefits, problems, and investment opportunities. The analysis of the literature presented several findings.

First, blockchain technology is mostly used to issue and verify academic credentials, communicate students' competencies and learning achievements, and assess their professional potential. However, a slew of new uses is swiftly emerging, especially related to education for sustainable development. *Second*, this systematic review demonstrated how blockchain may assist the education sector and its sustainable development by offering a safe platform for sharing student data, saving costs, and improving trust and transparency. *Third*, this systematic review demonstrated that the implementation of blockchain technology is not without its drawbacks. Before deploying the technology, managers and politicians should consider the security, privacy, cost, scalability, and availability of the technology to make education more sustainable.

This systematic review revealed the limited applications of blockchain technology in the education sector of Saudi Arabia, its future development, and sustainability. In other words, the potential of blockchain technology remains untapped. Hence, there are significant opportunities to invest in blockchain technology, particularly in the education sector. However, both students and teachers are interested in the possibility of incorporating blockchain technologies into the price of education because it represents a substantial technological advancement that can help with security, simplification, and effective learning. This article's contribution to the literature consists of creating the opportunity for several other, related investigations at other educational institutions and even in other nations.

This systematic literature review is not without any limitations. It mainly focused on educational practical application analysis; hence it has some educational object limitations. Despite the various benefits of conducting this systematic review, there are certain drawbacks to be aware of. Some of these limitations include selection bias, publication bias, data extraction inaccuracy, and misclassification. *First*, researchers are more likely to choose articles that support their assertions when it comes to selection bias. A few methods to deal with such biases are to incorporate the greatest number of relevant articles, and a rigorous searching protocol for scientific databases was devised for this study. This was then followed by a pilot search using all alternative keywords. Adding to that, strong inclusion and exclusion criteria were developed to ensure that the articles included in the systematic review focused on issues that were closely related to the objectives of the study.

Second, the process of picking "favourable" articles over "unfavourable" articles is known as publication bias. To mitigate this risk, well-known scientific databases were used in this study to maximise the number of articles included in the systematic review. Third, data extraction inaccuracy

and misclassification pertain to the likelihood of various reviewers extracting data in different ways. All researchers in the current study were involved in the retrieval process of relevant publications to address this issue. All abstracts of the extracted publications were carefully examined for this systematic review. To include or exclude each piece, opinions were formed. Different viewpoints were resolved accordingly among all the researchers.

Data availability statement

The original contributions presented in this study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

The author solely contributed to the collecting data and writing all parts of the manuscript from the introduction, literature review, analysis, conclusion, and recommendation.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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