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TOPICAL REVIEW

A Systematic Literature Review on Blockchain-Based Systems for Academic Certificate Verification

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ABSTRACT In the past few years, there has been significant progress made in the area of blockchain. The use of blockchain technology has the potential to revolutionize the educational system by providing individuals with innovative and cost-effective ways to learn, as well as by altering the way teachers and students work together. Additionally, blockchain technology can be utilized for the issuing of unchangeable digital certificates, and it can enhance the present limitations of the existing certificate verification systems by making them quicker, more reliable, and independent of the central authority. The application of blockchain in the context of education has generated significant scientific interest in this field. Nonetheless, research endeavors on the adoption of blockchain in the verification of academic credentials are still in the development phase. In order to shed more light on the field, in this paper we focus on extensively reviewing the body of knowledge on blockchain-based systems for academic certificate verification. Hence, the purpose of this survey is to compile all relevant research into a systematic literature review, highlighting the key contributions from various researchers throughout the years with a focus on the past, present, and future. In this work, we have identified 34 relevant studies out of 1744 papers that were published between 2018 and 2022 by employing the PRISMA framework. We distinguished six major themes covered by the research articles analyzed and also identified research gaps that need to be addressed and explored by the research community. Based on the findings of this review, we provide some recommendations for future research directions and practical applications that can assist researchers, policymakers, and practitioners in the field.

INDEX TERMS Blockchain platforms, smart contracts, academic certificate verification, systematic literature review, security and transparency, fraud prevention, ethereum, automatic certificate generation.

I. INTRODUCTION

In the age of digital transformation, education is changing, as is the way individuals learn and interact with educational establishments. Also, with the advancement of social life, the demand for bettering human knowledge has risen dramatically. From bachelor's to doctoral students to lifelong learners, more and more individuals nowadays are using online tools to learn and improve their skills. Infante et al. [1] indicated that only the number of learners reached by MOOCs (Massive Open Online Courses) increased from 300,000 to 220 million between 2011 and 2021. The growing demand for online, digitized courses poses challenges, but it also opens up vast new markets for educational institutions. Various study approaches, such as short-term, online, and part-time courses, provide access to a vast array of courses for multiple disciplines, ranging from professional to soft skills.

Nevertheless, as a result of a lack of community trust, the value of many certificates obtained online is diminishing over time [2], [3]. This is primarily because these certificates

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are easily forgeable. Furthermore, many Internet-based universities award degrees with minimal work required [4]. According to a recent Forbes study, the degree mill industry is estimated to generate $7 billion a year worldwide in fraudulent diplomas and transcripts [5]. Consequently, in order to avoid having a further negative impact on society, this problem must be prevented. Traditionally, the certification authority verifies diplomas or certificates because it is difficult to distinguish between genuine and fake certificates without specialized tools and knowledge that the certificate issuer can only provide.

In recent years, blockchain has emerged as a promising technology that automatically records and verifies transactions [6]. In simple terms, blockchain is a cryptographically secure protocol for creating an immutable digital data structure that is used to keep track of asset transactions between members of a public or private peer-to-peer network. Blockchain's key characteristics include transparency, trust, speed, and the elimination of the centralized system's single point of failure. Despite blockchain's actual use in business and finance, its applications in the education domain have gained traction in recent times [7].

Blockchain technology has the potential to revolutionize the educational system by introducing more accessible and affordable learning options and altering the dynamics between educational institutions and their students [8]. The process of managing student tuition payments is one that requires a significant investment of time and involves a large number of parties, including students, parents, scholarship foundations, private loan companies, state institutions, and the frequently enormous bureaucracy of university financial departments. With the help of blockchain technology, we can streamline this procedure, reducing the amount spent on overhead and ultimately bringing down the price of education. Meanwhile, the technology has already been implemented for open learning models like pay-as-you-go classes that employ smart contracts and accept cryptocurrency as payment [9], [10]. Furthermore, blockchain has the potential to revolutionize the way universities manage their courses by securely storing digital syllabuses and coursework [11]. In the past, institutions have used hard drives for this purpose, but these devices can be damaged or hacked. Additionally, blockchains and smart contracts can make it simpler for instructors to monitor their student' progress [12]. This is because smart contracts can automatically check each assignment and give the next assignment to the student until the whole syllabus is done. Teachers can also use the same smart contract technology to provide grades that are more accurate and reliable.

Another way in which blockchain technology can enhance the quality of distance learning is by streamlining the accreditation process, making it more open to scrutiny, and facilitating easier access for those with the necessary permissions. This technology can also be harnessed to issue immutable digital degree certificates and improve the current limitations of the existing certificate verification systems [13], [14].

Performance, speed, and dependence on centralized authorities are considered limitations of existing blockchain systems [13]. As a result, numerous systems designed to verify diplomas are still in the development phase. In practice, they are facing problems since, with blockchain, it is difficult to manage the data that requires updating. The reliance on the consensus algorithm, the high reliability that can be increased, the need for human participation in the present techniques for verification, and the absence of initial data verification are further limitations stated in [14].

Despite such advancements, however, the utilization of blockchain smart contracts to prevent the forgery of degree certificates remains limited and speculative in nature. Still, certificates are frequently forged, including diplomas and transcripts. Although diplomas can be issued at any time and in any location, they are frequently falsified through hacking and forgery [15]. One of the factors contributing to these challenges includes security and privacy, among others. Using blockchain technology, a digital version of the certificate could be created that is immune to forgery, tampering, and repudiation. Additionally, the system would become more transparent while still guaranteeing the privacy and convenience of all parties involved in the ecosystem. But keeping up with the requirements of GDPR in Europe and the UK [16] on top of the requirements of state and federal data protection laws in the United States [17] can still be a challenging process.

In this paper, we critically investigate the body of knowledge related to blockchain technology's implications for preventing diploma and certificate forgery in higher education settings by providing answers to research questions using a method that employs a stepwise framework for carrying out systematic literature reviews (SLR) [18]. Thirty-four baseline articles are reviewed following the Preferred Reporting Items for Systematic Literature Review and Meta-Analysis (PRISMA) framework for systematic literature review. The PRISMA statement provides recommendations for systematic reviews that reflect advances in identifying, selecting, evaluating, and synthesizing studies [19].

The main contributions of this study are the following:

1. A PRISMA framework-based systematic review of 34 primary studies
2. An analysis on blockchain-based systems for academic certificate verification
3. A summary of the field's opportunities, challenges, and suggestions for further study

In addition, this SLR presents an in-depth and extensive analysis on the topic of blockchain-based diplomas based on six generated themes, as shown in Figure 1: *type of blockchain (classification)*, *automatic generation of diplomas*, *security and transparency,adaptability*, *conceptual models,* and *enabling technologies*. Also, this work focuses on the most

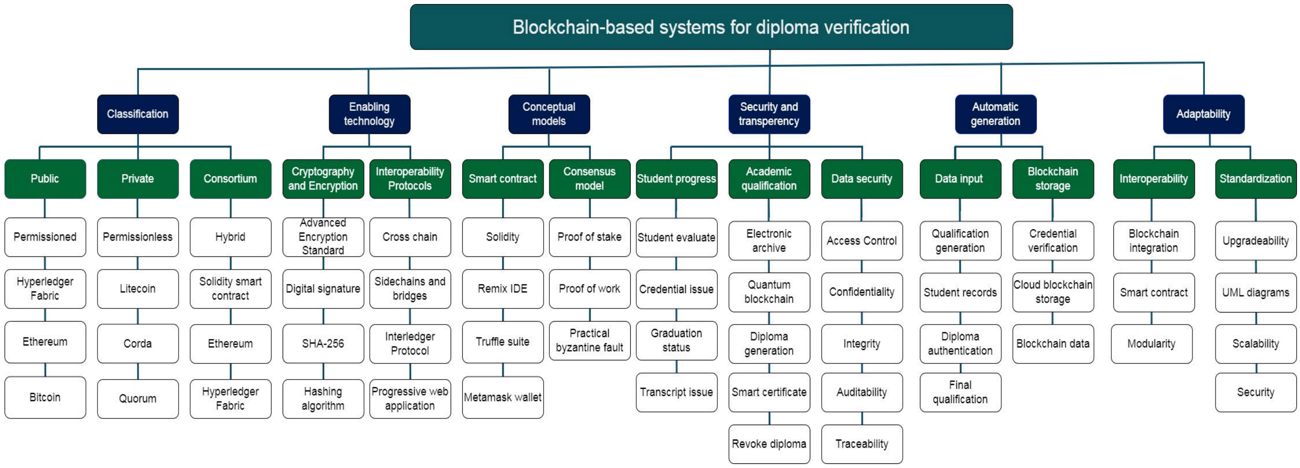

FIGURE 1. Taxonomy with the main themes and sub-themes.

significant challenges and potential future research directions in the domain. We believe this is the first research endeavor that incorporates a SLR on blockchain-based diplomas that addresses all these themes.

The rest of the article is organized as follows. In the next section, we detail the state-of-the-art in blockchain application in education. Here we identify seven application categories of blockchain in the education context and highlight some general challenges encompassing the implementation of this emerging technology. In Section III, we detail our research design and search strategy. Next, in Section IV, we present and discuss the six themes that were found in this systematic review. Section V elaborates on the research questions' findings, whereas Section VI presents the identified challenges and research gaps, along with some recommendations and future research directions. Finally, Section VII concludes this SLR.

II. BACKGROUND AND RELATED WORK

A. OVERVIEW OF BLOCKCHAIN

Blockchain technology was born at an important economic moment when the world was facing major economic crises, bankruptcies of some world-renowned banks, and where people were in a panic and began to lose trust in banks, feeling insecure about conducting different transactions. It is no coincidence that most people know the creation of blockchain technology as Bitcoin because the first stage of the development of blockchain technology has been the phase of cryptocurrencies, especially Bitcoin as a cryptocurrency. To this day, Bitcoin remains one of the most priced cryptocurrencies [20] [21].

Due to the special data management in the form of chains and the security it offers, blockchain is one of the technologies that has recently marked a revolution in many spheres of life, where it finds a wide range of applications like health, government, industry, agriculture, hotels, and airlines [22]. Blockchain technology offers a distributed architecture in which more computers can be connected at the same time and access the information they need. Thus, making a transition from a centralized way of data management to a decentralized, transparent, but on the other hand, to a much more secure way of managing data [23]. Despite the decentralized mode of operation, what makes blockchain technology special is the generation of hash values, and the storage of these hash values in the blocks of the blockchain network. Each block in the network, among other things, stores not only its own hash value but also the hash value of the previous block, so any eventual change in the data will change the hash value of the block, and it will be detected very easily [24].

The application of blockchain in artificial intelligence is also very important. The application of blockchain to intelligent devices is made possible by the implementation of smart contracts, consensus algorithms, and the generation of hash values in chain blocks. Relevant research in the application of blockchain technology in artificial intelligence is geared towards the creation of a network that will integrate space, air and ground, and will be the successor to the 5G network [25].

Besides the distributed architecture, immutability due to hash values, and security it offers, blockchain technology is also characterized by transparency, democracy, consistency, and integrity. In the blockchain network, everyone is free to join the network on a given platform and start generating transactions [26]. When it comes to the benefits of blockchain in education, the use of blockchain technology has the potential to enhance educational outcomes, simplify administrative procedures, and increase accountability and transparency. Unlike other sectors like industry or health, where blockchain is finding a good and comprehensive application, in higher education institutions, the adaptation of blockchain technology for data management is seen as a big challenge. However, in some higher education-based services, blockchain is showing good and transparent results, such as in payment methods and work contracts [27].

Transparency is one of the important characteristics of blockchain technology. When services are transparent, there is less chance of them being misused, as the possibility of their verification is easier [28].

Another very important application of blockchain technology is in the creation of virtual spaces, known as the metaverse. However, such an implementation is not straightforward due to the different characteristics of the metaverse, such as heterogeneity, immersive realism, hyper spatiotemporality, sustainability, and the issue of privacy and security in such a virtual space [29].

The application of blockchain technology in higher education institutions (HEI), is also important for the e-learning process. This technology allows educational institutions to have greater collaborations, enabling students to exchange knowledge with each other and achieve professional knowledge in the fields they study. This would be achieved due to the successful implementation of blockchain in HEI, and having the smart contract as an important part of the security of this system would pave the way for electronic learning. The same system would be modified for the generation of electronic certificates, or even electronic diplomas, for students who complete distance learning [30]. Overall, the use of blockchain technology in HEI can be summarized, among others, into several points [31]:

- management of the various certificates that are given to students, either for the acquired knowledge or for the needs of the students,
- assessment of students' knowledge in different fields,
- provides a safe, transparent environment for the development of learning,
- fast, online payment of various student services,
- accumulation of points from general evaluations in a given course and generation of credits and final grade,
- protection from unauthorized access and identification of access to certain services (it is known exactly who and what competence they have in the system)
- development of electronic learning by creating different virtual environments, online generation of certificates for the completion of courses and the possibility of online payment through currencies determined by the respective institutions themselves.

The integration of blockchain into existing systems through HEI has many challenges, which are also related to the field of application on the one hand, but on the other hand, In Figure 2, we have presented some challenges that are related to the application of blockchain in higher education institutions. Among the many challenges are the generation, verification, and revocation of diplomas from the blockchain system, the training of academic staff, teachers, and students to use the blockchain system, the cost and energy used, the maintenance of the system, the classification of services, and the insertion of diplomas generated previously in the blockchain system [32].

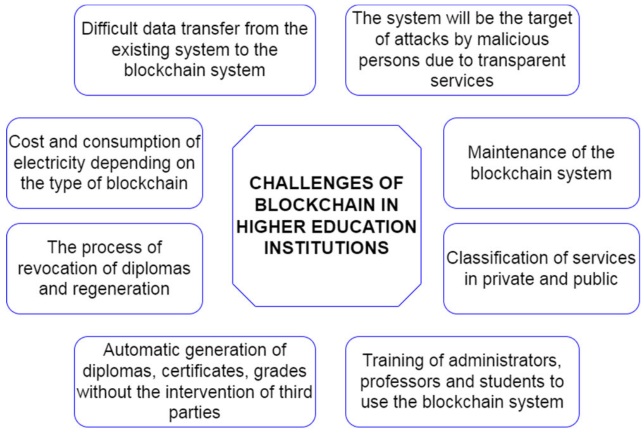

FIGURE 2. The challenges of implementing the blockchain system in higher education institutions.

Security is one of the most important elements that makes blockchain technology useful in most cases. The main elements that characterize the security of blockchain technology are: hash values that are attached to each block in the network, with which immutability is identified and guaranteed; the proof of work, which is actually a mechanism that alerts the blockchain to various cyber-attacks on the system; and consensus, which, in fact, after the network blocks are validated, and is the part that unites all peers among different miners who have nothing in common [33]. Proof of work (PoW), as a consensus mechanism that aims to regulate the process and the rights of miners, consumes a lot of electricity, and on the other hand, it does not have good practical results. A solution to overcome this challenge is platform-free proof of federated learning (PF-PoFL), Wang et al. [34], proposed to use artificial intelligence to use lost computing power to solve difficult and meaningless POW puzzles and perform practical tasks through federated learning. In addition, the energy consumed by blockchain systems can be reduced by using the framework proposed by Wang et al. [35], which is applied to charging electric vehicles. This framework is based on the division of the energy network into smaller services, through the blockchain network, providing private networks of energy expenditure for each transaction carried out in the blockchain system. The same is achieved by leveraging edge computing, multi-signature mechanisms, and simulations have shown that the cost of electricity consumption is reduced.

The generation of diplomas through the blockchain system is one of the preventive measures to prevent the falsification of diplomas in higher education institutions. There are many ways to implement such a system in practice, which depend on the platform, the type of blockchain, the programs used, and the databases; however, each blockchain system must have the necessary parts that make such a system fully functional.

Thus, in Figure 3, we have adapted a simplified architecture of a blockchain system [19], which represents the process of generating a diploma in electronic form. The

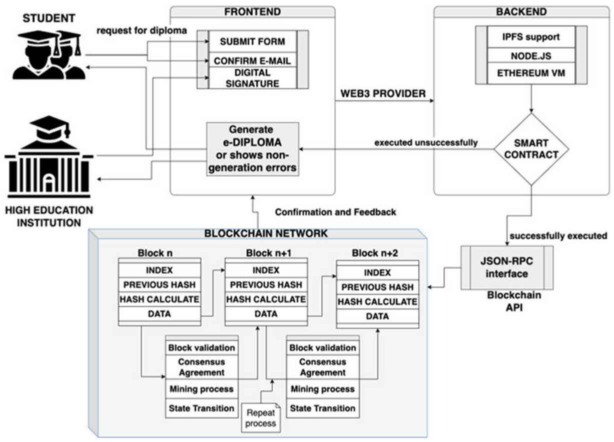

FIGURE 3. Simplified architecture of the blockchain system in high education institutions.

same could be adapted for the process of verification or even revocation of the diploma in a higher education institution.

The blockchain system for the generation, verification, and revocation of diplomas would include the following actors: students, higher education institutions, the blockchain network, and the application part of the system, which is FrontEnd and BackEnd. Communication between students and institutions for higher education is done through the application part, namely FrontEnd and BackEnd. FrontEnd represents the design part of the system, making it easy to use both by the student and the academic staff of the higher education institution. The BackEnd is the part in the background that processes all the requests that are made in the FrontEnd part, where it converts all the requests and directs them to be executed. Whereas a blockchain network represents the database, and the platform where all transactions are executed [20].

In the blockchain system architecture in Figure 3, students after having fulfilled all their obligations to the institution of higher education, i.e., have finished their studies, they have the option to request the generation of a diploma. All this is done through the application part of the blockchain system. What is most important during the student's request is the attachment of the student's digital signature, in addition to other data that accurately identifies the student. The essence of the operation of this system is the checking of hash values. Every service that has been executed before in the blockchain system has certain hash values that are stored in the blockchain network. Therefore, in order to generate diplomas, a necessary control of the services and their values is necessary, including all the courses attended, assessments made, payments, etc. The respective institution can only generate the diploma in electronic form and digitally sign it after confirming that the student who made the request has all of the unique hash values created at the beginning. The same process is also used for verification of the diploma as well as revocation, which in fact represents the deletion and regeneration of the diploma from the beginning.

B. RELATED SURVEYS

The application of blockchain systems in higher education institutions, in particular for the generation, verification, and revocation of diplomas, is a challenge in itself. In this direction, different researchers have investigated challenges, difficulties, and different frameworks on how to achieve that process [36], [37], [38], [39]. However, there is still no concrete result on how to reach a fully functional solution with the sole purpose of preventing the misuse of diplomas. Also, there is a lack of literature to systematically review and document the application of blockchain systems for HEIs, specifically for the generation, verification, and revocation of diplomas. A challenging factor for the blockchain system for data generation and verification is also data auditing and privacy. One of the alternatives in this direction is the creation of a framework for the management of distributed data in the smart data grid, which will above all enable detailed control of data access, data management while maintaining traceability. The execution of the smart contract even off-chain, with the sole purpose of faster execution and increasing the performance and credibility of the services, can be achieved by creating mechanisms, such that the storage of the data is done in blockchain cloud storage using encryption algorithms, while data computing is done in trusted execution environment, such as Intel SGX [40].

In Table 1, we showcase a summary on the features of past surveys. It is important to note that none of these surveys are systematic, which is the main issue the current paper addresses. Characteristics of blockchain applications in the education domain and a comparison with similar research are included in [36], and [38]. However, the authors do not explore the issue of integration, verification, and revocation of diplomas through the blockchain system, which is investigated in our work. Moreover, Kumutha et al. [38], estimates that very little attention is paid to transparency and security and their implications for generating and verifying diplomas. Ghazali et al. [37] reviewed the security aspects of blockchain and introduced a blockchain framework for diploma verifications, however, details and motivations on how the system can be implemented practically and what tools are needed for the implementation, are not provided. Lastly, Renato et al. [39], reviewed blockchain solutions applied in the educational landscape. There are two main limitations to this review. First, there is no framework for categorizing the papers on how a blockchain system can generate and verify diplomas. Second, the scope of the work is general, and the authors do not follow any particular protocol in the review process. Another recent review was conducted to examine blockchain-based digital certificate verification approaches [41]. The differences between various applications, their implementation mechanisms, and the corresponding challenges were reviewed. However, the

TABLE 1. Summary of retrieved past related reviews.

Studies	Features
[36]	Characteristics of some blockchain applications for education, comparison with some similar research, and a brief description of technical issues.
[37]	Blockchain security issues, the proposal of a framework for the implementation of Hyperledger Fabric in the creation of a blockchain system for the verification of degrees.
[38]	Introduction to blockchain, makes a comparison of some educational applications and their challenges regarding the application of blockchain in education
[39]	For the search query "diploma and blockchain", the papers have been presented as a table, where for each, the contribution of that paper to this topic has been given. Then some blockchain initiatives in education are described.
[41]	A review of a number of blockchain-based digital certificate verification systems is presented in this study. Papers are compared in terms of their goals as well as potential process issues in the future.
[43]	The characteristics of blockchain, types of blockchain are described. Analysis of related works and some educational models are explained. Challenges for the adaptation of blockchain in education are also described.

main limitation of this work is the methodological approach; namely, the authors do not apply any typology of literature reviews, nor do they follow a rigorous review protocol, as indicated by Xiao and Watson [42].

These distinctions provide the rationale and foundation for a systematic review of the blockchain systems for diploma verification. The main characteristic that can be seen in these other works is that the proper structuring of a review is missing.

III. RESEARCH DESIGN

A. PROCEDURE

We followed the procedures outlined by Moher et al. [19] to complete this SLR (Systematic Literature Review). Finding the most effective methods by analyzing data is the main goal of SLR. This method asks focused, narrow questions and adheres to a strict set of rules. The studies' quality is thoroughly examined, and any reviewer-induced biases are sought out and systematically removed. In addition, a research protocol must be devised [44].

Our search strategy utilized a four-step PRISMA approach to ensure that all applicable studies were identified and evaluated. Figure 4 depicts the overall search process. The PRISMA first step was to create a research protocol by settling on a research question, defining a set of search terms, and identifying the bibliographic databases to search. The inclusion criteria were applied in the second stage, and the exclusion criteria were applied in the third. The process was finished with the collection and examination of data.

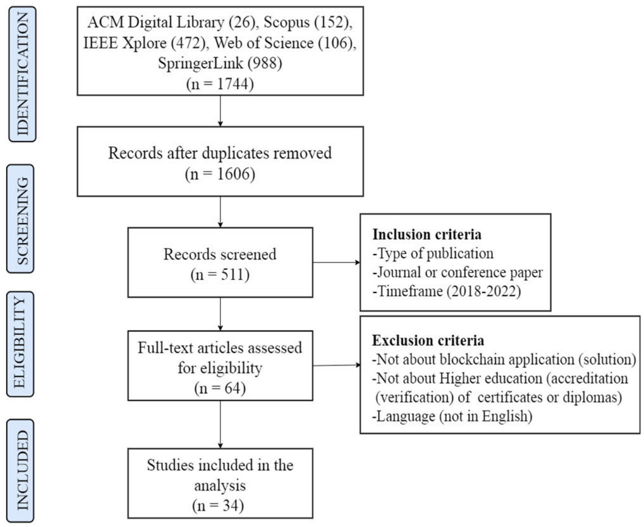

FIGURE 4. PRISMA search methodology.

The research questions (RQs) to drive this study are as follows:

- RQ1: What are the opportunities of blockchain technology towards the prevention of diploma and certificate falsification in higher education institutions?
- RQ2: What platforms, frameworks and practical, real-world solutions have been developed to overcome the falsification of diplomas in higher education institutions?
- RQ3: What are the current developments and potential challenges of the automatic generation of diplomas?

B. SEARCH STRATEGY AND DATA COLLECTION

Stage 1 entails developing a research protocol, determining a research question and keywords, and identifying bibliographic databases, as noted in [19]. For our search purposes, we used the following online research databases and engines: ACM Digital Library (DL), IEEE Xplore (Xplore), SpringerLink (Springer), Scopus (Scopus), and Web of Science (Web of Science). The query terms used are displayed in Table 2. When creating a search query, each group of keywords is joined together using the OR operator, while the groups themselves are joined together using the AND operator.

In the search strategy process, stage 2 is referred to as the screening stage, and it involves the application of inclusion criteria. At this point, the studies that were relevant were chosen based on the following criteria: (a) the publication must be a paper presented at a conference or published in a journal that applies peer review; (b) the papers must have been published sometime between 2018 and 2022; and (c) the papers must be written in English. This decision is based on the findings and background of previous studies. Study designs in papers published before 2018 were not appropriate to answer particular research questions. Therefore, we have

TABLE 2. Search string (query).

("BLOCKCHAIN")
AND
("ACADEMIA" OR "HIGHER EDUCATION INSTITUTION" OR "UNIVERSITY")
AND
("VERIFICATION" OR "ACCREDITATION")
AND
("DIPLOMA" OR "CERTIFICATE")
AND
("FRAUD")

TABLE 3. Studies found in different academic repositories.

Year	ACM DL	IEEE Xplore	Scopus	Web of Science	Springer Link	Total
2018	3	33	4	2	5	47
2019	2	36	20	7	4	69
2020	8	32	26	17	12	95
2021	4	39	44	34	17	138
2022	9	30	56	39	28	162
Total	26	170	150	99	66	511

selected a well-balanced publication year duration for this SLR in order to have reliable data with which to address the objectives of this review. As shown in Table 3, following the application of the aforementioned criteria, a total of 511 records found in different repositories were accepted as relevant studies for the purpose of further exploration and screening, out of a total of 1606 papers.

It is important to note that we did not include for analysis any papers that lacked a complete text or were written in a language other than English. These papers were excluded from consideration.

C. SELECTION OF RELEVANT STUDIES

At stage 3 of the application of the exclusion criteria, studies that were not about using blockchain technology in higher education or verifying diplomas were eliminated. At this point, all of the titles, abstracts, and keywords were analyzed in order to determine which papers qualified for the subsequent stage. It was determined that a total of 64 papers should continue to be included in the analysis. In addition, after carefully reading and observing the eligible papers, it was discovered that thirty out of sixty-four papers lacked full text, or were narrative review papers, without providing rich information on the blockchain-based diploma verification process. Because of this, those papers were disqualified, which brought the total number of relevant papers to 34.

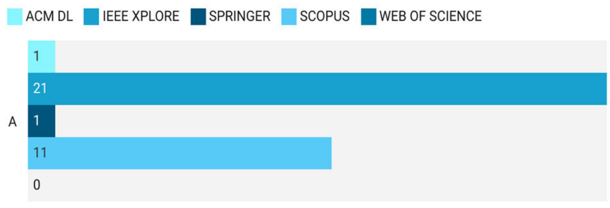

FIGURE 5. Distribution of research papers in academic repositories.

In Figure 5, we present the total number of the selected studies identified during the last stage. From the figure, it is clearly seen that the most scientific papers are from IEEE Xplore, with 21 papers, followed by Scopus with 11 papers.

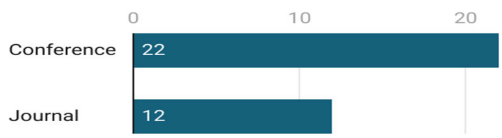

FIGURE 6. Number of collected conference and journal papers in 2018-2022.

Figure 6 showcases the distribution of studies among the 34 papers; 22 were conference papers while 12 belonged to journals.

A detailed summary of the relevant papers, their description and correlation to the research questions is provided in Table 4.

D. LIMITATIONS AND THREAT TO VALIDITY

Any research work involves a number of restrictions. Several factors should be considered when evaluating this systematic review of the literature, as they may impact the validity of the findings. These factors include:

- Only papers written in English-language were chosen for the study. We discovered related articles in other languages while searching the research databases; these articles are not included.
- The included relevant papers in the study are articles extracted from the six digital research databases presented in Figure 4. Therefore, we may have missed papers that were indexed in other digital libraries.
- Only scholarly journal articles and conferences were chosen for this study. Non-peer-reviewed scientific studies were not included. This includes brief articles, experience reports, and assimilation studies, which typically present work in progress or preliminary studies deemed to have little relevance to the field.

- We did not include papers published prior to 2018 since our search did not yield enough relevant studies that were in the context of our study and that could have given us sufficient information to answer the research questions, evaluate the evidence critically, and draw the appropriate conclusions. In this study, only works published between 1 January 2018 and 25 November 2022 were chosen. There may have been conference papers presented before November 25, 2022, that were not published by the study's cutoff date, so they were not included in the literature review.

IV. THEMATIC ANALYSIS

The SLR approach must be well described in order for literature reviews to be trustworthy and independently reproducible [76]. This process also entails the qualitative analysis and assessment of the relevant papers. For conducting the qualitative analysis of the papers, a thematic analysis to cluster and synthesize analytical themes was used. Thematic analysis is well suited for methodically analyzing a broad range of qualitative information in order to improve accuracy and sensitivity in data comprehension and interpretation [77]. Multiple iterations of careful reading and coding are used in the thematic analysis to find and organize dominant, recurrent, or unexpected themes. There are six stages to this process: *familiarizing with the data, creating initial codes, looking for themes, reviewing themes, defining themes*, and *naming the themes*, as described in [78]. In our particular instance, the overarching process yielded a total of six themes, each of which is examined in greater depth in the following sections. The 34 papers were organized into groups, and common threads were searched for and categorized into themes. All authors engaged in conversation in order to finalize and name the themes, and they continued their conversation until an agreement was reached. Table 5 presents the identified themes and their relationships with the relevant papers.

After having identified the list of relevant studies and themes, the next step was to explain and analyze the themes so that the research questions could be answered.

A. THEME 1: TYPE OF BLOCKCHAIN

The application of blockchain in higher education systems has a lot of challenges, and among them is the classification of the services that the system offers as public or private. This classification is good to consider in the early stages of creating the models and frameworks since the blockchain itself is also divided into private, public, and consortium [52]. The difference between these types of blockchains lies in the transparency of the services they offer. In the public blockchain, all services are public, transparent, and permissionless; however, the execution of the request is slower and consumes more energy, unlike the private blockchain, where services are executed faster [70]. Consortium blockchain is otherwise known as a hybrid mode of operation, where some services are public and some are private, depending on the nature of the system being created and the policies of the respective institution [38].

From the reviewed papers, it is obvious that blockchain technology cannot be applied in all fields of education because education is not an industry, and students are not cryptocurrencies that can be executed [79]. Hence, there is a lack of research interest among researchers in this direction, as most of the research is oriented only to cryptocurrencies and the economic benefits that this technology brings [62]. The selection of a public over a private blockchain depends on the type of services for which the blockchain system will be implemented in a particular institution [23]. However, if the system is more comprehensive and starts from the period of student registration until the end of studies, i.e., from the enrollment process until the generation of the diploma, it is more than necessary to use the consortium blockchain, i.e., to use two types of blockchain, public and private [54]. Public services of HEIs can be classified those documents that the university issues to society (for example, diplomas, certificates, and certificates of passed exams), so that anyone could check their validity and the accuracy of the data in those documents at any time [23]. Private services in the blockchain system can be categorized as all services within higher education institutions, where teachers, students, and administration will have access to record transactions related to the student file (this system would be more resistant to security breaches than traditional database-based systems) [22]. When classifying services as private or public, great care must be taken to safeguard the privacy of data, and the relevant institution's policies must be rigorously adhered to.

B. THEME 2: AUTOMATIC GENERATION OF DIPLOMAS

The automatic generation of diplomas and many other documents in higher education institutions would avoid any possible misuse that may occur [57]. However, to what extent such a process is possible and how it can be achieved remains a challenge! To accomplish this process, the blockchain must first be installed during the first stages of student registration, and the entire process should be carried out online and through the blockchain system, including payments, evaluation by professors, exams, and credits earned [54]. Automatic generation of the diploma is only possible when the student has completed all exams and payments and has submitted an online request for diploma generation. In the interim, the system examines the student's obligations, including payments and examinations, without requiring the student to take any action. This would prevent any other user from accessing the system during the generation of the credential, but the diploma would be generated automatically and without intervention for a brief period of time, in contrast to traditional universities where this process is longer [57]. Such a process that can be generated automatically would facilitate the diploma verification process, and the security of

TABLE 4. A summary of the identified studies and their correlation with the RQs.

Studies	Objectives	Relation to RQs
[8], [13], [33]	platforms for generating, verifying and revoking diplomas	RQ1, RQ2, RQ3
[47]	degree verification	RQ2
[48]	monitoring student progress	RQ1
[49], [50]	automatic management of student files	RQ2, RQ3
[51], [52]	pilot projects for generation and verification of diplomas	RQ1, RQ2
[53]	an overview of verification of diplomas, a design of a system	RQ1, RQ2
[54]	a model for student enrollment	RQ1, RQ2, RQ3
[33], [55]	real-time monitoring, generation and verification of diplomas	RQ1, RQ2
[56]	a model for the process of holding exams and verifying diplomas	RQ1, RQ2
[57], [58], [59]	models for verification based on Ethereum platform	RQ1, RQ2, RQ3
[60], [61]	frameworks for generation of academic documents	RQ1, RQ2
[62]	national blockchain platform for verification diplomas	RQ1, RQ2
[63]	the Merkle tree model for verification diplomas	RQ1, RQ2
[64]	model based on crypto-governance	RQ1, RQ2
[65]	design the blockchain system through UML diagrams	RQ1, RQ2
[66]	a private blockchain system for diploma verification	RQ1, RQ2
[37], [67]	blockchain systems based on the Hyperledger Fabric platform	RQ1, RQ2
[68]	generation of smart certificates	RQ1, RQ2
[69]	Cerberus, an on-chain smart contracts system for verification	RQ1, RQ2
[70]	blockchain system based on quantum cryptography	RQ1, RQ2
[71], [72], [73]	blockchain systems based on the Interplanetary file system	RQ1, RQ2, RQ3
[74]	testing blockchain system using the RISC-V architecture	RQ2, RQ3
[75]	verification of diplomas based on multiple signatures	RQ1, RQ2

TABLE 5. Themes and their relation to the relevant papers.

Themes	Studies
Type of Blockchain (Classification)	[37], [45], [46], [52], [53], [56], [57], [59], [60], [61], [63], [65], [66], [67], [69], [70], [73]
Automatic generation of diplomas	[13], [45], [46], [49], [51], [53], [56], [57], [58], [59], [61], [65], [71], [74]
Security and transparency	[33], [45], [46], [47], [49], [51], [53],[56], [57], [58], [59], [60], [61], [63],[64], [65], [66], [67], [68], [71], [72],[74], [75]
Adaptability	[50], [53], [56], [60], [71], [72]
Enabling technologies	[37], [45], [47], [48], [50], [53], [54], [57], [59], [66], [71], [72], [73]
Conceptual models and frameworks	[13], [33], [37], [45], [46], [50], [51], [52], [53], [55], [56], [58], [60], [61], [62], [63], [64], [65], [66], [67], [68], [69], [70], [72], [73], [74]

the data would increase since it could be generated without the intervention of any third party.

The automatic generation of diplomas, their verification, and their regeneration (due to possible problems that may appear or technical errors) is a transparent process, easily accessible, and above all, a process that would keep track of any intervention in the system [64]. Automatic generation of diplomas through the blockchain system also eliminates the process of document notarization, since in many countries such a process is still active, whereas with the automatic generation of diplomas, each of them is digitally signed, and the same can only be generated and issued by the relevant institution [46].

The automatic generation of the diploma or even certificates is possible through the smart contract, since the smart contract is executed only after the prerequisites are met, respectively only after the data is verified, then the diploma can be generated or verified [68]. Such a process undoubtedly requires a lot of work, presents challenges, and, above all, ensures the safe transfer of all preliminary diplomas to the blockchain system, which must be carried out correctly and without errors.

C. THEME 3: SECURITY AND TRANSPARENCY

Data security plays a very important role in any system that deals with data management, since any decryption of data can lead to major disasters, violations of authority and privacy, and even the misuse of personal data. Thus, when designing a blockchain system for higher education institutions, it's very important to keep roles, access rights, and permissions separate [73]. Diploma administration in higher education institutions is a service that can be easily managed by blockchain, as diplomas can be viewed as database transactions, and the same can be more easily managed in the blockchain's distributed network [80]. What makes blockchain technology special and more secure is hash coding, which is a very important process as it identifies each process [58]. Every change in the process changes the hash code. A characteristic of the hash code is that the inverse process cannot be generated; if a process is accompanied by a certain hash value through the hash generator, we cannot return to the starting point, which makes it difficult, for instance, in the process of revocation of diplomas when technical errors are made [56].

Another phenomenon that makes blockchain technology and its services safe is the way they operate in a decentralized form [62]. This means that there is no control by certain individuals, but all security depends on the system itself, the algorithms that are used, the system architecture, the framework, and the security layers that are used within the system [65].

It is very important to emphasize the inclusion of quantum cryptography and quantum computers in blockchain systems. From the latest research done in this direction, it appears that quantum computers have extremely great power for the management of blockchain systems and, at the same time, for protection from possible attacks by malicious individuals [70]. The creation of smart contracts and the programs used for their execution are of great importance for the security of blockchain systems [72]. Security and transparency are always two processes that are closely related to each other [32].

Every process that is transparent also requires higher security, since it is the target of various attacks. However, security and transparency depend on the type of blockchain [43]. The blockchain system for HEIs must provide transparent, always-accessible services that provide students with a variety of services at all times, whether for diploma generation, verification, or regeneration due to potential technical errors.

D. THEME 4: ADAPTABILITY

Often, due to economic and time-related reasons, it is preferred to use previously created software platforms, which can be adapted and reused in other applications of the same nature [80]. The reuse of existing platforms or even platform architectures is possible if the platforms are open source or public blockchains [81]. Even some established educational platforms offer the possibility of reusing their architectures without changing the transaction distribution policies, accepting the existing policies of the related platform [70]. In this context, a national platform that would be implemented by all institutions of higher education could also be enhance the process. In such a case, it would be even easier for the verification of diplomas in particular, because it is very easy to check if the diploma presented by the appropriate person belongs to that institution or not, through the online blockchain system that offers services uninterruptedly [46]. Nevertheless, it is very important to pay great attention to security and the authentication method during the adaptation of educational platforms [52].

As indicated by Hsu et al. [82], there is a tendency to prefer generating diplomas through blockchain systems. However, in the case of adapting an existing architecture, the most important challenge revolves around the authentication of students. For higher security during the generation of diplomas, it is necessary that, in addition to the needed digital signatures, other mechanisms for security that help with more accurate verification should be used. Among them is the use of cryptographic schemes during the creation of the architecture of the blockchain system, as well as the use of identification mechanisms such as facial recognition or fingerprint identification [82].

The architecture that is used during the creation of a blockchain system is the basis for the functionality of the system and, above all, its security [70]. However, it is crucial to analyze the pros and cons of the existing, publicly available systems, and based on those parameters, it may be advisable to create a new blockchain system for higher education institutions. In this way, a more secure system will be created, along with all of the necessary mechanisms that provide all of the system's services, such as the generation of diplomas, their verification, and even their annulment.

E. THEME 5: ENABLING TECHNOLOGIES

In order for the blockchain technology to function properly, it must have the auxiliary tools to operate, the databases where the data are stored, the related techniques to carry out the execution of the transcripts, and the operating network, among others [72]. During the creation of a blockchain system, it is necessary to have a programming language that is dedicated to the creation of smart contracts. Smart contracts actually present the services that users create in that system [45].

There are various programming languages that enable such a thing, but Solidity is the most adequate programming language for creating smart contracts [83]. For smart contract testing, since each execution in the blockchain network has its own cost, complementary applications are used for compilation and execution that can also be found online [84]. They have no real cost but are actually executed by calculating the cost of the transaction in Ethereum gas [85]. For the creation of virtual blockchain infrastructure, applications are also used depending on the platform used, so if Ethereum is used as the platform, the Ethereum Virtual Machine is preferred [57]. The reason EVM is used more is that it allows developers and practitioners to run programs the way they prefer without having to involve predefined methods and commands [50]. It is more than necessary for the creation and design of the system to use interfaces that are easier for people who are not computer literate. For this reason, web-oriented applications are used, including HTML, CSS, and JavaScript [72]. Depending on the nature of the system, various databases or distributed file storage systems, such as IPFS (InterPlanetary File System), are used to store data in the blockchain.

Blockchain-based systems for higher education institutions are systems that necessitate data security, secure data transmission, quick data access, and cost-effectiveness. On the basis of a thorough analysis of these factors, an architecture for the operation of the blockchain system and all the auxiliary tools required for optimal operation must be developed in advanced.

F. THEME 6: CONCEPTUAL MODELS AND FRAMEWORKS

One of the most challenging tasks during the creation of any system, including the blockchain system, is the creation and definition of the model and framework, as an essential component of blockchain technology [61]. The framework actually plays the role of converting the smart contract into an understandable language to be executed by the machine, respectively, with other tools that enable the testing, control, and verification of the smart contract [86]. One of the frameworks used in the creation of blockchain systems is the Truffle framework [87], which actually represents an opportunity to make the work of developers and practitioners easier and offers more opportunities for the creation of the blockchain system [39]. Another framework used in the blockchain system is the Lisk framework [49], which does not use ledgers but its own private tokens. For web applications in blockchain systems, the ReactJS framework is needed, which only requires the use of NodeJS and actually represents JavaScript on the server side [66].

For higher education institutions to switch from traditional data management systems to the blockchain system, a blockchain framework should be first established [61]. This framework must be based on well-researched and tested architectures and mechanisms [74]. One of the frameworks that is used when dealing with a consortium blockchain system is the Hyperledger Fabric framework [37], which presents a framework with previously defined conditions such that only participants who have obtained permission in advance can join the blockchain network and observe or even perform certain transactions. The advantage of using this framework is its transparent nature, free access to networks, prior authentication of all participants in the network, and a certain time limit for any transaction that is carried out [82]. The conceptual model and the framework are the building blocks for making a blockchain system that is safe and, most importantly, works. This is because if the system is well designed with all the details, including the architecture of the system's operation, the implementation part is an easier job and is done much faster [45], [88].

During the creation of a blockchain system, a new framework can be created from inception, or existing frameworks can be modified using already-created tried-and-true educational platforms. Both approaches are subject to obstacles, and this is the most difficult phase of the blockchain system development process for HEIs. Verification, generation, and revocation of diplomas are processes that involve the student's privacy; therefore, it is of the utmost importance, during the framework's construction, to distinguish which issues should be treated as public and which should be treated as private.

V. FINDINGS

A. ANSWERS TO RESEARCH QUESTIONS

In the following sections, we elaborate on the findings from the research questions that were crucial for this systematic review.

RQ1: What are the opportunities of b lockchain technology towards the prevention of diploma and certificate falsification in higher education institutions?

Research shows that there are misuses in higher education institutions, despite the efforts to prevent them. Even today, we have different cases of misuse and falsification of documents, especially diplomas, an important document for people seeking employment in public and private institutions. Blockchain technology would undoubtedly help in this context; the generation and verification of diplomas would be done precisely through the system, and the opportunities for falsification of documents and especially diplomas would be prevented. Multinational companies, such as IBM and Alibaba, among others, are doing their best to promote blockchain technology in other countries of the world, while Asian countries, such as Japan and South Korea, are leading countries when it comes to the application of this technology. It is also worth noting that among European countries, Estonia is trying to digitize every service and turn the country into a digital state where every service is based on blockchain [13].

When we talk about forgeries in institutions of higher education, in addition to the forgery of diplomas as an important document, we also have cases where the diplomas are generated by non-existent institution. In such cases, forgeries could be made within the diploma by changing the data inside, or falsifications are made during the notarization process when a student performs abroad, or even falsifications could be made by third parties or administration employees by changing student files deliberately. Blockchain technology offers the possibility of verifying credentials without the need for an intermediary or third party since all data from the beginning of the studies to the graduation will be stored in the blockchain and any possible changes will be observed [46].

The advantage of using blockchain technology in higher education institutions is transparency and online access to public data. Legitimacy is not compromised, and there is no need to worry about data integrity as blockchain takes care of data immutability. Whatever doubts we have about the degree records, they can be easily verified in the blockchain system [61]. When using blockchain systems, it is preferable to use quantum and super quantum computers as they are more resistant to cyber-attacks in a distributed blockchain network [70]. A blockchain system for higher education institutions would not only prevent fake degrees but also prevent fake institutions and the recipient of the diploma, who may be a fake person. This can be done using biometric identification and Hyperledger Fabric mechanisms, through which data access is controlled [82].

In order to prevent any misuse and have evidence of it, it is recommended to install a blockchain system in higher education institutions, from the enrollment process to the awarding of the diploma. In this way, the students will be continuously followed up on for every assessment, evidence in the lessons, and payment made on time, and in this way, every doubt can be easily verified [51].

RQ2: What platforms, frameworks and practical, real-world solutions have been developed to overcome the falsification of diplomas and certificates in higher education institutions?

The literature indicates that most practitioners and developers are focused on cryptocurrencies and the benefits they bring [57]. Thus, they aren't particularly interested in making the blockchain applications operational and tailored for HEIs. When it comes to the creation of a blockchain application for HEIs, it is noteworthy to mention that it is difficult to adapt the application for all the modules of the system, or to create smart contracts that will respond to all the necessary services for such a system.

As for the tools needed to create a blockchain system, the application through which it will communicate with the blockchain network is needed first, followed by the database or file system that will serve for the storage and distribution of data in the network, web technologies that will be used for the design of the, and standards that enable the creation and distribution of applications from the desktop to the cloud [72]. Almost all pilot projects that have been created must have used these programs to reach a practical solution, although obviously different researchers may use different applications that aim to accomplish the same tasks. For example, in the pilot project performed by Badlani et al. [73], the Ethereum platform is used to communicate on the blockchain network, Ganache for smart contract testing, Solidity for smart contract programming, Truffle to host smart contracts on Ganache, and Metamask cryptocurrency is used for conducting transactions. Django REST Framework is used or the backend part, and for the frontend, HTML, CSS, and JavaScript are used.

When it comes to the platforms used to implement the blockchain network, the most open platforms in terms of network access, where anyone can make transactions, are Ethereum and Bitcoin, while Hyperledger is a platform with limited permissions, where only previously defined miners can be part of the network for carrying out transactions [37].

Many models, frameworks, design architectures, and even practical solutions for the generation and verification of diplomas have been proposed in the literature. Many of them were only pilot projects that have been implemented only through models, representing only architectures without any practical implementation, but those that have found application, have been practically tested. Those platforms that are developed and proposed by the research community are presented in Table 6.

The main characteristic of these platforms is that they are mostly implemented on the Ethereum blockchain, and the services are executed in the form of smart contracts.

RQ3: What are the current developments and potential challenges of the automatic generation of diplomas?

With the implementation of the blockchain system in higher education institutions, there is also the possibility for the automatic generation and verification of many services, including diplomas. To date, there is no existing public platform for HEIs that enables the automatic generation of diplomas without intermediaries, although there are proposals and opinions in this direction from various researchers. With the application of the blockchain system in institutions of higher education, misuses regarding the generation and verification of diplomas are prevented. Nevertheless, every automatic process implies removing the intermediary to reach the result. Automatic generation would make it possible to overcome all concerns about possible abuses because most of the work would be done without the intervention of the administrators of the respective institution [51].

A very important process during the automatic generation of diplomas and their verification by the blockchain system is undoubtedly the university registration process. Since the blockchain system is applied at the beginning of the student's studies, including the application, registration in the specific course, semester payments, student evidence, and evaluations by teachers, the automatic generation at the end of the diploma is much easier. This is because the system itself will generate the data depending on the inputs given by the student, the administrator, or teacher himself in the specific case [54]. Automatic generation is challenging and requires a lot of work and commitment during the design of the mechanisms, since for any possible error in the given inputs, the diploma must be revoked, and the revocation of the diploma is a process in itself full of other related challenges.

Unlike the conventional applications that users are installing, whether on a particular operating system or the web, blockchain systems for each smart contract execution have certain costs. The more executions that are performed, the more will increase the cost of the blockchain network on which these services are executed. Also, cost and the platform where the services are executed play an important role in the execution time of those services [57].

Stana et al. [49] has proposed a model which has the ability to automatically detect fake institutions using artificial intelligence via automatic data sorting. Ali et al. [58], considers that in blockchain systems for the generation and verification of diplomas, some processes can be carried out automatically, starting from electronic verification, authentication, privacy verification. Thus, making the role of third parties unnecessary during these processes.

TABLE 6. A summary of the Blockchain educational platforms for diploma verification.

Study	Name	Solution (standard)	Public/private	Execution of services
[13]	CVSS	System	Ethereum	Smart contract
	OPENBADGES	Digital badge	Ethereum	Smart contract
[49]	G-CLOUD BRIEFCASE	Electronic archive	Ethereum	Artificial Intelligence
[59]	BCDIPLOMA	Credential platform	Ethereum	Smart contract
[60]	EDUCTX	Credit platform	Ethereum	Proof-of-Stake (POS)
	DISCIPLINA	Platform (a proof of stake)	Ethereum	Proof-of-Stake (POS)
[67]	OPENCERTS	Platform	Ethereum	Smart contract
	BLOCKCERTS	Standard	Hyperledger fabric	Proof-of-work (POW)
	BTCERTS	Open source	Bitcoin	Cryptographic technique
	BLOCK.CO	Platform	Bitcoin	Proof-of-work (POW), Proof-of-reputation
[69]	CERBERUS	Platform	Ethereum	On-chain smart contract
[71]	BCERT	System	Ethereum	Smart contract
[73]	EDUCRYPTO	Cryptocurrency education	Ethereum	Smart contract

Process automation, as important as it is for blockchain systems, is also difficult to apply and is associated with many challenges related to the process of generating and verifying diplomas. The smart contracts themselves are executed automatically after the prerequisites between the two parties are met, but it is challenging since they are immutable, and the challenge relies on the creation of a standard smart contract for the generation and verification of diplomas as well as the possibility of updating them [89], [90].

Maintenance of the system also poses a challenge to the automation of processes in blockchain systems for the generation and verification of diplomas. It is a fact that the maintenance of blockchain systems is higher than that of centralized systems. Therefore, it is envisioned that by employing artificial intelligence, automatic monitoring of the system and alerts for any suspicious issues can be achievable, as well as the system's ability to learn, develop, and repair flaws from previous actions [91].

VI. DISCUSSIONS AND IMPLICATIONS

A. IDENTIFIED GAPS

The technological innovation behind blockchain enables educational institutions to collaborate more effectively, which in turn makes it possible for students to share their knowledge with one another and advance their level of expertise in the subjects they are studying [32]. Developing new systems or integrating blockchain technology into pre-existing systems at educational institutions presents a number of challenges, some of which are specific to the field of application.

In our systematic review, we found that there is a need for more work to be done on blockchain-based systems for diploma verification in many directions.

The list presented in Table 7 summarizes some of the most pressing concerns, where each challenge is mapped to our research questions.

TABLE 7. Identified gaps linked to research questions.

Identified Gaps	Research Question
Complex process of transferring diplomas	RQ1
The demand for maintenance	RQ1
Inadequate security mechanisms	RQ1
Need for auxiliary tools	RQ2
Intermediaries	RQ3
Limited frameworks/models	RQ3

1) **Complex process of transferring diplomas.** One of the challenges is the process of transferring diplomas generated by the institution of higher education from the establishment to the implementation of the blockchain system. This process is quite difficult and requires maximum commitment from the institution's administration so that the data is verified accurately, and no mistakes are made during their insertion into the system [46].
2) **The demand for maintenance.** Most of the approaches identified in the studies explored in this SLR circumvent the need for maintenance. The maintenance of the system is of primary importance, since the institution does not have the equipment, adequate personnel for maintenance. It must therefore assign an external company for maintenance, and in this aspect, it depends on what the cost of such a service will be [32].
3) **Inadequate security mechanisms.** Improved security during diploma generation requires the use of additional security mechanisms, such as digital signatures, that aid in more precise verification. These include the incorporation of biometric identifiers like a user's face or fingerprints into the blockchain's architecture design [82], and the use of cryptographic schemes during the design phase.

4) **Need for auxiliary tools.** For the implementation of a blockchain system, more auxiliary tools are needed, i.e., more support tools that enable the practical implementation of that system. In non-blockchain systems, a programming language, a database, and the security mechanisms used for data transfer are enough [72].
5) **Intermediaries.** The process of automatic generation of diplomas is difficult to achieve without intermediaries, but not impossible [46]. Because most of the work would be performed without the intervention of the institution's administrators, automatic generation would make it possible to eliminate all concerns regarding potential abuses, even in the blockchain system [51]. However, this challenge was still not fully addressed or solved in the reviewed papers.
6) **Limited frameworks and models.** We found no literature, framework, or model that shows exactly how the entire process of generation, verification, and revocation of diplomas in higher education institutions can be automatically generated in a practical way. The process of automatic revocation is difficult or impossible, and verification is the only process that can be executed without the intervention of a third party [13], [73], [92].

B. RECOMMENDATIONS AND FUTURE RESEARCH DIRECTIONS

In this section we draw attention to several research directions that researchers in the field can pursue while considering the development of blockchain-based diploma verification systems.

First, from a *scalability and interoperability* perspective, the process of implementing blockchain systems in higher education institutions should go in stages, where first the services that are more easily adaptable should be implemented, up to the generation and verification of diplomas. It is very important to analyze and see the possibility of data transfer from existing databases to blockchain databases, respectively, to analyze the most used blockchain cloud platforms and explore the possibility of data conversion in a secure form. However, in order to achieve the highest performance and scalability in conducting transactions in the blockchain system, a combination of off-chain and on-chain storage should be made, as well as an interconnection of the blockchain networks included in the system [93]. To facilitate transactions without using third-party interfaces, each network has a unique approach to blockchain interoperability. Cross-chain technology thus has enormous promise for allowing blockchain interoperability, which may resolve a variety of problems and eliminate a multitude of limitations on blockchain and other networks. It is also crucial because it enhances chain efficiency, reduces segmentation, and makes it easier for users to interact with different blockchains [94].

Second, from a *security, privacy, and verification* perspective, the verification of diplomas by a blockchain system would facilitate the long and tiring work of the administrators in higher education institutions. Above all, it would prevent possible forgeries, as it would be possible very easily and for a short time to verify that the diploma belongs to the designated institution. However, generating, and revoking diplomas remains challenging, as blockchain security is based on unique hash values. Every revocation of the diploma means changes in hash value, which question the student's identity. More research should be done on blockchain databases and the possibilities of implementing the same in current systems, with the sole purpose of ensuring that the data is initially transferred safely. A viable solution would consider data privacy and data protection regulations (like the General Data Protection Regulation). It's worth repeating that the immutability of data on the blockchain could make it harder to adhere to certain regulations, such as the "right to be forgotten" [95]. Solutions need to consider social and organizational factors, interact with pre-existing technological solutions, and address the issue of archiving previously issued certificates and data.

Third, from a *trust and sustainability* perspective, more empirical research is required to ensure the trustworthiness of this technology. People have gained trust as every service is transparent, secure, and immutable. However, how would the credibility of blockchain-enabled credential-issuing organizations be measured or validated? After analyzing the reviewed literature, we have evidenced that using blockchain enables additional options and benefits, such as new online learning models. There are group discussions, presentations, and research assignments belonging to these online learning classes and models. For instance, Nicosia University is using Distributed Ledger Technology (DLT) to verify credentials for MOOCs. In order to offer trustworthy data storage and management services, Sony Global Education has decided to implement blockchain technology. When it comes to online education, the Massachusetts Institute of Technology (MIT) has also developed a digital badge based on the blockchain. DLT is being used for the first time to keep track of degrees and other academic records at The Holberton School. Here, distributed ledgers use a student ID for each record [96].

Despite these uses, there is still a trust and knowledge gap in the market regarding the potential of blockchain technology in education, especially in the context of verifying diplomas. Blockchain's distributed ledgers hold great promise for streamlining and centralizing management in the academic sphere. Nevertheless, fully-fledged solutions are still missing, and its actual use is partly limited to verifying identities and degrees, and in some cases, paying for tuition and making charitable donations.

It has been determined that the technical and philosophical limitations of blockchain are the primary reasons for its slow adoption in the educational sector [97]. There is currently no working example of a global education blockchain that operates on the same massive scale as cryptocurrencies (in millions). Simply put, there is no compelling reason to carry out its proof-of-work. Thus, future research endeavors may further explore the reasons behind the mentioned constraints to blockchain adoption.

In particular, the alignment of the real application of blockchain in education with an authentic philosophy of sustainable development of education deserves additional research attention. Higher education is a highly regulated activity, which represents another, very important, challenge for the real implementation of blockchain systems. Every real implementation of this system must be fully compliant with the positive legislation framework in the country/region, which could include laws, bylaws, statutes of HEIs, internal rulebooks, decisions, etc. Additionally, the system should enable flexibility in order to be capable of implementing the frequent changes that take place in the legislation, which is a special challenge in itself.

VII. CONCLUSION

Higher education institutions are among the many organizations that have started utilizing blockchain as a new technology. Blockchain technology can be leveraged for the issuance of immutable digital certificates, and it can improve the current limitations of existing certificate verification systems by making them more efficient, trustworthy, and decentralized.

This literature review examines the state-of-the-art related to the adoption of blockchain in the verification of academic credentials, such as diplomas. Three research questions were developed to outline the scope of the review. The initial corpus of 1744 articles that met the search criteria has been subjected to a rigorous quantitative and qualitative step-by-step filtering procedure. Our analysis of the screened records shows that the number of articles exploring this topic has grown steadily over the time period under consideration. During the year 2022, there was a particularly substantial rise in the number of articles that were published. Based on the PRISMA framework criteria, only 34 articles were included for final investigation.

The following six themes were found using qualitative analysis of the reviewed papers: blockchain categorization, automatic certificate (diploma) generation, security and transparency, adapting existing architectures, blockchain technology for preventing forgeries, and conceptual models and frameworks. Each theme was presented alongside relevant examples from the filtered references that met all the criteria for this analysis.

In light of the literature review's findings, we've highlighted several obstacles to widespread adoption of blockchain technology for diploma verification. Automation of processes, the immutability of smart contracts, expensive maintenance, lack of training (knowledge), off chain transfer, big data management through blockchain systems, energy consumption, adaptability, and identity verification are some of these issues. Suggestions and prospective directions have been discussed to address some of these difficulties.

We believe that the findings of this study will inspire future research in blockchain development to further understand its application implications in educational settings.

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