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Blockchain and machine learning in education: a literature review

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ABSTRACT

There is a growing influence around the use of technology in education, with many solutions already being implemented and many others being explored. Using various forms of technology to assist the educational process has increased dramatically in the previous decade in education systems in many respects. Both machine learning and the blockchain have had a significant impact on education. The purpose of this study is to conduct a literature review on the application of machine learning and blockchain technology in educational institutions. Additionally, this study examines the potential applications, benefits, and challenges those educational institutions may face as a result of using machine learning and blockchain technologies. Using machine learning and blockchain in educational systems will have a positive impact on the entire educational process and student achievement. Researchers, academics, and practitioners will benefit from this study to focus on a wider range of educational applications and solve the related issues of machine learning and blockchain technology in the education sector.

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1. INTRODUCTION

In today's world, it has been observed that education is critical to the development and advancement of human races and that civilizations with strong and well-developed educational infrastructures have dominated society. Education provides us with a basic understanding of our surroundings, shifts people's perspectives on things, and shapes their opinions. Because education is a human-centric phenomenon, it may be transformed into a technological phenomenon. Today, a person's need for a combination of knowledge and technology has become critical. Technology has progressed so far in recent years that it is now being used to improve academic performance in the education sector.

Artificial intelligence, machine learning, blockchain, big data, the internet of things (IoT), augmented reality, cloud computing, and other technologies have transformed the traditional educational system, making it a better platform for student development [1]. Although education is developing at a faster rate than ever before due to advances in technology, there are still many areas that have yet to be explored, and there will always be opportunities for improvement. Machine learning and blockchain, two of the most disruptive technologies, have helped to replace traditional educational approaches with highly technical and effective methods [2]. When combined, technology and education have the potential to transform the current education system, which is used by many teachers, educational institutions, corporations, administrations,

and organizations to pass on knowledge. At its core, blockchain can enable users to communicate and exchange data inside a blockchain-based framework to support the objective of retaining trust, efficiency, and transparency in the education sector with non-centralized databases that are established based on high-secure policies [3]. Meanwhile, machine learning is emerging as a new educational frontier. It has the potential to revolutionize not only the way education is given but also the way students learn. By giving real-time feedback based on individual student behavior and other criteria, machine learning promises to provide tailored training in the classroom. This raises the quality of learning opportunities [4]. In addition, machine learning is also useful in the analysis of students' outcomes, discovering their weaknesses, and therefore getting accurate assessments and evaluations, consistently leading to improving the learning outcomes. Moreover, machine learning, which is one of the most powerful modern technologies, is in charge of both artificial intelligence and human interaction [4]. As a result, machine learning assists computers in discovering hidden insights without the need for programming. In this paper, we are focusing on examining the value of two burgeoning technologies in the field of education, which are blockchain and machine learning. Furthermore, this study examines the potential applications, benefits, and challenges that educational institutions may face as a result of using both machine learning and blockchain technologies.

2. RELATED WORK

This section will discuss the related works that addressed the application of machine learning and blockchain in the education field. The first subsection 2.1 covers the machine learning applications in education. Then in subsection 2.2, the blockchain applications in education are highlighted. Lastly in subsection 2.3, the combination of blockchain and machine learning technologies in education is covered.

2.1. Machine learning applications in education

Neural networks, support vector machines, decision trees, and cluster analysis were used to predict students' test performance and develop the future generation's ability for Industry 4.0 competencies as explained in [5]. It was found that non-linear kernel methods and neural networks are better at making predictions in terms of prediction accuracy when compared to the other methods assessed in the same study, while in [6], the author used 50 training models, each of which represented an entire school, in this research. It was discovered that there is a wealth of data on schooling statistics that machine learning algorithms can use to provide meaningful findings. Furthermore, the initial application of machine learning might yield valuable insights into student learning, additional work is needed to effectively analyze the vast amounts of data in education. In addition, machine learning classification models were utilized in [7] to predict students' academic performance. It was carried out by employing standard and hybrid techniques, as well as fuzzy logic, and the results were compared. They concluded that the hybrid machine learning classification technique produces superior results in terms of accuracy and other characteristics, and hence it should be favored in producing prediction findings, which should assist improve student performance and reducing dropout rates.

Nieto *et al.* in [8] compiled survey data to show which academic decisions matter most to directors, as well as the variables that go into such decisions. In a real-world case study, they used machine learning algorithms to predict graduation rates. The confusion matrix and the receiver operating characteristic curve were used to compare support vector machines with artificial neural networks (ANNs). It was discovered that the support vector machine performs better and is easier to train than the artificial neural network. In addition, a comprehensive evaluation of the existing literature was conducted on machine learning models [9]. They derived 11 machine learning models that previous researchers had used in their experiments. Following data mining, these models were implemented on two public datasets. Decision tree and random forest were shown to be the most accurate of these 11 machine learning models. In these investigations, it is possible to identify students who may be at risk and take appropriate precautions to assist them to succeed Likewize the review in [4] includes the general concept of machine learning in education, the researchers reviewed the types of machine learning and mention its applications and benefits.

Likewise, in [10], Gull *et al.* evaluated the accuracy of students' performance by examining a previous course's results. They evaluated a variety of classification methods and determined that the linear discrimination analysis approach was the most accurate. A model based on linear discriminant analysis was trained to predict students' final test scores with an accuracy of 90.74%.

Another case study in [11] was to determine the current state of machine learning applications in education. The study shows how many distinct methods provide benefits to each individual, how humans interact with machines, as well as how data is stored and retrieved as needed. The researchers also discussed how virtual assistants are employed in machine learning and how machine learning is used in artificial intelligence.

As a step forward to improve learning strategies, the research work proposed in [12] integrated technologies, including artificial intelligence and data analysis, with learning management systems. Defining this objective is what is meant by new normality, a focus on strong educational methods where certain tasks are carried out online. It is surrounded by techniques that allow students to have virtual assistants at a distance, to help guide them throughout their learning.

Al-Fairouz and Al-Hagery [13], [14] employed various machine learning algorithms to analyze the student's academic data as educational data at Qassim University, In the Faculty of Economics and Management. The objective was to find out new unseen patterns with insights and identify the drawbacks and difficulties of the analysis. The analysis focused also on discovering the unusual cases or anomaly cases within the student's data. The findings were very excellent and useful for the decision-makers and at the higher administrative level.

2.2. Blockchain applications in education

Day by day the importance of blockchain is increasing, so there are many applications of blockchain in the field of education have developed, some of these important applications will be highlighted, for example, in [15], Chen *et al.* explored how blockchain technology might be used to resolve some education problems and how it might be utilized in education. An overview of the benefits and features of blockchain technology is presented, followed by a discussion of recent blockchain applications in education. This article discusses the educational applications of blockchain technology by investigating its present and future uses. A few potential challenges of implementing blockchain technology in education have been highlighted at the end. In addition, Rahardja *et al.* [16] provided an overview of the literature on the significance of blockchain technology in the Indonesian education system. The authors offer an Edu-tech approach for determining the system's usability and readiness.

Yumna *et al.* in [17], identified existing educational difficulties and identified blockchain properties that could help overcome them. They used systematic literature reviews to identify and collect relevant data from the shortlisted research. Issues are described in three dimensions: physical, digital, and financial. The results of the investigation suggested that educational institutions' main concerns are manipulation danger, verification complexity, and record exchange. Moreover, in [18], a systematic literature review (SLR) was conducted following the guidelines provided by Okoli and Schabram [19]. The SLR was generated with three main objectives: (1) the applications that were developed in education using the blockchain technology, (2) the advantages that could bring to education when merging with blockchain technology (3) the expected challenges of involving blockchain technology in education. In the end, the research demonstrates that blockchain technology's application in educational settings is currently limited. As a result, blockchain's full potential remains untapped.

Juricic *et al.* [20] provided a quick summary of present systems, their current condition, and their future orientation, as well as specific suggestions and upgrades for current systems that would improve them and, as a result, the field of education. It also recommended blockchain integration levels in higher education, which, when paired with data extraction, may help institutions, businesses, and students develop and broaden the field of education. Its proposal for improvements in educational institutions depends on multiple various dimensions such as division to courses, employer benefits, introducing smart contracts, extraction of skills from courses, and extending student profiles with different sources.

Besides, Hameed *et al.* [21] reviewed the technical gap between the two types of educational projects. They focused on exploring some of the blockchain-based projects and protocols used in these projects. They also analyzed the features of the blockchain that are being used and the services provided by the current educational projects using the features of the blockchain to improve the implementation of this technology in education.

Guo *et al.* [22] proposed a digital rights management system based on blockchain for authentication of multimedia resources in an online learning environment. It includes a new network architecture based on the combination of public and private blockchains for sharing and managing multimedia resources for online education. Also, it is based on three smart contract schemes for recording multimedia digital rights, secure storage, and unmediated verification of digital certificates.

Moreover, Liyuan *et al.* [23] proposed an employment, education, and skill certification framework based on a two-stage blockchain. In the first stage, when a trust organization checks the employee's education and employment details, new blocks are created. In the second stage, they used a Vickrey-Clarke-Groves (VCG) game-based incentive mechanism to identify the Nash equilibrium and assure social cost minimization to motivate verifiers to engage in the skill verification process. They suggested that the proposed system offered a reliable, non-modifiable, and permanent source of employee information. In [24], the task was concentrated on the potential uses of blockchain technology for tracing and tracking in the educational sector. Some issues were demonstrated such as academic credentials fraud, student inability to choose an optimal career field, non-homogenous student groups, and unauthorized dispersal of copyrighted

educational material across the internet. Also, a few blockchain-based solutions for existing problems have been proposed using its tracing capabilities. As an example, a blockchain-based verification system could be designed to prevent fake degrees. Additionally, proposing some techniques with blockchain to help students and guardians understand their potential. Finally, the challenges of integrating blockchain technology in education were presented.

Blockchain-based security framework and proof of work (PoW) blockchain are proposed [25] to secure academic certificates. To objectively compare PoW blockchains, researchers have devised a new quantitative framework based on real-world network effects and blockchain specifications. PoW-powered blockchains are pushed to their limits in terms of certificate verification by the framework's observation of their impact on blockchain security provisions in terms of miners. The framework also allows for the evaluation of the impact of network layer parameters on PoW-based blockchain security.

The study [26] focused on presenting blockchain technology for education as a viable solution for certifying a credential. The literature review comprehensively discussed the usage of blockchain technology. By employing blockchain technology to eliminate false diplomas, they determined that educational quality in the country would be improved as a result. Through a review of the literature in [3], the work done by various researchers, the properties of blockchain technology, and the prospective uses of blockchain technology in education were examined. According to [27], gamification and blockchain technology could be combined to improve education. It was found that 71% of students who have used a system that incorporates the concept of gamification with blockchain integration claim they enjoy using it and that it has a positive effect on their characters.

Research on blockchain applications in higher education is reviewed in [28], using a Systematic Bibliometric Literature Review. There are new means of sharing, delivering, and securing knowledge data and student records that are being developed using blockchain technology, according to the research. Using blockchain technology in higher education has improved efficiency, effectiveness, privacy control, technological advancement, and security of data management systems by a large margin.

Blockchain technology and its impact on education were explored in a theoretical work [29]. The author argued that blockchain technology is an emerging technology, not yet widely used, and its evolution is unpredictable. In the literature devoted to harnessing its potential for education, there is speculation as to its prodigious potential. They speculate on how industrial and financial blockchain may be adopted by education and its various subdomains.

The focus was to look at the many applications of blockchain in education, by conducting a comprehensive review of the literature as described in [30]. They were able to identify the advantages and disadvantages of using blockchain technology in education. This study looks at blockchain as an emerging technology and how it can be used to restructure systems and improve education outcomes. In addition, Ocheja *et al.* [31] discussed the blockchain of learning logs and how learner data and digital material may be shared and transmitted across institutions and platforms.

Manoj *et al.* [32] used blockchain and smart contracts for token-based decentralized credit transfer in educational systems. The proposed system verifies certifications obtained locally as well as from another well-known online educational platform. Each student's credit value is saved in the tokens form in their wallet, and tokens collected in the wallet when each course is completed. After each course, faculties transfer credits to students' wallets based on the identifier of the student's address, which is a blockchain with many signatures composed of public and private keys. They found that the system was resistant to various attacks. Also, They evaluated the scalability of the system by load testing, which involves increasing the number of universities that register on the blockchain platform and monitoring the maximum and minimum response times.

Garg *et al.* [33] proposed a decentralized online education review and ranking system based on blockchain. The centralized reviews systems of online courses are liable to manipulating and tampering. So, the proposed system provides a decentralized, trustworthy system that ensures the rating's integrity as well as the independence and integrity of content reviews by subject matter experts (SME).

In light of the COVID-19 epidemic and the increasing demand for online and automated solutions in academics, this study [34] presented an overview of a blockchain solution. Decentralization, data integrity, and security are just a few of the advantages this technology has to offer. Using the proposed solution, the current educational system will be able to recruit new students and collect new statistics while also reducing the amount of paperwork required to complete duties.

Deenmahomed *et al.* [35] used blockchain to design and implement a transparent and distributed transcript, examination, and certificate system. The system is composed of three modules namely “New User Accounts,” “Examination System,” and “Blockchain”. When a student finishes all of his modules, he receives a digital certificate that is stored in the blockchain. A blockchain wallet gives the student access to his updated transcript and certifications. The blockchain and the system itself are managed by a group of

administrators from various institutions involved in the proposed system's usage. They clarified some advantages of the system which were scalable and modular, easy to use, operating anonymously and transparently, decentralized, and secured. Some disadvantages of the system are smart contracts are often exposed to unanticipated risks that are not illegal, as well as the performance will decrease as the number of users increases.

Another study in [36] discussed the opportunities and challenges of applying blockchain technologies in the education sector as two key research questions. The first question is, how does blockchain technology contribute to improving student learning and educational institutions? The second question is, what are the barriers to blockchain implementation in the education sector? In order to provide a complete and diversified analysis, two research approaches were used: case-based and research-based. This research used interviews and research on private and public higher education institutions utilizing blockchain technology as part of the first approach. This research gave abstracts of research papers by education, legal, and technical professionals as part of the second strategy.

Blockchain technology was proposed for an education system that is based on graduation requirements indexes of universities, with a professional certification system and automated evaluation software as can be seen in [37]. This allows the curriculum to continue to be improved by the conversion of an evaluation of student achievement to an evaluation of student competency is completed, and the results of the evaluation of student competency will be sent to the curriculum. The socio-emotional and cognitive development of students appears to be a major issue that has yet to be addressed in the digital world. This study [38] added to the body of knowledge about blockchain adoption in higher education and assessed the technology's impact on student learning outcomes [39] included the study of competition models based on blockchain technology, the design of blockchain's application mode and frame, analysis of evaluation criteria and algorithm, development of an operational skill evaluation model, and experimentation with the operational skill competition evaluation system based on E-Business Sandbox.

Li *et al.* [40] outlined a blockchain-based e-learning certification system that uses a hybrid network structure of private and public blockchains, likewize four specific smart contract models for e-learning evaluation and credit exchange, issuance and storage of digital certificates, digital certificate verification, and e-learning voucher allocating. In [41] the researchers identified, analyzed, and tested some of the blockchain-based tools currently in development, in order to increase efficiency and reliability, and provide independent degrees. As a proof of concept, a prototype was presented that can issue, verify, and share certificates. The results of the experiment, which examined the use of blockchain technology, were presented.

Xiao *et al.* [42] developed a unified and trusted data-sharing infrastructure for open learning based on a consortium blockchain extended architecture. They developed it as a proof-of-concept which showed the blockchain system's implementation was capable of operating in a production environment and outperformed related research. It, however, had limits and opportunities for improvement. As well in [43], a bibliometric analysis presented the gaps in scientific works in higher education. In addition, it analyzed the most common applications of blockchain technology in higher education throughout the world and made recommendations for further research. Moreover, the authors of [44] conducted a systematic content analysis of the literature to identify the factors which affect the adoption and applications of blockchain in education. They revealed important themes at the macro-level and the micro-level to direct future research on how blockchain might affect education management and development.

In addition, a comprehensive study of blockchain applications in the field of education was presented in [45]. It concentrated on two primary themes: educational applications and educational benefits of using blockchain technology. It discussed several research gaps and the challenges that need to be filled as well as educational areas that might be investigated in future blockchain adoption research. As well, Oganda *et al.* [46] showed that combining blockchain technology with the Smart Program Education platform, which is based on massive open online courses (MOOCs), is a promising trend in online education development. They conducted a literature review and used the business model canvas, which gives three theoretical contributions and guidance on what blockchain is.

The work achieved in [47] focused on utilizing blockchain and IoT applications in the education sector and exploring areas where they may be valuable. It discussed how blockchain technology and IoT may be used in education to improve the teaching-learning process. It also discussed the benefits and challenges of using these applications. Moreover the researchers in [48] presented a critical study of blockchain technology's use in education, focusing on its applicability opportunities and limitations, as well as the consequences of its effect on educational development. They examined real-world applications of this technology, using the Massachusetts Institute of Technology (MIT) as an example. Kuleto *et al.* in [49] provided insights into an alternative in which Higher Education Institutions (HEI) use a blockchain network to deliver the best possible sustainable education system. The opinions of students were studied, and they concluded that blockchain technology had a significant beneficial impact on learning outcomes. The research

work [50] investigated the use of blockchain in course design and evaluation in Chinese universities, as well as the importance of teachers' perspectives and experiences with blockchain in course design.

2.3. The combination of blockchain and machine learning technologies education

Singh [51] examined the concepts of big data, machine learning, and blockchains in this article, as well as how blockchain technology can be used in the machine learning community. Wahaibi and Jose [52] looked at how artificial intelligence and blockchain technologies can be combined to solve issues regarding academic qualifications fraud. The solution is divided into two main parts. Firstly, the distributed ledger-based on the blockchain can be used to reduce the number of fake certificates or academic degrees. The solution's second task is to use an artificial intelligence algorithm to determine which candidates are most suited for the position based on past data acquired from the network. It will then offer a suggestion to the organization to assist in the selection of the best applicant.

The research work in [53] proposed a blockchained federated machine learning system, which is called "BlockFedML", through the BlockFedML, they worked to develop security parameter collection methods, checkpoint-based smart contracts, incentive policies and procedures, and transfer learning. They outlined the BlockFedML methods and its applications. In [54], it was explained how the combination of machine learning and blockchain technology addresses common security threats. Moreover, Mohammadi and Rabieinejad [55], relied on four well-known machine learning methods in predicting blockchain forks, which are K-nearest neighbor (KNN) models, Naive Bayes, decision trees, and multi-layer perceptron models. They used these techniques as standalone models or in combination with clustering. They concluded that the best result belongs to the combination of multi-layer perceptrons and clustering with a prediction accuracy of 99.75%. Among standalone models, the decision tree with 87.64% accuracy had the best results. The authors have planned to conduct more studies on the prediction of hard and soft forks by analyzing blockchain records using machine learning techniques.

Similarly in [56] deals with the integration of blockchain and machine learning, the researchers introduced which main concepts, classes, and typical applications were shortly introduced. Some key features of the blockchain (decentralization, transparency, security, and immutable) are presented, which can benefit machine learning methods, and ideas, such as data and model sharing, security, and privacy, decentralized intelligence, and trustful decision-making. Furthermore, some open issues for future research are discussed, for instance, big data processing, security and privacy, scalability, efficient consensus protocols, and management of resources. Finally, some broader perspectives are discovered, such as big data, IoT, and edge computing to find more research opportunities.

In addition, the study in [57] reviewed 18 accepted, high-quality articles and provided an abstract in the areas of blockchain, machine learning, and big data. As a result, they reviewed the technologies developed in different research areas, such as data representation, blockchain application, 3D shape recognition and classification, query method, classification method, and search algorithm, to provide insights into the future model. A complete examination of a machine learning application is offered in [58], to make BT-based smart applications more resilient to threats. Besides, in [1], researchers analyzed blockchain and machine learning technologies in the education area. They advocated the synergistic usage of these two technologies for the advantage of stakeholders in the field of education which include, universities, students, and employers.

Many aspects of the use of the blockchain framework in the context of online education are examined in [59]. The use of blockchain in machine learning applications is also being examined for its potential benefits. The research work accomplished by [2] presented a system combining blockchain technology with machine learning technology. They presented that students' data can be stored on a blockchain and machine learning can be used to forecast their future career roles. The placement company can obtain the verified and validated student data of a student quickly by requesting the data of the student directly on the blockchain. Through the use of a trained machine learning model, the student can obtain accurate predictions regarding suggested jobs for him. As a result, it will prevent future counterfeiting and insecurity from negatively impacting student achievements. As well, a framework was proposed in [60], which combined artificial intelligence and the blockchain to address the challenges of e-learning process components. As part of the framework, the university develops its university blockchain, mines new blocks, checks the blockchain validation, and adds transactions to improve its e-learning process.

Furthermore, artificial intelligence was employed to solve challenges posed by the online exam and produce successful learning outcomes. Additionally, by implementing the blockchain phase, the data of the learner will be treated as secure, private, and decentralized. A set of articles were reviewed in [61], which use machine learning techniques to study a blockchain system or structure or implement blockchain technologies to improve machine learning, which led them to demonstrate the two technologies' ability to collaborate efficiently and effectively.

The convergence of collaborative machine learning and blockchain was surveyed by [62], where the researchers focused on the description of the group's applications and inventions, dividing the merging approaches into two categories; the protocol that facilitates data sharing and the marketplace that stimulates model sharing. They also analyzed the limitations and future research directions of these applications by taking advantage of developments in machine learning, marketplaces, and blockchain platforms. Tanwar *et al.* [63], presented a thorough analysis of the use of machine learning to make blockchain-based smart applications more robust to attacks. They explained how these technologies may be used in a variety of smart applications, including unmanned aerial vehicles (UAVs), smart grids, smart cities, and healthcare. Also, future research concerns and challenges were discussed.

3. METHODOLOGY

The methodology followed in this research is described in this section. The authors searched well-known databases such as IEEE, SpringerLink, Google Scholar, and others for related papers. "Machine Learning", "Blockchain", and "Education" were among the search Keywords. The search was limited to articles published between 2017 and 2022 due to the large number of studies connected to machine learning and blockchain in education. Two methods were used to extract data: i) research extraction, and ii) research screening. The authors eliminated numerous papers based on irrelevant titles throughout the research extraction process, leaving 75 papers. After that, the authors read each paper's abstract and conclusion. As a result, 13 papers that were repeated or outside the scope of the study were excluded. A thorough review of the aspects described in the literature concerning machine learning and blockchain used in the education field was undertaken. Figure 1 illustrates the related papers based on publication year and subject.

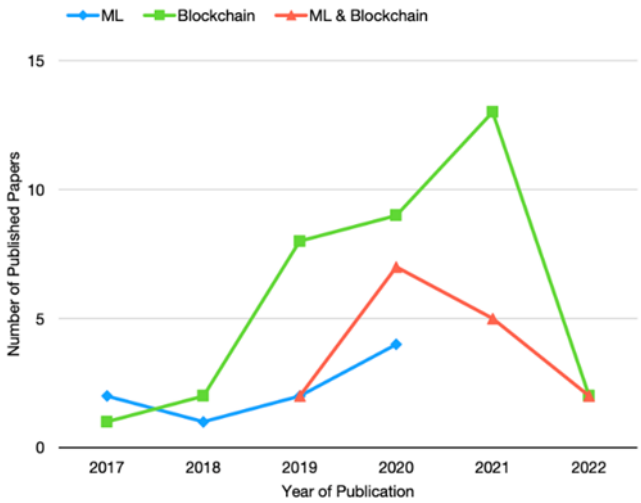

Figure 1. Related papers based on publication year and subject

4. DISCUSSION

This section addresses the most important insights from the literature, as well as the numerous uses of blockchain and machine learning in the field of education, the anticipated benefits, and the potential challenges. In section 2.1, we examined eleven papers on using machine learning in education. Table 1 illustrates the educational fields and the employed machine learning algorithms with the papers' contributions in them. The academic performance of students is the most educational field that applies machine learning as in [5], [7], [10]. The most used machine learning algorithms are neural networks, support vector machines, and classification methods. The review papers on using machine learning in education [4], [9], [11] are excluded from Table 1.

In section 2.2, from examining thirty-five papers on applying blockchain in education, we found some educational fields uses blockchain. Table 2 illustrates the educational fields with the papers' contributions to them. The Certifications System is the most educational field that applies blockchain as in [25], [32], [40], [41]. The other fields are digital rights management [22], skills verification [23], review and ranking [33], transcript and examination [35], and sustainable education [49]. The review papers on using blockchain in education are excluded from Table 2.

Table 1. Summarizing the contributions of selected papers in using machine learning in education

Research	Year	Educational Field	Machine learning Algorithm	Contributions/Finding
[5]	2017	Students' Test Performance	- Neural networks - Support vector machines - Decision trees - Cluster analysis	Non-linear kernel methods and neural networks are better at making test performance predictions in terms of prediction accuracy
[6]	2017	Schooling Statistics		Discovering that there is a wealth of data on schooling statistics that machine learning algorithms can use to provide meaningful findings
[7]	2018	Students' Academic Performance	Machine learning classification models	Hybrid machine learning classification technique produces superior results in terms of accuracy and other characteristics
[8]	2019	Academic Decisions	- Support vector machines - Artificial neural networks	Support vector machine performs better and is easier to train than the artificial neural network.
[10]	2020	Students' Academic Performance	Machine learning classification models	Linear discrimination analysis approach is the most accurate
[12]	2020	Virtual Assistants		Allowing students to have virtual assistants to help guide them throughout their learning.
[13], [14]	2020	Students' Academic Data Analysis		- Finding out new unseen patterns, insights, and identifying the drawbacks and difficulties of the analysis - Discovering the unusual cases or the anomaly cases within the student's data

Table 2. Summarizing the contributions of selected papers in using blockchain in education

Research	Year	Educational Field	Contributions
[22]	2020	Digital Rights Management System	- Proposing a digital rights management system based on blockchain for authentication of multimedia resources
[23]	2019	Skills Verification	- Proposing an employment, education, and skill certification framework based on a two-stage blockchain.
[25]	2020	Certification System	- Proposing PoW of proposed blockchain-based security framework
[27]	2021		- Showing that gamification and blockchain technology could be combined to improve education
[31]	2021	Connecting Learning Records and Contents	- Presenting the blockchain of learning logs platform - Sharing and transmitting learner data and digital material across institutions and platforms
[32]	2021	Certification System	- Verifying certifications obtained locally as well as from another well-known online educational platform
[33]	2022	Review and Ranking System	- Proposing a decentralized online education review and ranking system based on blockchain
[34]	2021		- Presenting overview of a blockchain solution in education using Hyperledger project
[35]	2021	Transcript, Examination, and Certificate system	- Implementing a transparent and distributed transcript, examination, and certificate system based on blockchain
[37]	2017	Learning Outcome	- Blockchain-based education system that is based on graduation requirements indexes of universities, with a professional certification system and automated evaluation software.
[39]	2018	Skills Verification	- Developing an operational skill evaluation model
[40]	2019	Certification System	- Blockchain-based certification system
[41]	2020	Certification System	- Blockchain-based certification system as Proof of Concept
[42]	2021	Data-sharing infrastructure for open learning	- Developing a unified and trusted data-sharing infrastructure for open learning based on a blockchain
[49]	2022	Sustainable Education System	- Using a blockchain in HEI to deliver a sustainable education system

In section 2.3, it was analyzed eleven papers that combined blockchain and machine learning technologies. Table 3 summarized four of them, which are related to the education sector. This table illustrates the contributions of that combination in education fields. It is noticeable that the combination has a vital role in securing education processes as in [52], [53]. The review papers [1], [59] are excluded from Table 3.

4.1. Blockchain and machine learning opportunities in transforming education

Based on the literature many promising applications help in the evolution of the education sector by using machine learning and blockchain technologies as shown in Figure 2. First, the blockchain educational

applications will be discussed in detail. Following that, the educational applications of machine learning will be highlighted. Finally, both machine learning and blockchain applications will be expressed.

Table 3. Summarizing the contributions of selected papers in combining blockchain and machine learning in education

Research	Year	Educational Field	Contributions
[52]	2020	Academic Qualifications Fraud	- Combining AI and blockchain to solve issues regarding academic qualifications fraud.
[53]	2019	- Security Parameter Collection Methods - Checkpoint-based Smart Contracts - Incentive Methods - Transfer Learning	- Proposing a blockchained Federated Machine Learning System to build Security Parameter Collection Methods, Checkpoint-based Smart Contracts, Incentive Methods, and Transfer Learning.
[2]	2021	Students' future career roles	- Combining blockchain technology with machine learning technology to forecast students' future career roles.
[60]	2021	E-learning process components	- Framework combines artificial intelligence and the blockchain to address the challenges of e-learning process components.

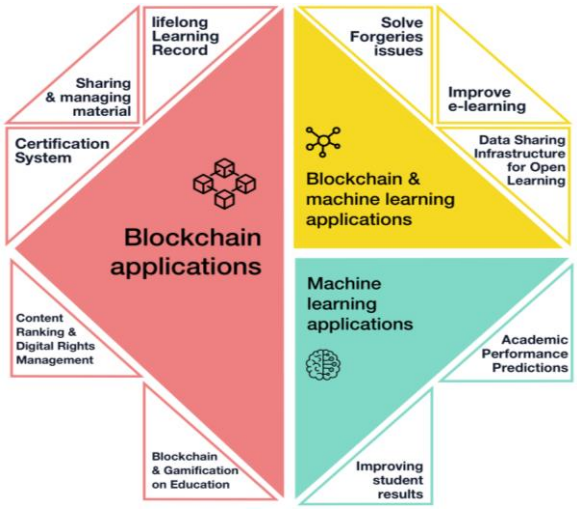

Figure 2. Applications of blockchain and machine learning

4.1.1. Blockchain applications

a). Blockchain for lifelong learning record

Blockchain technology is presented in [37] as a means of creating an educational system based on the graduation requirements indexes of universities, with a professional certification system and automated evaluation software. The result of this procedure will allow the curriculum to be further improved by converting evaluations of student achievement to evaluations of student competency. The results of the evaluation of student competency will then be sent to the curriculum.

Research in [50] developed a model based on the Funnel e-learning model to investigate how blockchain technology can enhance education and lifelong learning. According to the findings of this study, blockchain features that are most applicable to e-learning environments include traceability, transparency, reliability, authenticity, and integrity. In addition, e-learning materials development and instruction design are positively affected by course purchase, the ranking of tutors, learner motivation, and research supervision. The future work proposed in this study aims to apply blockchain technology for extending and modeling other e-learning models that have been presented in this study.

b). Blockchain as a decentralized ledger for sharing and managing material

The blockchain of learning logs (BOLL) platform presented in [31] allows different educational institutions to connect students' learning records across different environments with verifiable and non-modifiable blockchain transactions. Currently, the BOLL system operates as a consortium blockchain on which approved institutes are responsible for writing and verifying student learning logs. Furthermore, their smart contracts store permissions and only unlock records for teachers or other authorized users. The BOLL

system supports teaching and learning in a useful and desirable way. As part of their future work, they aim to deploy the BOLL system in multiple learning environments, conduct in-class experiments with students, and evaluate the feedback they receive to improve the system. Forthermore, blockchain technology was used in [64] to establish a controllable and auditable access control framework for decentralized online education (DOE) to explore the creation of a privacy policy.

c). Blockchain certification system

The study [39] included the development of an operational skill evaluation model and experimentation with the operational skill competition evaluation system based on E-Business Sandbox, as well as the study of competition models based on blockchain technology, the design of blockchain's application mode and frame, analysis of evaluation criteria and algorithm, and development of an operational skill evaluation model. The contribution in [40] characterizes a blockchain-based e-learning certification system that employs a hybrid network structure of public and private blockchains, as well as four smart contract schemes for e-learning assessment and credit exchange, digital certificate issuance and storage, digital certificate verification, and e-learning voucher allocation. They intend to enhance and practice their implementations of the proposed system in the future, focusing on smart contract implementations for each functional module, and creating new application cases for blockchain in online education.

Liyuan e*t al.* [23] suggested two-stage blockchain-based employment, education, and skill certification framework. New blocks are established in the first step when a trust organization analyzes the employee's education and job data. They employed a (VCG) game-based incentive mechanism in the second stage to locate the Nash equilibrium and ensure social cost reduction to attract verifiers to participate in the skill verification process. They claimed that the proposed system provided a permanent, dependable, and non-modifiable source of personnel data.

The result of [48] employed blockchain to create a distributed and transparent transcript, examination, and certificate system. "New User Accounts," "Examination System," and "Blockchain" are the three components that make up the system. A student obtains a digital certificate that is recorded in the blockchain when he completes all his modules. The student can obtain his updated transcript and credentials using a blockchain wallet. A group of administrators from various organizations participating in the planned system's use control the blockchain and the system itself. They outlined some of the system's benefits, including its scalability and modularity, ease of use, anonymity and transparency, decentralization, and security. Furthermore, some limitations, such as smart contracts, are typically vulnerable to non-legal threats, and their performance will worsen as the number of users rises.

Handayani *et al.* [25] proposed a blockchain-based security architecture and a PoW blockchain to protect academic certificates. Researchers developed a new quantitative methodology based on real-world network effects and blockchain specifications to objectively evaluate PoW blockchains. The framework's observation of their influence on blockchain security requirements in terms of miners pushes PoW-powered blockchains to their boundaries in terms of certificate verification. The system also enables the assessment of network layer factors' influence on PoW-based blockchain security.

Using blockchain technology to manage diplomas was achieved [39] through the development of the CertEdu prototype, in which academic certificates could be issued, revoked, shared, and verified. However, tests also found that disconnected operation is still a problem. The unpredictability of issuance costs is also a concern. We conclude by saying that the use of blockchains in academic certificate management is feasible and offers clear advantages over traditional digital solutions from the perspective of privacy, distribution, and revocation. However, to fully utilize the technology, the centralization points proposed in this work, such as the validation of issuer profiles and revocation, would need to be moved to the blockchain itself.

Token-based decentralized credit transfer was carried out by the authors of [32] using blockchain and smart contracts. As part of the proposed system, certifications obtained locally as well as online are verified. Each student's credit value is saved in a token form in their wallet, and tokens will accumulate in their wallet as courses are completed. During each semester, faculties transfer credits to students' wallets based on a unique address identifier, which is a blockchain containing many signatures composed of public and private keys. They found that the proposed system was resistant to a variety of attacks, thus ensuring its security. Furthermore, they tested the system's scalability by increasing the number of universities registered on the blockchain platform and monitoring the maximum and minimum response times.

d). Blockchain content ranking and digital rights management

Garg *et al.* in [33] provide trustworthiness online, followed by a consortium-based onboarding of SMEs backed by stakeholder endorsement. Using this system, all reviews are safe and transparent, so one cannot provide fake reviews. Future work will integrate the machine learning-based recommendation engine with the proposed system to determine the course's category based on the learners' levels (Basic/Intermediate/Advanced), and the parity score will be based on the weighted formula.

A digital rights manager based on public and private blockchains for sharing and managing multimedia resources for online education has been proposed by the authors of [22]. An entirely new architecture based on public and private blockchains is included in the project for the sharing and management of multimedia resources online. Furthermore, it is based on three different smart contract schemes for recording multimedia digital rights, setting up secure storage, and for evaluating digital certificates meritedly.

e). Blockchain and gamification on education

According to [27], gamification and blockchain technology might be integrated to improve education. Its weakness is that it assesses the effect of gamification techniques on educational management at Higher Education Raharja as an indication of how these institutions can prepare themselves to cope with the disruptions of modern society. According to the findings, 71% of students who have used a system that includes the notion of gamification with blockchain integration enjoy using it and believe it has a beneficial impact on their personalities. In the future, this study will attempt to implement the gamification technique not only in higher education but also throughout all Indonesian campuses.

4.1.2. Machine learning application

a). Academic performance predictions

In this regard, Xiao *et al.* [42] conducted a full review of the available literature on machine learning models. They developed 11 machine learning models that had previously been employed in experiments by other academics. These models were tested on two public datasets after data mining. The most accurate machine learning models were found to be decision tree and random forest. It is feasible to identify learners who may be in danger during these investigations and take appropriate safeguards to help them succeed. They want to employ these machine learning models in a real-time University student database in the future because the current data is insufficient.

To predict students' academic performance, machine learning classification models were used [7]. It was performed by using standard, hybrid, and fuzzy logic, and results were compared. The study concluded that hybrid machine learning classification achieves superior results in accuracy and other characteristics, and hence should be preferred for producing prediction findings that can improve student performance and reduce dropout rates. Ciolacu *et al.* [5] used neural networks, support vector machines, decision trees, and cluster analysis to estimate students' performance at examinations and shape the next generation's talent for Industry 4.0 skills. According to the study, non-linear kernel methods and neural networks are better at making predictions than the other methods.

To predict the grades of students in a later term, the research [10] used a combination of logistic regression, K-nearest neighbors, classification, analysis of linear discriminant, regression trees, Gaussian Naive Bayes, and support vector machines. According to the experiments, linear discrimination analysis is the best method for accurately predicting how effectively students would perform on their final exams. 49 records out of a total of 54 were correctly predicted by the model, with a 90.74% accuracy.

The result in [6] employed 50 training models, each of which represented an entire school. They realized that there is a vast amount of data on education statistics that machine learning algorithms may employ to provide useful results. Additionally, while the initial use of machine learning may give useful insights into student learning, more effort is required to successfully evaluate the large volumes of data in education.

Researchers analyzed survey data to determine which academic decisions matter the most to directors, as well as the factors that influence those decisions [8]. They employed machine learning methods to estimate graduation rates in a real-world case study. Support vector machines (SVMs) and ANNs are compared using the confusion matrix and the receiver operating characteristic curve. The results show that the SVM is outperform in terms of accuracy. In addition, they mentioned some future work, such as the fact that other success criteria should be addressed in future studies. In addition, they will develop a decision-making model for higher education institutions, as well as analyze and compare several machine learning methods such as random forest, decision trees, and logistic regression.

b). Improving student results

The study [15] suggests that learning management systems be integrated with technology such as artificial intelligence and data analysis to improve learning. An emphasis on strong educational models where some tasks are carried out online, surrounded by technology that allows students to have virtual assistants to help guide them throughout their study, is what is meant by new normalcy. In the future development, it is planned to incorporate two equally significant technologies into this paradigm. The blockchain is one of these technologies, and it aims to safeguard the data and procedures of students and the institution. Moreover, the inclusion of the IoT will be considered important. In this modality, the inclusion of devices to obtain data that allows the educational model to be continuously improved is desirable. Furthermore, the involvement of the

IoT will be significant. The incorporation of devices to collect data that allows the instructional model to be continually modified is desirable in this modality.

4.1.3. Educational application using blockchain and machine learning

a). Solve forgeries issues

Shah *et al.* [2] described a system that uses blockchain and machine learning technologies. They show how data from kids may be kept on a blockchain and machine learning can be used to predict their future job prospects. By asking for a student's data directly on the blockchain, the placement provider may instantly acquire verified and validated student data. The student can acquire reliable predictions about potential jobs by using a trained machine learning model. As a consequence, future counterfeiting and insecurity will not have a detrimental influence on student progress. On the other hand, in [52] looks at how artificial intelligence and blockchain technology may be used to overcome concerns with academic credentials fraud. The solution is split into two stages. To begin with, the blockchain-based distributed ledger may be utilized to minimize the number of false credentials and academic degrees. The second aspect of the solution is to utilize an artificial intelligence algorithm to decide which candidates are most fit for the job based on previous network data. It will then make a recommendation to the organization to help them choose the best candidate. One of the study's primary future tasks will be to put the recommended approach into practice.

b). Improve e-learning

Researchers examined blockchain and machine learning technologies in the field of education in [1]. They recommended the combined use of these two technologies for the benefit of educational stakeholders such as universities, students, and employers. Future research might include the identified features to improve learning success predictions.

An AI-based blockchain framework for the e-learning system (AIBEL) framework was developed to address the issues of e-learning process components by combining artificial intelligence and the blockchain as explained in [60]. To strengthen its e-learning process, the institution creates its university blockchain, mines new blocks, validates the blockchain, and adds transactions as part of the framework. Furthermore, artificial intelligence was used to tackle the online exam's problems and provide good learning results. Also, the learner's data will be considered safe, private, and decentralized by using the blockchain phase. Their next research article will focus on artificial intelligence, which has the potential to be a game-changing tool for individualized learning and the security of online tests.

The goal of [50] was to develop a blockchain-based e-learning paradigm. To achieve its goals, this work employed a positivist research theory and descriptive design. Traceability, transparency, dependability, authenticity, and integrity are the blockchain properties that are most suitable in an e-learning environment, according to the findings of this study. Course purchase, tutor rating, learner motivation, research supervision, and program fragmentation were all shown to have a favorable influence on the development of e-learning resources and instruction design. Proof of learning, student records management, learning outcomes evaluation, and tuition payment, on the other hand, have been identified as critical in e-learning governance and finance. Future research in this area will focus on using blockchain technology to expand and model other e-learning models developed in this study.

c). Trusted and unified consortium-blockchain-based data sharing infrastructure for open learning

To create a consistent and trustworthy data-sharing infrastructure for open learning, [51] presented a consortium blockchain extended architecture with integration and cross-chain functionality. A blockchain-integrated open learning scenario schema, a blockchain-integrated open learning application model, and a pragmatic blockchain integration framework make up the overall architecture. The test results suggest that the blockchain system's implementation is suitable for use in a production setting and outperforms similar research. It does, however, have limits and optimization possibilities that will be investigated more in the future.

4.2. Benefits of the Blockchain and machine learning adoption in education

Machine learning and blockchain are two examples of emerging technologies that can improve the quality and strength of educational systems. Many prospective breakthroughs in a wide range of educational areas may be made possible through the integration of machine learning and blockchain technologies. Learning about how students learn and perform can be enhanced with the help of machine learning which will give valuable insights. Student academic performance and graduation rates can be predicted using machine learning approaches [5], [7], [8], which aid in the decision-making of educational administrators. When it comes to identifying students who are not performing well, machine learning may be able to provide an early warning system [10]. This is a helpful tool for educators to use when trying to figure out how to best help students who are struggling academically. New patterns and insights can be discovered [13] to identify

students who may be at risk and take appropriate safeguards to help them succeed [9], which also may be valuable for the decision-makers and higher administrative level.

On the other hand, blockchain is a cutting-edge technology that will aid in the advancement of education. Data storage management, data security and integrity, decentralization, and system trust are just a few of the advantages of using blockchain [17], [34]. Additionally, by leveraging the tracing capabilities of blockchain, a few solutions to current problems could be designed, such as preventing fake degrees and diplomas [24], [26]. Consequently, students would gain a better understanding of their potential and be able to make better decisions in the future [24] if blockchain were used to manage their records and performance. Furthermore, owing to its distinctive features such as greater dependability, enhanced fault tolerance, efficient operation, and scalability [25], blockchain can be utilized as an alternate medium for storing digital certificate documents [26]. Blockchain technology can be utilized in higher education to improve efficiency, privacy control, and technological innovation [28], as well as to provide better learning platforms and record-keeping to increase student motivation, collaboration, and participation [38]. Overall, the integration of machine learning and blockchain technology in education will tackle challenges associated with academic credential fraud [52] and common security concerns [54].

4.3. Challenges of the Blockchain and machine learning adoption in education

Although blockchain and machine learning have proved their potential in an educational environment, multiple challenges need to be considered when implementing these technologies in education. The main challenge for machine learning is to have high-quality data to operate well and deliver accurate predictions and results. While blockchain technologies are still in their early stages in the education field, they also may have several difficulties. According to [1], some of them are the high computational power requirements that can not be met by usual computers, the time-consuming process of adding a new block to the blockchain, and the need to change the centralized infrastructure of education, which takes a lot of work.

Moreover, many studies have examined the primary challenges to blockchain adoption in the educational sector. One of them that can arise in educational systems while implementing blockchain is poor transaction speed [18], which may impose constraints when growing blockchain in education solutions globally [36]. The issue of transactions being available to anybody with blockchain access is also a challenge that has to be considered, as this data may be collected and made public elsewhere [36]. Additionally, the user may be needed to store numerous complex parameters, such as the primary key, public key, and recovery seeds, for purposes of security. The terminology used in blockchain may also be unfamiliar to those in the education sector [18]. Cost is regarded as one of the primary challenges, which includes the cost of transforming the environment, establishing the infrastructure, developing the blockchain, and employee training on the blockchain [30]. Moreover, blockchain may also face trust concerns [30] when it comes to safely transmitting students' and instructors' information across the blockchain network, and administration difficulties [18] since all institutions must agree to share their data before certificate verifications can be completed. Furthermore, the immutability of the blockchain is based on the fact that the data contained in the blocks can never be altered. As a result, immutability may limit the use of blockchain for sensitive student data, such as admissions, certificate verification, and exams that require the right to remove or change [28].

5. CONCLUSION

Understanding the use of technology in education is an important research subject since the evolution of each country begins with the development of its education system. Over the last decade, education systems have grown significantly in many aspects, one of which is the use of various types of technology to enhance the educational process. Machine learning and blockchain are two technologies that have had a big impact on the educational process. The goal of this research is to perform a review of the literature on the usage of blockchain and machine learning technologies in educational institutions. The most significant applications of blockchain and machine learning are summarized, which are grouped into three categories: blockchain applications, machine learning applications, and integrated blockchain and machine learning applications. Benefits of the Blockchain and machine learning adoption in education, including early predictions of student performance that aid administrators in making decisions, as well as the use of blockchain to store digital certificate documents, prevent the creation of fake degrees and diplomas, improve learning platforms, address common security concerns, and so forth. Moreover, issues that educational systems may encounter, such as the requirement for high-quality data for machine learning processing, and the necessity to handle a variety of blockchain-related challenges, including scalability, privacy and security, cost, trust, and immutability. Overall, this study emphasizes the significance of blockchain and machine learning technologies and their promising role in the education field. According to this study, educational systems' integration of blockchain and machine learning will have a favorable impact on the whole educational process and student performance.

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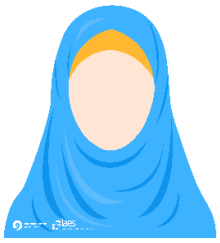

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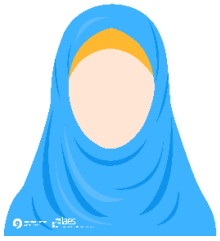

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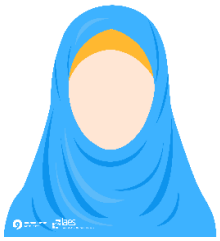

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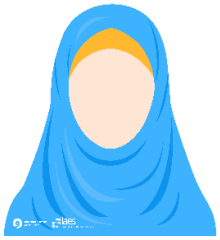

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