Review Article

Exploring the role of blockchain technology in medical education: Future opportunities and challenges

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Abstract

Background & Objective: Today, blockchain technology presents a new framework that can help address some challenges facing health and medical education. Accordingly, there is a growing interest in using this important technology, especially among medical educators. Looking towards the future of educational technology and considering the end of the COVID-19 pandemic, medical education experts are expected to accept blockchain technology widely. This study aims to investigate all aspects related to the application of blockchain in medical education.

Material & Methods: The study was conducted through a PRISMA systematic review of 10 databases, namely Scopus, Web of Science, Eric, Wiley Online Library, ProQuest, Springer, Noormags, Magiran, and Irandoc, in December 2022, and was updated in February 2023. By utilizing the strategies of this systematic review, a total of 980 related articles were identified, of which 187 were selected. After screening and criteria were applied, 18 relevant articles were selected to complete the research.

Results: The results show that the application of blockchain technology in medical education has the most significant impact in the two sectors of education and healthcare. In health and treatment, blockchain technology plays a crucial role in registering patients' treatment records, storing treatment information, and ensuring the security and durability of information. In medical education, blockchain technology is utilized to issue educational certificates, enhance credibility, offer cloud storage space, and enhance the quality of teaching and learning. The trend in research methods is shifting towards mixed methods.

Conclusion: According to this study, blockchain technology in medical education creates suitable capacities for learners and teachers through a systemic approach and collective wisdom. Despite the positive aspects and efforts to address the challenges, the field of medical education is still experiencing an exponential trend in the use of technology. We expect more research and the integration of blockchain technology in medical education in the short term.

Keywords: blockchain, medical education, learning, systematic review

Introduction

Medical science holds a privileged position in society, encompassing various fields, with medical education being one of the most critical (1). Like other fields of education, medical education relies on various assumptions, such as experiential learning, reflective practice, and preferred teaching approaches. These assumptions have led to the adoption of competency-based education (2). Today, many unique and significant advances in medical education, including evidence-based learning, simulation, structured assessments, clinical and medical competency monitoring, and the integration of new technologies, are enhancing learning and teaching (3). Medical education is divided into primary, graduate, and continuing professional education. The ultimate goal of medical education is to cultivate a knowledgeable, skilled, and up-to-date community of healthcare professionals (4). Therefore, medical education is suitable for advancing education in academic and related organizations by utilizing new technologies (5).

On the other hand, while technology has significantly impacted many areas, such as industry, educational systems need to embrace technological advances faster. Consequently, many technologies still need to be utilized

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in education (6). Holon IQ, has identified four education-enhancing technologies that should receive increased spending and focus by 2025. These technologies include augmented reality, virtual reality, artificial intelligence, robotics, and blockchain (7). Blockchain is one of these technologies, semantically defined as a distributed ledger of chained and consecutive cryptographic blocks, with each block recorded in peer-to-peer networks (8). Furthermore, nodes operate similarly and are validated by other network components (9). Three eras of blockchain technology have been identified, each corresponding to the definitions of blockchain presented in that era. The current focus is on the third period of blockchain implementation and research (10).

According to Figure 1, each block in the blockchain contains essential information, including data, the block's hash, and the previous block's hash. The type of data stored in a block varies depending on the type of blockchain. For instance, a cloud blockchain used by a medical education institution stores information such as learner and instructor details, grades earned, and history. Another crucial block component is its hash, a unique human fingerprint that identifies the block and its content. When a block is created, its hash is calculated, and any changes made will result in a different hash. This feature of the blockchain makes it very secure and safe (11–12).

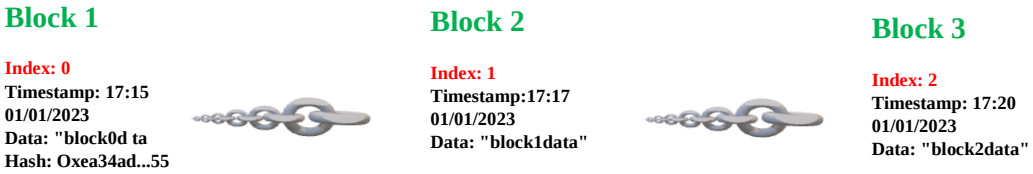

Figure 1. Blockchain structure

Blockchain technology has several key features, such as cryptographic hashing, decentralization, transparency, and verifiability (13–15). These features are repeated and configured in the elements approved by the main structure of the blockchain. Although research indicates that the utilization of blockchain technology in medical education is still in its early stages, several studies have confirmed its potential benefits. For example, research by Peters (5) found that blockchain technology in medical education offers significant benefits and can capture the attention of medical education officials towards this technology.

Another study by Tapscott et al. (28) found that a blockchain-based system for recording, crediting, and evaluating educational outcomes could be an effective method for educators to recognize the significance of their academic and systemic accomplishments. In a medical school, for instance, the curriculum can be linked to the faculty responsible for each course or block. Curriculum evaluation can be conducted within the blockchain system, which can also track the time professors dedicate to teaching, developing teaching materials, and mentoring. This approach ensures transparency for all users and leads to consensus among stakeholders.

In another study, the educational program "Blockchain," in collaboration with "Sony Global Education," provided a platform for storing the educational experiences of learners and issuing valid and official certifications (15). This platform also records informal learning activities such as competition results, internship experiences, etc., which can serve as a reference for employers and executives in organizations and universities to assess learners' abilities (16).

Implementing blockchain technology in medical education has several benefits, such as providing access to knowledge, developing models and strategies to reduce costs and improve learner experiences, standardizing curricula (17), tracking student achievements throughout the curriculum, and documenting competencies acquired through a wide range of expertise. Additionally, it can serve as a digital registration system for each participant. The research conducted so far also shows that blockchain can record the influence that instructors have on learners and can integrate with Competency-Based Medical Education (CBME) and Trusted Professional Activities (EPA) to address many of the challenges of CBME (18–19). Overall, blockchain technology is an effective method

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for addressing many of the challenges encountered in medical education (20).

Because blockchain technology is becoming more popular and important in medical education, and because there hasn't been any systematic review research in this area before, this study will use a systematic review method to look into how blockchain technology can be used in medical education. The researcher has agreed to explore the following questions based on the Population Intervention Comparison Outcome Time (PICOT) method by reviewing relevant studies:

1. What evidence supports the use of blockchain in medical education learning environments?
2. What methodological approaches have been used in applying blockchain to medical education learning environments?
3. What opportunities and challenges are associated with using blockchain in medical education?

Material & Methods

Design and setting(s)

For this study, we employed a systematic review approach to investigate and analyze articles on the application of blockchain technology in medical education. The systematic review, also called research synthesis, aims to present a comprehensive and unbiased summary of numerous related studies in a specific field (21). It shares many characteristics with a literature review. However, it seeks to uncover all evidence related to a query rather than focusing on concepts or theories, especially in research that reports quantitative data (22).

Participants and sampling

Search strategy

The PRISMA method (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was utilized to conduct this systematic review. To identify relevant articles, a systematic search was conducted in seven external databases: Scopus, Web of Science, Eric, Wiley Online Library, ProQuest, Mesh, and Springer, as well as three internal databases, namely Noormags, Magiran, and Irandoc, in December 2022 and February 2023. The search was then updated. Furthermore, a manual search was conducted on Google Scholar to complement the search. The combination of two keywords, "blockchain" and "medical education," was utilized in the English database as per Table 1 and in the Persian database as per Appendix 1. These two keywords were chosen to enhance precision in identifying relevant articles, given their frequent appearance in databases and recent research on the Mesh site and other related platforms. Synonyms or other indicators were not included in the word search to improve the accuracy and quality of the research. The search used the boolean operators AND, OR, and NOT. Both OR and AND were utilized in the search term. Primary and secondary topics were precisely identified, and redundant synonyms were avoided.

Table 1. Keywords used in systematic review

OR		OR
Blockchain	**AND**	Medical education

Data collection methods

The dataset obtained from the search included articles that assessed the use of this technology in medical education environments based on specific keywords. The article selection process involved several steps. Initially, study titles were screened to determine eligibility based on predefined criteria. Subsequently, the abstracts of all primary studies were screened for eligibility using consistent criteria. Finally, the full text of the remaining articles was thoroughly examined. No restrictions were imposed on the publication date, study design, participant age, geographic location, or language. Various sources were considered, including articles from published periodicals, collections of conference articles, doctoral dissertations, and theses. However, editorials, commentaries, book chapters, and newspaper articles were excluded.

Articles that only reported the number of statistically significant studies without providing the effect size or total number of studies in a specific comparison were also excluded. The CASP checklist, a vital tool for assessing the validity of articles in systematic reviews, was utilized. Each article was evaluated for quality based on ten quality criteria, with a score between 1 and 5 assigned for each criterion. The 2018 version of the CASP checklist was utilized in this study to evaluate the validity and reliability of the qualitative analysis in the selected articles. To ensure accuracy and quality, two expert reviewers independently conducted the selection process, which included title screening, abstract screening, and full-text review. Any discrepancies among the reviewers were resolved through discussion. In cases of disagreement, the quality of articles was evaluated using "Harzing's Publish or Perish" software, which considers indicators such as h-index, g-index, hI-norm, hI-annual, and hA-index. Two evaluators analyzed

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and assessed conflicting articles, and a final decision was made based on their evaluation.

The output of the systematic search

The results of the systematic search depicted in Table 1 involved searching various English and Farsi databases using specific keywords and criteria. This process yielded 980 articles. The PRISMA diagram illustrates the division of the search into targeted and systematic sections. In the systematic search, 980 articles were retrieved from 11 domestic and foreign databases. Among these, 187 were identified as duplicates, resulting in 156 unique studies being screened. After reviewing the titles and abstracts, 35 articles were selected for full-text review, with 17 meeting the specified criteria. Additionally, two articles from the targeted search were included, increasing the total number of articles for the systematic review to 18. Figure 2 provides a visual representation of the study selection process. No additional records were found through alternative sources. Each phase of the selection process, including the rationale for title screening, application of the desired criteria, and final article selection for systematic review, is outlined. Five criteria were used for screening the full text of the articles: 1) Articles not relevant to the desired topic were excluded. 2) Articles that did not primarily focus on utilizing blockchain in medical education were excluded. 3) Non-journal articles were excluded. 4) Articles without online full texts were excluded. 5) The most recent study was selected in cases of duplicate first authors.The data from the selected articles for critical analysis was extracted using standard forms and input into Microsoft Excel software. All data was extracted using standardized forms, and one reviewer analyzed the data while a second reviewer confirmed its completeness and accuracy. The extracted information was categorized according to the research questions outlined in the results section. Descriptive, quantitative, and correlational techniques were employed to analyze and interpret the studies related to digital competence and professional development. Additionally, keyword analysis was used with social network analysis (24), comparative database analysis, and visualization using VOSviewer software. After defining axes, categorical thematic content analysis was done, and qualitative methods were used to condense the data and find classification clusters (25). The extracted information from the articles was organized into columns with titles such as title, objective, author, method, period, country, year of publication, and results in an Excel spreadsheet. The information from the final articles included in this systematic review was extracted and presented in standardized tables.

Data analysis

In the qualitative research evaluation, a systematic process was employed using standard forms for data extraction and Microsoft Excel for data entry to minimize bias. Three reviewers were involved in the process to ensure accuracy and completeness. The first reviewer extracted the data, and the second reviewer checked for accuracy and completeness. The data was classified according to the research questions, and a combination of quantitative and mixed qualitative article analyses was used to determine the semantic use of the desired keywords.

Kennock and Young (2008) independently reviewed studies to determine their quality. In a systematic review, bias can occur during the article selection process, and employing appropriate selection methods can significantly reduce bias. According to the selection criteria of the studies, the second reviewer evaluated the articles' title, abstract, and full text. A third reviewer analyzed and discussed any disagreements until a consensus was reached. Using the Kappa coefficient ranking statistic to assess the agreement among the reviewers in the article selection process resulted in a value of 0.698, indicating a high level of agreement between them. To enhance certainty, the Cochrane Collaboration's risk of bias tool and the Critical Appraisal Skills Program (CASP) checklist were utilized to evaluate the quality of studies and potential biases. The CASP checklist, which consists of 10 items, provided an opportunity to evaluate the quality of all selected studies (CASP Institute, 2022). The findings indicated that while all the studies were conducted well, some could be improved regarding participant selection, data collection, and data analysis.

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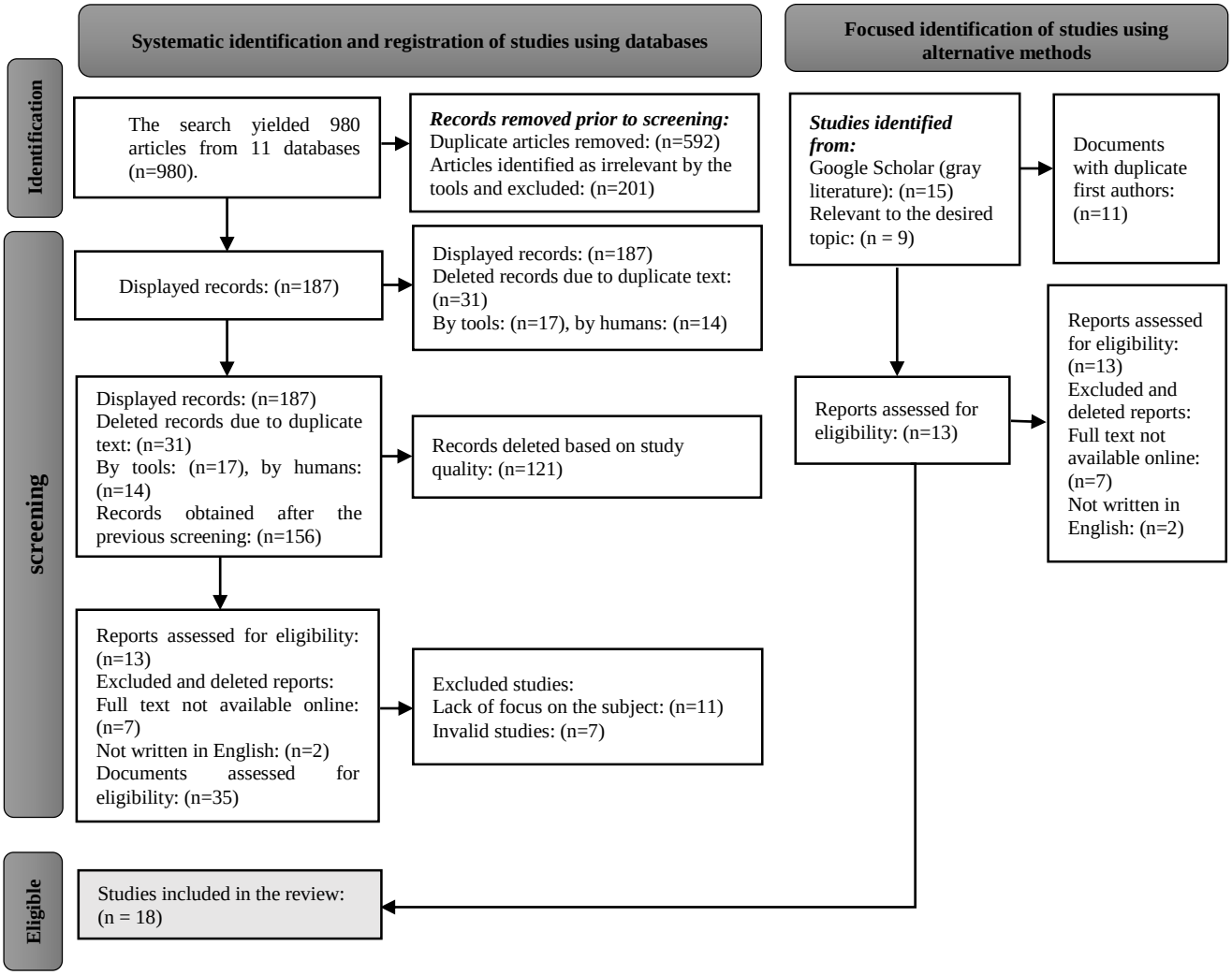

Figure 2. PRISMA chart for the stud

Results

Three research questions accompany the research findings in this section. A four-stage perspective involving description, analysis, explanation, inference, and discussion has been utilized to elucidate the results of this analysis. Overall, the articles covered a broad scope, addressing various educational strategies, employing diverse evaluation methods, including participants of different ages and nationalities, and yielding results from different perspectives. All of these aspects will be elaborated upon in detail.

Content Analysis

Each table in the article offers distinct explanations for each section. Appendix 1 provides a comprehensive overview of the studies included in the article, with the quality column assessing the relevance of the articles based on the checklists used. Additionally, in alignment with the response to the second research question, the articles exhibited diversity in the methods employed, addressing various issues, utilizing a wide range of theoretical models, and adopting various methodological approaches. This diversity is reflected in Table 2, which categorizes the studies into quantitative, qualitative, and mixed methods. The review and experimental surveys comprised the most significant number of studies among the two categories of research methods, operational and conceptual. The number of articles mentioned for each method is based on the formula (n + 1). For instance, 15 operational articles were identified for the case study method, resulting in 16 articles based on the formula (15 + 1). Additionally, due to some studies needing to fully specify their method type and being unidentifiable upon

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review, an additional study has been included for each method using the formula for calculating the number of studies.

Types and Fields of Study

Table 3 provides an overview of various types and fields of study. To clarify, a review encompasses all scientific literature in the field as defined by the author, while a theoretical analysis includes references essential to the analysis only.

Table 2. Research methods used in the articles

Research method	Practical	Conceptual	Number
Case Study	15	-	16
Comparative	-	10	11
Content analysis	-	9	10
Delphi	-	6	7
Experimental	22	-	23
Mixed method	18	18	36
Fundamental	-	11	12
Review	33	-	34
Survey	-	17	18
Theory	-	19	20
Total			187

Table 3. Concepts used in the articles

Type	Practical	Conceptual	Number
Education	16	13	29
Arts and humanities	9	12	21
Trade and international	5	3	8
Management	2	3	5
Accounting	25	4	29
Computer science	1	5	6
Communications	6	9	15
Growth	2	1	3
Engineering, education	5	7	12
Human-computer interaction		4	4
Librarianship and information	2	5	7
Innovation	6	1	7
Psychology	4	1	5
education	10	26	36
Total			187

The results indicate that the survey method is the most common type of study, followed by theoretical and case studies. While there were twelve performance assessments, most studies did not specify participants' exact skill levels and relied on self-assessment. In total, 187 studies utilized various methods such as surveys, comparative analysis, content analysis, case studies, Delphi studies, experiments, integrated methods, fundamental research, reviews, surveys, and theoretical analysis.

Thematic categories from the Scopus journal classification were used to categorize the study fields. As per the classification, it was observed that this technology has made minimal inroads in medicine and is still in its early stages, but has gained more traction in other medical fields, such as treatment and development discussions.

General Concepts

Table 4 presents an overview of the concepts discussed in the articles. Notably, the discussion of medical education has yet to be emphasized as a critical concept, with most articles not focusing on this aspect. In the studies conducted in education, coaches and trainers have been the primary focus. In contrast, other groups in education and upbringing have received less attention.

Table 4. Overview of the concepts used in the articles

Type	Number
Blockchain	97
Artificial intelligence	42
Lifelong learning	19

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Multiliteracy	15
Augmented Reality	14
Total	187

Target Population of the Studies

The reviewed study participants included medical and health community members, such as doctors, patients, trainers, and trainees (students). The geographic scope of the studies included Croatia, Canada, India, Germany, Switzerland, the United States, Spain, China, Norway, Taiwan, and other countries. The results can be generalized to other countries and implemented accordingly.

Discussion

As per the systematic review questions, the first addressed the evidence of blockchain use in medical education learning environments. The articles examined in this research indicate that universities and medical education institutions have adjusted their performance and operational plans, especially in the era of COVID-19. There is a growing focus on applying new technologies, such as blockchain, in medical education. While medical education has traditionally focused on treatment and increasing productivity in the health sector, there is now a noticeable interest in education and learning among students. In recent years, there has been a shift in focus toward medical education and treatment, particularly in treatment methods, patient health, medical device manufacturing, and related areas, as evidenced by studies. Since 2019 and the global spread of COVID-19, blockchain technology has gained significance in trade, commerce, the economy, and income (28–30). The application and perception of new technologies in medical education have adapted to the existing conditions and aimed at improvement, leading to fundamental changes. The third wave of blockchain technology has garnered more attention in medical education, prompting researchers, organizations, and educational institutions to explore its use, leading to significant transformations. Recent developments and applications in both the health and education sectors have highlighted the potential of blockchain technology in medical learning and education. This includes securing patient information, controlling access to patient data, storing data securely, issuing valid and non-falsifiable documents, utilizing cloud space for various purposes, ensuring easy access to content and data, establishing a scientific foundation, managing health supply chains, handling medical insurance, ensuring security in applications, and incorporating Internet of Things technologies related to health and medical education (31–33).

In response to the second question, it can be observed that, based on the diagram and the review of evidence and studies, research methodology approaches in the application of blockchain in medical education have shifted towards qualitative and mixed methods in recent years (34). The research approach of articles during COVID-19 has shown a preference for the mixed method. Additionally, survey methods are the most common type of study in this field, followed by theoretical studies and case studies. Studies aiming to expand knowledge in this field have predominantly chosen the case study method. Based on the reviews, the approach in the studies that utilize data and design based on blockchain technology to address challenges and issues shows a promising trend. It is expected that this trend will continue in the coming years. (According to Figure 3)

In the third question of this research, the opportunities and challenges of using blockchain in medical education were analyzed using Meredith and Colague's SWOT matrix. This matrix analyzes strengths, weaknesses, opportunities, and threats and is crucial for comparing information and presenting four types of strategies (35). The efficacy of a SWOT matrix analysis hinges upon an organisation’s capacity to engage its human resources in strategic planning processes (36). Moreover, this matrix has become a fundamental tool for organizations to assess their position. It is widely used for analyzing organizations' internal and external environments, including medical education, when making decisions (37, 38). This matrix outlines the four components of internal or external considerations. Firstly, strengths refer to the internal elements of the organization that distinguish it from others and contribute to its excellence. On the other hand, weaknesses are internal factors that hinder the organization's success and impede its growth process. Opportunities refer to external factors that can give the organization a competitive advantage in achieving its goals. It presents positive environmental aspects and opportunities to address gaps and initiate new activities. Conversely, threats can harm the organization, acting as obstacles or potential obstacles to achieving its goals (39, 40).

Strengths: The field of medical education has demonstrated significant interest in utilizing blockchain technology as a competitive advantage. Other strengths include the fact that resources have historically been

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focused on health and treatment in the medical field and related institutions. However, there is a growing emphasis on the field of medical education. This has led to advancements in security and the issuance of documents and certificates by universities and institutions.

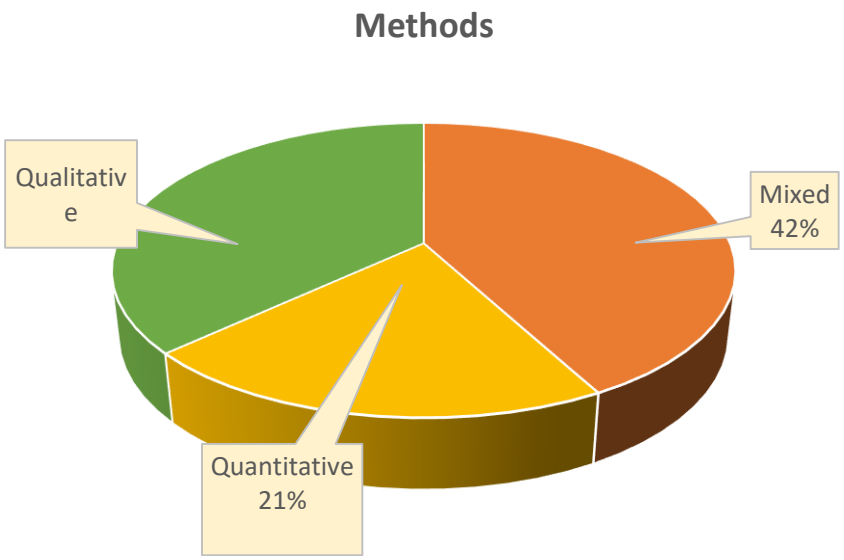

Figure 3. Overview of the methods utilized in the articles

Weaknesses: The potential for blockchain technology development is most prominent in medical education. Organizations and institutions can utilize this technology for educational purposes, such as issuing university degrees, reconciling grades and courses, and providing a private and secure space. The need for more attention to integrated educational approaches could result in adverse outcomes. The need for more resources in education-related organizations and institutions, compared to sectors like health and treatment, is evident. The trial-and-error approach to implementing blockchain technology requires significant time to establish a stable mechanism, which poses a weakness in the medical education sector.

Opportunities: Further development in this field can be achieved by utilizing blockchain-related technologies. For instance, combining various platforms for educational record storage and health professions training can enhance performance. Increased focus on the medical field can facilitate the adoption of blockchain technology, especially in the education and learning sector, serving both general and specific target communities. The experience of virtual and electronic education during the COVID-19 pandemic could create a competitive environment in medicine. Blockchain technology's accuracy, reliability, and reasonable cost offer significant opportunities, providing support and secure cloud space for resource maintenance and storage.

Threats: Privacy violations and data source manipulation pose significant threats to organizations that lack a specific mechanism for managing such issues. The ambiguity surrounding blockchain technology can also be considered a threat because it can compromise the privacy of individuals and organizations. Unclear legal responsibilities at the onset of technological implementation can pose threats. Competitors seeking to undermine the technology's security and stability for commercial and financial gain also threaten the field.

In this systematic review, 187 articles presented conceptualizations of medical education through the application of blockchain technology. This recognition indicates concerns about the need for more attention to education applications in this field. The diagnosis and treatment section was studied in more detail, revealing a predominant focus of attention in this area. Furthermore, it was observed that most existing measurement tools target learners, highlighting the need for more utilization of blockchain technology in medical education,

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especially within formal and informal medical education institutions.

Conclusion

In conclusion, modern technologies, including blockchain, have significantly transformed the field of medicine, particularly in medical education. Over the past few years, there has been a noticeable shift in the application of blockchain technology from the treatment and health sector to education. The various applications of this technology in medical education, such as data storage, issuance of educational certificates, enhancement of organizational security, and improvement of human resources skills and potential, signify the growing focus on this area. As with any emerging technology, blockchain has strengths, weaknesses, challenges, and opportunities. The results of surveys indicate that the progress made is primarily due to its positive aspects. The included studies confirm the potential for blockchain technology to undergo three different periods of evolution, reflecting its positive impact on medical education research. The results also highlight the substantial growth in interest in the emerging field of blockchain in medical education over the past two decades. Researchers have explored a wide range of issues, focusing on the effectiveness of specific educational methods and their application in medicine and health. The attention given to this field is increasing, and blockchain technology has proven to be a powerful tool for analyzing complex medical data and has gained popularity in medical education research. Furthermore, the use of blockchain technology in addressing challenges related to COVID-19 and its impact on the prediction, acquisition, and development of science in the medical field underscores the necessity of this technology in medicine.

In summary, blockchain technology has the potential to create significant capacities in medical education, and its systemic approach and collective wisdom are contributing to its exponential use in the medical education process. Blockchain technology will continue to be the subject of extensive research in medical education in the coming years.

Ethical considerations

All ethical principles have been observed in all stages of this article.

Artificial intelligence utilization for article writing

Artificial intelligence was not used in this study.

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Conflict of interest statement

The authors reported no potential conflict of interest.

Author contributions

H. Moradimokhles and M. Pourjamshidi were responsible for designing the study and supervising the study. O. Mozafari did the final review of the articles, and M.Yenkimaleki did the literary editing and implementation of the Journal format.

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Data availability statement

This research is a systematic review that does not have specific underlying data.

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Appendix 1. Studies included in the systematic review

NO	Title	Authors	Year and country	Study design	Quality %	Journal	Main findings
	Opportunities for use of blockchain technology in medicine	Radanović and Likić (41)	2018 Croatia	Qualitative	87	Applied Health Economics and Health Policy	Blockchain technology plays a crucial role in the advancement of healthcare and patient involvement. It enables secure and efficient management of medical data and information, including patients' personal data. By streamlining treatment and insurance costs, it offers a new approach to medical care. However, the lack of necessary infrastructure and technical limitations pose significant challenges that

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						prevent the full potential and capacity of this technology from being utilized.
	'Fit-for-purpose?'– challenges and opportunities for applications of blockchain technology in the future of healthcare.	Mackey et al. (42)	2019 USA	Mixed	95	BMC Medicine	Blockchain technology has a high level of importance in the field of medical and clinical care. It has the capacity to store various types of data from clinical trials and implement smart contracts related to the trial in the form of block trials. By facilitating medical affairs, it can increase efficiency and streamline processes. However, the optimal models and technical work must be determined in order to fully utilize this technology. Despite the challenges that come with implementing blockchain technology in medicine, the need for it is greater than ever.
	Blockchain technology: a data framework to improve validity, trust, and accountability of information exchange in health professions education.	Funk et al. (43)	2018 USA	Qualitative	85	The Association of American Medical Colleges	Blockchain technology provides a framework for trust and data exchange in professional training, enabling better tracking of information and content.
	The quantitative strategic planning matrix: A new marketing tool	Meredith et al (35)	2018 Canada	Qualitative	81	Jmir Medical Informatics	The study presents BlockTrial, a blockchain-based clinical trial data management solution that enables patients and researchers involved in clinical research to interact with each other. This solution offers immediate benefits by allowing patients to better control access to their data and providing researchers with useful tools to maintain adherence to reporting requirements. BlockTrial plays a crucial role in promoting trust in medical research output throughout the clinical research community and beyond.
	Industry 5.0: A survey on enabling technologies and potential applications	Maddikunta et al. (45)	2021 India	Mixed	88	Journal of Industrial Information Integration	The concept of Industry 5.0 aims to combine the creativity of human experts with the efficiency, intelligence, and accuracy of machines to achieve production solutions that use efficient and user-preferred resources. Compared to Industry 4.0, this approach emphasizes the collaboration of tools and devices to realize educational organizations. This research investigates the potential technologies and applications of Industry 5.0, including intelligent healthcare, cloud space for education, supply chain management, and production of intelligent educational systems, among others. Key technologies of Industry 5.0 are also discussed. It is concluded that a better understanding of the concept of Industry 5.0 is necessary for changes in the field of education,

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						particularly in the field of medicine, to take place in the near future.
	Towards a stakeholder-oriented blockchain-based architecture for electronic health records: design science research study	Beinke et al (46)	2019 Germany	Quantitative	90	Journal of Medical Internet Research	Analyzing and examining the effectiveness of blockchain for improving EHR/data security, traceability, and smart contracts is crucial in developing blockchain solutions. Blockchain-based technologies are also being considered to ensure people's privacy and acceptance, making them useful for patients.
	Patient-centric blockchain-based electronic health record data management for cancer care	Dubovitskaya et al. (47)	2020 Switzerland	Mixed	96	Journal of Medical Internet Research	In healthcare, a distributed ledger can be considered as an immutable and transparent shared history of all actions taken by eHealth users. The FHIR standard is being utilized to establish a pilot network of healthcare institutions in the US and Switzerland to further test ACTION-EHR with patient data. Such a system can significantly reduce data transfer time, improve decision-making for medical care, and reduce overall costs. By leveraging the power of blockchain, healthcare providers can create a more efficient and secure system for managing patient data and improving the overall quality of care.
	Accelerating health data sharing: a solution based on the internet of things and distributed ledger technologies	Zheng et al (48)	2019 Spain	Quantitative	81	Journal of Medical Internet Research	The use of lot technology can help address a range of blockchain issues such as cost, efficiency, and flexibility, as well as managing access to health data. A blockchain prototype has been developed, resulting in data integrity and flexible access.
	Design of evaluation system for digital education operational skill competition based on blockchain	Wu and Li (38)	2018 China	Mixed	93	2018 IEEE 15th International Conference on E-Business Engineering (ICEBE)	This article examines some of the limitations of the existing competition landscape and the implementation of blockchain technology in the realm of digital education. Specifically, the article explores a blockchain-based operational skill evaluation system, outlining its design, participation policy, and maintenance plan. Additionally, the article proposes an operational system that utilizes smart contract technology to effectively integrate with the operational skill evaluation model presented here. This system can automatically execute contracts developed by participating members of the alliance chain, thereby reducing the possibility of human error and minimizing the need for subjective expert judgment, which is often a weakness of the current FAHP model. Finally, the article proposes the use of machine learning to train a new evaluation model in educational institutions, with the aim of continuously

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						optimizing the model as more data is collected.
Using blockchain technology for continuing medical education credits system.	Rathod et al. (50)	2020 India	Mixed	89	2020 Seventh International Conference on Software Defined Systems (SDS)	This study presents an example of a peer-to-peer credit system that can enhance the existing CME credit system. The system is characterized by robust blockchain mechanisms, such as security, decentralization, and immutability, which are continuously developed and enhanced through infrastructure and technical advancements. With an improved infrastructure, this system has the potential to revolutionize the CME credit system.
Blockchain in health care: hope or hype?	El-Gazzar and Stendal (51)	2020 Norway	Qualitative	94	Journal of Medical Internet Research	Exposed to the testing and examination of blockchain technology regarding sensitive information and data/requirement to use the full capacity of blockchain/the need for this technology to design feasible scenarios by governments/examining the negative and positive consequences of blockchain for patients and health care workers
A survey of blockchain-based strategies for healthcare	De Aguiar et al. (52)	2020 Brazil	Mixed	79	ACM Computing Surveys	In addition to its limitations, blockchain technology can offer a transparent distribution of data that is immutable and cannot be tampered with. Blockchain has proven to be an effective solution for challenges in various fields, including lack of connection between payers and providers, genomic data, and data analysis.
Blockchain in Educational Methodologies. Radical Solutions and eLearning	Bartolomé (53)	2020 Spain	Qualitative	92	Radical Solutions and eLearning Practical Innovations and Online Educational Technology	Blockchain technology has the potential to revolutionize the field of educational certificates by enabling safe and secure distribution of educational data. This research has highlighted the current limitations of the existing system and the need to improve them to fully harness the potential of blockchain technology.
Current status, issues, and challenges of blockchain applications in education.	Ma and Fang (54)	2020 China	Qualitative	96	Ijet	This research has investigated the practical and technical models introduced by blockchain for education, which, despite their potential benefits, still face challenges such as the construction and maintenance of technology platforms. The study has also identified the limited scope of blockchain technology, which includes the preservation of learning records and the creation of a decentralized education ecosystem.
A survey on opportunities and challenges of Blockchain technology adoption for revolutionary innovation.	Duy et al. (55)	2018 USA	Mixed	86	Acm	Blockchain technology is a rapidly emerging field, but it faces challenges in terms of legal acceptance and the need for specialized labor. Governments should design an efficient legal framework to support its growth. This technology has a wide range of applications, including data storage, healthcare, and insurance payments.

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	Blockchain in health care innovation: literature review and case study from a business ecosystem perspective	Chang and Chen (56)	2020Taiwan	Qualitative	90	Journal of Medical Internet Research	To improve collaboration between healthcare providers and communities, blockchain technology can create a network that transfers the values of this sector. However, technical limitations such as privacy and large-scale acceptance need to be investigated and addressed to make it a viable solution.
	Is blockchain technology suitable for managing personal health records? Mixed-methods study to test feasibility.	Park et al. (57)	2019 Korea	Quantitative	93	Journal of Medical Internet Research	Based on the results, it is evident that numerous medical applications have been successfully implemented using blockchain technology.
	The current state of research, challenges, and future research directions of blockchain technology in patient care: systematic review.	Durneva et al (58)	2020 America	Quantitative	87	Journal of Medical Internet Research	Health Information Technology (HIT) research has proven to be useful in addressing critical challenges such as privacy and data security. In recent times, blockchain technology has been instrumental in solving the challenges of providing medical services during the Covid-19 pandemic. Surveys have shown that HIT research is primarily focused on using blockchain technologies to address current challenges.

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