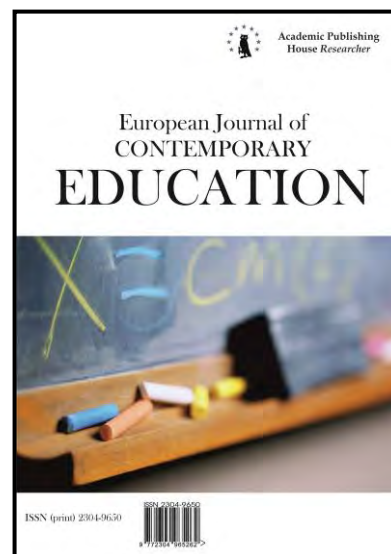




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## Application of Blockchain Technology in Higher Education

Elena P. Fedorova<sup>a,\*</sup>, Ella I. Skobleva<sup>a</sup>

<sup>a</sup>Astrakhan State University, Astrakhan, Russian Federation

### Abstract

Emergence and development of the blockchain technology, which is able to transform into “a most powerful disruptive innovation”, shall definitely concern universities. Moreover, nowadays the blockchain technology meets the challenges that both the system of higher education and the entire society are currently facing. Advantages of the blockchain technology are decentralized open data, absence of forgeries, safe storage of information, and reduction of transaction expenses related to data checkup, control, and verification.

This paper provides a critical analysis of application of the blockchain technology considering with its applicability opportunities and restrictions in education; it also aims to identify the consequences of its influence upon the development of education. The article analyzes real cases when this technology was applied, with the Massachusetts Institute of Technology (MIT) as an example. The MIT applied it to protect and validate the certificates that it issued. Another example is the Sony Global Education that forms individual data on its trainees' competencies and productivity; a third one relates to the University of Nicosia, which was the first to use smart contracts and accept cryptocurrency as a form of payment. The paper also considers the elements of the blockchain technology at universities (both in Russia and outside it), which participate in massive open online courses. It determines the scope of application of this technology in the Russian educational system. In addition, this article provides a literature review related to application of the blockchain technology; the review includes works by such renowned researchers as D. Tapscott, B. Bleir, A. Watters, A. Grech, A. Camilleri, M. Swan, A. Zaslavsky, etc. The paper analyzes the obtained findings of the survey that its authors have conducted among experts, professors, and specialists involved in accreditation.

Thus, the paper provides an analysis of opportunities and restrictions related to application of the blockchain technology in higher education.

**Keywords:** blockchain, higher education, smart contract, digitalization of education, massive open online courses, human capital, transactions, universities.

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\* Corresponding author

E-mail addresses: [lenafedorova@mail.ru](mailto:lenafedorova@mail.ru) (E.P. Fedorova)

## **1. Introduction**

Nowadays the world system of education is undergoing substantial changes related to the development of new technologies and digitalization of the educational environment. Education is becoming mass and personalized simultaneously. According to the global education market intelligence firm, HolonIQ, “**population growth will be a key challenge for the Education sector. By 2035, there are expected to be 2.7 billion students worldwide**”, with slightly more than 500 million today (Spies, Brothers, 2020). The number of students will be growing thanks to Asian and African countries, where approximately 90 % of the population under 30 years old reside. Professional education is expected to apply digital technologies. The world market of education will have achieved approximately 10 trillion USD by 2030. The share of the compulsory 12-year education expenses (K-12) will be 5.5 trillion USD, whereas that of higher education will be 2.5 trillion USD (Spies, Brothers, 2020).

The current share of educational technologies (EdTech) at the world market of education is 3 %, or 165 billion USD (Rakhmanova, 2017). With the average annual growth rate of the market of educational technologies amounting to 17 %, expenses for educational technologies are expected to double by 2025, thus achieving approximately 314 billion USD.

An advantage of digital educational technologies is that personalized education becomes possible thanks to them. The current tendency is that trainees prefer to obtain a set of high-quality professional competences individually. According to Ed Clark, Vice President for Information Technology Services and CIO at the University of St. Thomas, present-day young people have already obtained a digital personality in addition to their real one (Rudich, 2020). Influence exerted upon a student’s “**digital personality**” makes it possible to enhance the quality of education and increase the share of students who complete their studies successfully from 20 % (in the USA in average) to 60 % (at the University of St. Thomas).

The technologies of digital education make it possible to monitor how well a student has mastered new knowledge and skills, correct the learning process promptly; education becomes more personalized and flexible (Rudich, 2020).

Holon IQ determines four breakthrough technologies in the system of education (Spies, Brothers, 2020), expenses for which will have grown by 2025: augmented/virtual reality (AR/VR), artificial intelligence (AI), Robotics, and blockchain.

The blockchain technology presented in 2008 (Nakamoto, 2008) and initially applied to register cryptocurrency transactions is currently widely used in various nonfinancial activities.

Nevertheless, application of the blockchain technology in education is only at its initial stage; only a small number of educational institutions applies it now. At the same time, according to research findings, this technology has an outstanding potential in the sphere of higher education.

This article presents a Systematic Literature Review whose goal is to analyze the main trends and the structure of research activities in this field, as well as identify and systematize cases when the blockchain technology has been applied in the sphere of higher education.

## **2. Materials and methods**

To analyze literature sources related to blockchain in higher education, we have used the Multivocal Literature Review (MLR), which is a form of Systematic Literature Review (SLR). MLR includes so-called grey literature (GL), which is information in news editions, in blogs, on web sites, and in official documents. This information is used as a supplement to reviewed academic literature published in journals, conference proceedings, and monographs.

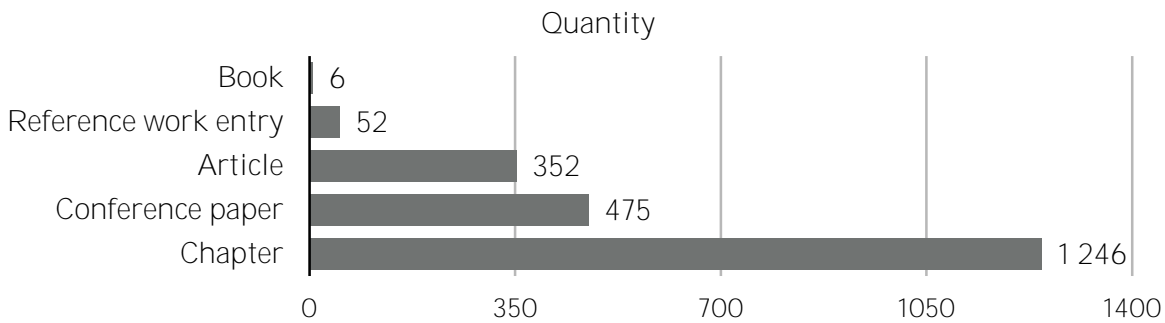
The process of literature review consists of three stages: (1) development of the search line; (2) application of the search line in selected search engines; (3) extraction of documents based on determined criteria.

We have used the following words and phrases in the search line: blockchain, higher education, universities, smart contracts, blockchain in education. At the next stage, the search line has been applied to the following academic search engines: Scopus, Web of Science, Scholar Google, Science Direct, SpringerLink, JSTOR, SSRN, and arXiv. At the third stage, we have searched by headings, abstracts, contents of both academic and grey literature, beginning with the initial page of search results. If any materials did not correspond to the search requirements, they were expelled from our analysis.

The extracted data have been systematized by groups of themes: application, advantages, problems, and prospects. For grey literature, the following quality criteria have been applied: a publication has an author and a data-line; its publisher is known; this source is supported with trustworthy and well-documented references; its author has published other works in this field.

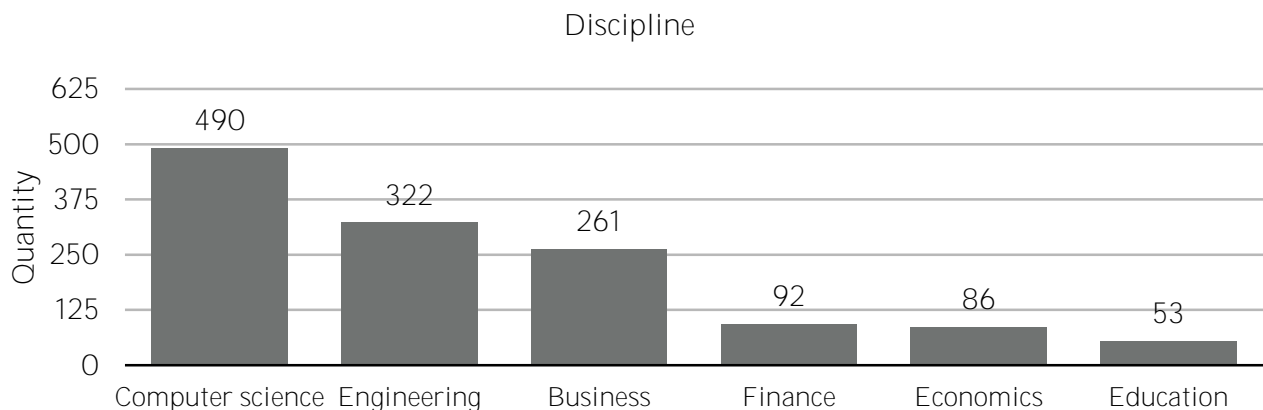
We have analyzed types of academic search engines and databases.

1. In such databases as Web of Science, Scopus, SpringerLink, we have found 2,131 sources by applying the phrase “blockchain in education” as for April 30, 2020. Figure 1 presents their content type distribution.



**Fig. 1.** Content type distribution

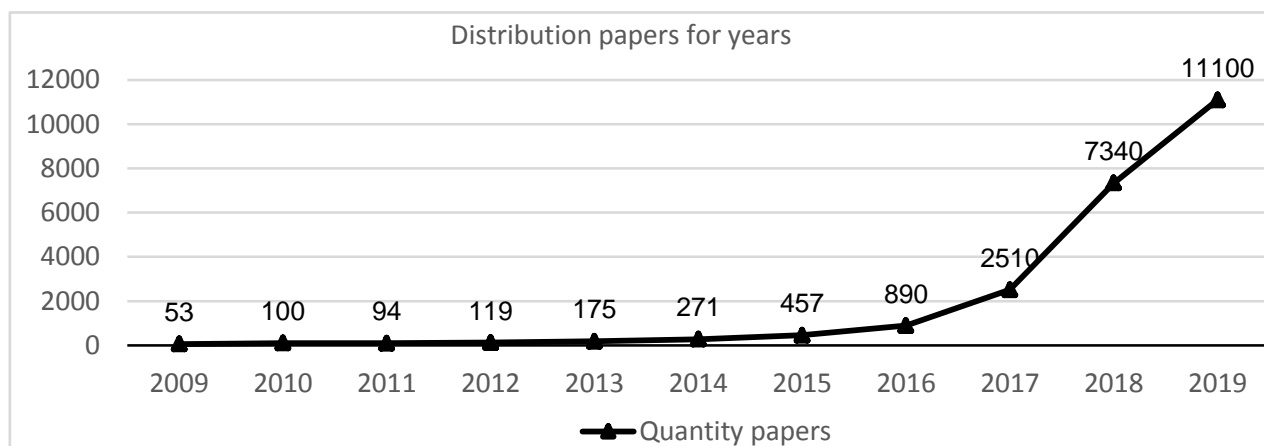
A majority of articles that consider application of blockchain relate to six fields of science: Computer Science, Engineering, Business and Management, Finance, Economics, Education (See Figure 2).



**Fig. 2.** Discipline distribution

Based on academic databases, one could conclude that there is only a small number of research papers related particularly to education – 53. However, there numerous papers related to both education and adjacent areas.

2. The Scholar Google databases contain information on researches from almost all the databases. It makes it possible to track the scientific community’s interest towards a particular field. Once one has typed “Blockchain in education” or “Blockchain for education”, one can track the dynamics of publications year-by-year up to 2019. Figure 3 presents annual (12-month-long) dynamics of publications.



**Fig. 3.** Distribution of papers for time

Our research determines the following temporal limitations to analyze research literature: October 2008 – March 2020. The reason for these limitations is that the cornerstone paper by S. Nakamoto (Nakamoto, 2008) was published in October 2008. That paper stimulated further research in the field of blockchain. There has been a considerable growth in the number of research papers since 2015, when M. Swan (Swan, 2015) published her paper, in which she indicates that it is possible to apply blockchain not only in the field of finances, but also in such areas as public administration, healthcare, education, science, culture, and arts. Adoption of national artificial intelligence development and digital economy transformation strategies by developed countries contributed to a growing number of publications in 2017 (See Table 1). As for March 01, 2020, 48 countries adopted this strategy; thus, research related to digitalization of economy (in particular, in the field of education) became of top priority in those countries.

**Table 1.** National artificial intelligence development and digital economy transformation strategies

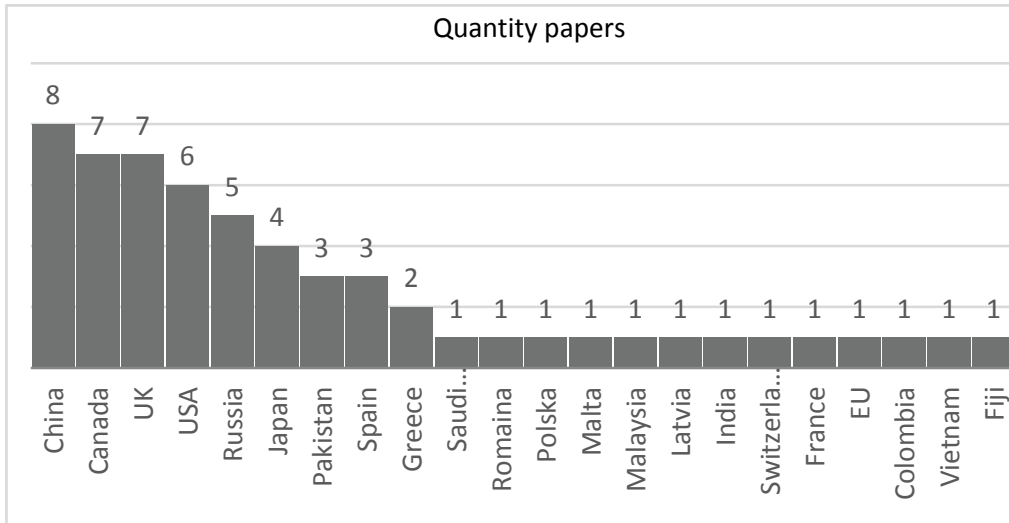
Year	Countries that adopted programs of national artificial intelligence development and digital economy transformation strategies	Number of Countries	Number of Countries (Cumulative)
2017	Canada, Japan, China, Singapore, United Arab Emirates	5	5
2018	Italy, South Korea, India, Pakistan, Kenya, Mexico, Sweden, United Kingdom, France, Ireland, Netherlands, Germany, New Zealand, South Africa	14	19
2019	Denmark, Qatar, Tunisia, United States of America, Australia, Estonia, Malta, Russia, Spain, Austria, Finland, Philippines, Saudi Arabia, Belgium, Colombia, Lithuania, Poland, Czech Republic, Luxembourg, Portugal	21	40
2020 (Jan-Feb)	Argentina, Norway, Chile, Switzerland, Brazil, Israel, Thailand, Vietnam	8	48

We have used several academic search engines to reveal that the largest number of publications concerning application of the blockchain technology in education is in Scholar Google (prior to 2020) – 18,440. Such a large amount is because this system includes research findings in all the world languages; it also comprises the most respectable search engines, such as Scopus, Science Direct, SpringerLink, JSTOR, SSRN, and arXiv. In these systems, our query “Blockchain in

education” has provided us with 1,641 sources, of which we have left only 48 for further consideration.

Of 134 GL sources, we have used only 4 in this paper.

This paper applies materials from 2008 to 2020. Figure 4 presents distribution of research of blockchain technologies by country.



**Fig. 4.** Distribution of blockchain-in-education research by country

Thus, the largest number of publications concerning the blockchain technology in education relates to two countries: China and Canada. At the same time, papers from other countries are also valuable and have a high citation index: Malta, Latvia, Fiji, Vietnam, etc.

**3. Results**

This paper is based on research findings by the most cited authors. To analyze their citation indices, we have used two databases – Scholar Google and SpringerLink.

We have grouped our Systematic Literature Review into three research categories: (1) research papers that determined tendencies in the field of the blockchain technology development; (2) review papers related to the development of blockchain in higher education; (3) specialized papers related to the development of blockchain in higher education.

Findings of Analysis of Research Papers that Determined Tendencies in Blockchain Technology Development

Table 2 presents research papers by authors who developed the theory of blockchain; these papers are the base for specialized research in various fields, including higher education.

**Table 2.** The Most Cited Authors Who Determined Tendencies in the Field of Blockchain Technology Development

Author & Name of Article	Year	Number of Citations	Type of Research Paper	Country
Nakamoto, S. Bitcoin: A Peer-to-Peer Electronic Cash System	2008	10,277	Article	Japan
Swan, M. Blockchain: Blueprint for a New Economy	2015	2,504	Book	UK

Kosba, A.; Miller, A.; Shi, E.; Wen, Z.; Papamanthou, C. Hawk: The Blockchain Model of Cryptography and Privacy-Preserving Smart Contracts	2016	1,166	Conference Proceedings	USA
Buterin, V. A Next-Generation Smart Contract and Decentralized Application Platform	2014	1,078	Journal Article	Canada

Satoshi Nakamoto is the most cited and influential author. In 2008, he published his article **“Bitcoin: A Peer-to-Peer Electronic Cash System”** (Nakamoto, 2008), which described the technology of the new cash system, which he named bitcoin, in a strict academic style, with all the necessary schemes and formulas. He describes an electronic payment system based on cryptography, not on trust. The system works without an intermediary (banks) and resolves the **issue of “double spending”**. **The author suggested a new technology of decentralized digital cash turnover**, which consists of two elements. First, it is the distributed registry (Blockchain), which S. Nakamoto developed; it is a chain of digital transactions in which each following block is linked with a preceding one by means of cryptography. Any correction of already submitted information related to transactions is impossible. It guarantees that all the transactions within the registry shall not be changed and that they shall be protected from theft or double spending. Secondly, S. Nakamoto presented a cryptographic algorithm of mining (obtainment) of bitcoins, which determined the mechanism of rewarding the network participants for their provision of sufficient resources (computer performance and electric power) to sustain the blockchain working capacity.

As several years have passed, the system suggested by S. Nakamoto has become of special value for programmers; it has been promoted and enhanced; however, no close attention was paid to research in this field.

In 2014, V. Buterin published his work **“A Next-Generation Smart Contract and Decentralized Application Platform”** (Buterin, 2014). Having presented advantages and restrictions of blockchain, he suggested the new Ethereum blockchain with an embedded programming language, which makes it possible for everyone to write smart contracts (Szabo, 1996) and decentralized applications, thanks to what the blockchain technology may be applied far beyond bitcoins. V. Buterin has developed three types of applications (1) financial applications that help users manage their assets and conclude contracts; (2) semi-financial applications that involve both money and nonmaterial assets; (3) nonfinancial applications, such as online voting and decentralized management. The new Ethereum blockchain is an open platform, which simplifies introduction of this technology significantly. It is also the reason for a profound interest towards it among both new startups and major developers of software and other businesses.

Implementation of this new blockchain stimulated further research and development in this field. A real problem and a crucial requirement towards its platforms was provision of data confidentiality. In 2015, the work **“Hawk: The Blockchain Model of Cryptography and Privacy-Preserving Smart Contracts”** by A. Kosba, A. Miller, E. Shi, Z. Wen, and C. Papamanthou (Kosba et al., 2015) suggested a solution to this problem. The main idea, which laid the foundation of the Hawk confidential smart contracts, implied application of a common software compiler to encode a smart contract with a cryptographic protocol. The Hawk software consists of (1) a private portion, where transaction data and other personal data are protected with cryptographic methods from the external environment, and (2) the public portion, which does not concern **private data or money. From the viewpoint of security, “on-chain privacy protects contractual parties’ privacy against the public (i.e., parties not involved in the financial contract), contractual security protects parties in the same contractual agreement from each other”, since the parties may desire to infringe the contract.**

Therefore, the development of Hawk as a system of intellectual contracts has made it possible to apply the blockchain technology in various fields.

In her paper **“Blockchain: Blueprint for a New Economy”**, M. Swan (Swan, 2015) considers blockchain as a new organizational paradigm to coordinate any sort of human activities. She identifies the following stages of the technological blockchain revolution: Blockchain 1.0, 2.0., and 3.0. Blockchain 1.0 was created and applied for cryptocurrencies; its goal was to make common

cash transactions easier. As for Blockchain 2.0, it was created for property bargains by applying the algorithm of smart contracts. In Blockchain 3.0, many applications were developed for such sectors as government, education, healthcare, and science. Nowadays Blockchain 4.0 is applied; it implies development of large-scale industrial applications on its base; those applications would be able to control numerous processes simultaneously, processing and storing huge data arrays, making those data logically correlated. Blockchain 5.0 is able to formalize over 80 % of events taking place in a human life, from logistics and sale/purchase of goods to copyright (Filatov, 2020). M. Sawn assumes that blockchain will develop from the idea of decentralized applications to the idea of decentralized autonomous organizations and corporations that operate without humans but comply with a set of business rules and regulations.

The number of research papers concerning blockchain in education is still relatively small; the number of citations per paper does not exceed 100, according to SpringerLink.

Let us divide the blockchain-related literature that we have analyzed into reviews and specialized research, with the latter referring to application of blockchain in a particular sphere of the educational process.

#### Findings of Analysis of Review Papers

As a rule, review papers are based on secondary data, whereas specialized ones are based on primary data. Blockchain is a rapidly growing field of research; our search for review papers that analyze its development trends has led us to only seven papers (See Table 3).

**Table 3.** Review papers related to application of blockchain in education

Author & Name of Article	Year	Number of Citations	Type of Research Paper	Country
Grech, A. and Camilleri, A. F. Blockchain in Education	2017	180	Report	EU
Chen, G., Xu, B., Lu, M. et al. Exploring Blockchain Technology and Its Potential Applications For Education	2018	53	Journal Article	China
Yumna H., Murad Khan M., Ikram M., Noreen S. and Sabeen R. Use of Blockchain in Education: A Systematic Literature Review	2019	7	Conference Proceedings	Pakistan
<b>Kamišalić A., Turkanović M., Mrdović S., Heričko M.</b> A Preliminary Review of Blockchain-Based Solutions in Higher Education	2019	4	Conference Proceedings	Slovenia
Alammary, A.; Alhazmi, S.; Almasri, M.; Gillani, S. Blockchain-Based Applications in Education: a Systematic Review	2019	10	Journal Article	Saudi Arabia
Hameed B., Murad Khan M., Noman A. et al. A Review of Blockchain Based Educational Projects	2019	1	Journal Article	Pakistan

The first review of application of blockchain in education is the work by A. Grech and A. Camilleri **“Blockchain in Education”** (Grech, Camilleri, 2017). This work is one of the five Highly Influenced Papers related to Blockchain in Education, according to Semantic Scholar (64 citations) and Scholar Google (181 citations). It is a report by the Joint Research Centre (JRC), the European Commission’s science and knowledge service, which describes real cases of application of

blockchain at universities. Application of the blockchain technology in higher education started in 2014, when the University of Nicosia, Cyprus (UNIC) commenced to apply this technology on an official basis to store and confirm its diplomas; it was also the first university that began to accept fees for studies as bitcoins (UNIC, 2014). Since 2017, the UNIC has been publishing all its **graduates' diploma projects (bachelors, masters, and PhDs) in blockchain by applying its own development** – the block.co blockchain platform (UNIC, 2014). This platform is used by both educational institutions and healthcare facilities, the public sector, transport, etc. In 2016, the Sony Global Education supported by IBM developed a blockchain platform to store, protect, and exchange information related to students' **performance and progress. The company regards blockchain as the main technology that can influence the educational landscape in the future** (Sony Global Education, 2016). The Massachusetts Institute of Technology (MIT) developed its blockchain-based Blockcerts in 2017; this application makes it easier to issue digital diplomas and professional certificates (Durant, 2017).

The work by A. Grech and A. Camilleri applies qualitative methods of research, such as interviews with experts and a literature review. The two authors propose eight scenarios to apply blockchain in education: (1) for permanent protection of certificates; (2) to verify the multi-stage accreditation; (3) for automatic recognition and transaction of credits; (4) as a lifelong training passport; (5) to track intellectual property and its rational application; (6) to receive payments from students via the blockchain; (7) to provide financing of students (issue vouchers to them) via blockchain; (8) to identify students (Grech, Camilleri, 2017).

The suggested development scenarios of blockchain in education (except for (7)) are mid-term and short-term ones. This research pays hardly any attention to long-term scenarios. Unresolved issues, which hamper application of blockchain, according to the two authors, are as follows: difficulties with data verification in the third-world countries, which have no centralized data management, and absence of a global system of standards. Of the six peculiar features of blockchain, the authors consider only three. Probably, it is because all the projects realized in this field were only at their pilot stage when this paper was written.

All the reviews that we have analyzed are based on the following classification of research papers, which considers with the specifics of the blockchain technology:

1. Decentralized processes of information storage and processing. Each network participant stores all the recorded information. It makes it possible to create geographically distributed networks, centralized databases, and backup (Yumna et al., 2019; Hameed et al., 2019).

2. Unchangeable data. Blockchain allows verification of the entire information sequence at any time (Hameed et al., 2019; Koyfmann, Tabernakulov, 2019; Yumna et al., 2019; Chen et al., 2018).

3. Tracking of transactions. The entire contents of transactions is readable for any network participant, but **access to change other participants' records is impossible without a special key** (Chen et al., 2018; Hameed et al., 2019; Yumna et al., 2019).

4. Mechanism of consensus: the participants maintain the network themselves. It implies mutual maintenance of all the nodes of the blockchain network. It helps resolve such issues as **risk of manipulation with data; it does not require a third party's interference** (Grech, Camilleri, 2017; Hameed et al., 2019; Yumna et al., 2019).

5. Cryptocurrency. It is applied to resolve issues related to proving execution of commitments, e.g., a reward may be issued as a cryptocurrency via a smart contract (Chen et al., 2018; Yumna et al., 2019; Hameed et al., 2019).

6. **A smart contract works with the parties' direct participation. It is a self-controlled working program, which is transmitted via the nodes of a chain of blocks. It is a proof of execution of commitments in the real-time mode; it contributes to reduction of losses related to commissions and internal audit** (Sharples, Domingue, 2016; Chen et al., 2018; Yumna et al., 2019).

Based on specific features of blockchain, its advantages and drawbacks, G. Chen (Chen et al., 2018) identified four trends of its application in the educational process: (1) identification of **parties involved in the process of education; (2) digital encoding of the parties' rights and commitments; (3) performance assessment of a student; (4) education as a source of income.**

The paper by A. Kamišalić, M. Turkanović, S. Mrdović, and M. Heričko (Kamišalić et al., 2019) identifies four fields of blockchain application that include 17 projects: 8 of them relate to



records storage and application; 2 projects are identified as efficient games; 3 projects are defined as digital market assets; 4 projects regard blockchain as a destroyer of traditional education.

The first field related to records storage and application includes: (1) a verifiable credential for completion of a digital currency course; (2) an open standard for applications that provide blockchain-based certificates; (3) control and provision of any type of digital microcredits; (4) blockchain-based verification of diplomas; (5) protection of copyright; (6) registration of **intellectual property**; (7) **copyright registration service applied for images**; (8) **copyright for artists' intellectual property**.

The second field relates to application of blockchain in education as a digital market asset: (1) charging fees in bitcoins; (2) an educational platform for cryptocurrency rates; (3) an educational portal contributing to exchange of knowledge.

The third field regards blockchain as an efficient educational game (gamification). Creation of educational online platforms that imply game experience in education: (1) verification of **students' diplomas**; (2) **formation of a lifelong academic passport**.

The fourth field, which regards blockchain as a destroyer of traditional education, includes the following projects: (1) educational platforms implying game experience in education and cryptocurrency-based scholarships; (2) digital platforms to record all what was studied; (3) platforms uniting students and their professors; (4) open publishing platforms that sustain the reviewing process.

One could remark that this classification has a drawback, since many projects mentioned by these authors might be referred to several fields.

**The authors of the work "Use of Blockchain in Education"** (Yumna et al., 2019) have selected another way to classify fields of research. They classify blockchain projects based on issues that this technology resolves. They identify three aspects of those issues.

The physical aspect comprises problems that are due to physical processing of documents and human actions: risk of manipulation with records when humans create them; difficulties in verification of records; single point failure (Grech, Camilleri, 2017).

The digital aspect includes issues related to documents that are stored electronically in the Internet: risk of forging digital records; risk of losing digital documents and their discredit; the problem of records exchange between institutions (Grech, Camilleri, 2017).

The financial aspect concerns issues related to management of money: transaction commissions; difficulties in verification of proofs of commitments execution (Chen et al., 2018), (Rooksby, Dimitrov, 2017).

We have analyzed reviews of research papers related to blockchain in education considering with problems related to application of the blockchain technology (Yumna et al., 2019). Let us supplement our analysis with the legal aspect, which relates to legal support of blockchain projects.

**Table 4.** Comparative table of blockchain-related reviews

Research	Existing problems in education				Features of blockchain	Problems with blockchain implementation
	Physical	Digital	Financial	Legal		
A. Grech, 2017	+	+	-	+	+	+
G. Chen, 2018	+	+	-	-	+	+
<b>A. Kamišalić, 2019</b>	+	+	+	-	+	-
H. Yumna, 2019	+	+	+	-	+	+
A. Alammary, 2019	+	+	-	-	+	+
B. Hameed, 2019	+	+	-	-	+	+
Our research	+	+	+	+	+	+

The analysis of reviews presented in this article (See Table 4) proves that many reviews are of fragmentary character; they do not describe all the aspects of blockchain application in education, since this is still a new field of research. Our research is different from previous reviews; it concerns a broader range of issues in education, which may be resolved by applying the blockchain technology; it also considers research findings over a longer period – from 2009 to 2019. This

research takes into account works written in Russian and analyzes specifics of blockchain application in Russia.

Findings of Analysis of Specialized Papers

Based on our analysis of specialized papers, let us propose a new classification of fields of blockchain application in education (See Table 5). This classification is based on specifics of blockchain, as well as on the problems that this technology resolves.

**Table 5.** Fields of blockchain application in education

Fields	Projects	Research Papers	Problems Resolved by Blockchain
Issue and storage of certificates and diplomas	Blockcerts; BCDiploma; UNIC Blockchain Certification Programs	(Sharples, Domingue, 2016; Grech, Camilleri, 2017; Chen et al., 2018; Budhiraja, Rani, 2020; Curmi, Inguanez, 2019; Bandara, 2018)	Physical, digital, legal
Identification solutions	Civic	(Grech, Camilleri, 2017; Mikheenko, 2018; Kirilova et al., 2018)	Physical, digital
Protection of intellectual property	Binded	(Guo et al., 2020)	Physical, digital, legal
New network of cooperation between students and their professors	ConsenSys	(Tapscott, Tapscott, 2017; Castañeda, Selwyn, 2018; Tapscott, Kaplan, 2019)	Physical, digital
Formation of an academic passport (portfolio)	TUDocChain BLOCK.CO	(Budhiraja, Rani, 2020; Klimonov, Popova, 2020)	Digital
Payment for studies with a cryptocurrency	TEduChain BitDegree	(Devine, 2015; Rooksby, Dimitrov, 2017; Rashidet et al., 2019; Zhou et al., 2020);	Financial, legal
Accreditation of educational institutions	QualiChain	(Kirilova, 2018; (Kontzinos et al., 2019).	Digital, legal
Administration of the educational process	QualiChain EduCTX	(SharplesDomingue, 2016; Kirilova, 2018; Turkanović et al., 2019)	Physical, digital, legal

1. Issue and storage of certificates and diplomas

This is the most widely spread field in which the blockchain technology is applied in education. A majority of article included in this review take into account applications to control the process of issue and storage of electronic certificates and diplomas. Nowadays ecosystems of digital certifications BADGR and Mozilla Open Badge (Grech, Camilleri, 2017) are applied in European

countries. The University of Nicosia (Sharples, Domingue, 2016; Chen et al., 2018) and the Massachusetts Institute of Technology (MIT Media Lab, 2020) were the first to develop and implement this standard to start issuing and verifying digital certificates. This is the MIT web site to verify certificates, which allows an independent data checkup: [credentials.mit.edu](https://credentials.mit.edu). In 2016, the Sony Global Education announced that it had developed a technology to store academic records (Sony Global Education, 2016). In 2017, the Malta College of Arts, Science & Technology began to issue Blockcerts-based digital certificates (Chen et al., 2018). The same year, Chinese researchers developed the ECBC blockchain to control certificates of education. It has a higher performance rate than the previous standard (Xu et al., 2017). The number of blockchains to issue diplomas and certificates grows every year (Bandara, 2018; Curmi, Inguanez, 2019; Budhiraja, Rani, 2020). Some researchers assume that blockchain undermines the role of traditional formal educational institutions, since it is an alternative supplier of diplomas and certificates (Nespor, 2019).

#### 2. Identification solutions

Students and faculty of large universities need to identify themselves on a regular basis while dealing with various units of their universities. In those cases, each unit of an institution collects **students' data for itself or applies the single-sign-on technology**, thanks to what a single copy of a **student's data is applied by all the parties within that institution**. Consequently, many people can **access a student's personal data**. To ensure security of those data, access rights of all those people require control; the data must be secured and protected from hacking. Once a student has submitted his/her data to the university admission commission, he/she is granted their ID as a key in return. Applying biometric information (Mikheenko, 2018; Kirilova et al., 2018) on any electronic device (e.g. a smartphone), a student may identify himself/herself with any university unit, e.g. **the local library or canteen; those units do not need to store or look through that student's personal data** (Grech, Camilleri, 2017). The following blockchain-based solution is proposed: the Uport system for independent self-identification (this Ethereum-based system has been developed by applying ConseSys). This technology consists of three components: a smart contract, libraries for developers, and a mobile application. However, citizens of 45 countries (including Russia) are prohibited to apply this system.

#### 3. Protection of intellectual property

Nowadays blockchain is widely applied in the field of intellectual property. Applying this technology, one can record the fact and the moment of creation of an object of intellectual property. The Binded platform is one of the projects that provide such opportunities. The structure of objects of intellectual property law is changing now. More and more frequently, those are digital records, not physical objects. The blockchain technology has no alternatives when it comes to intellectual property rights for digital records. For instance, extraction of data from a distributed registry for digital objects may be the only source of proofs that a particular individual has legal rights for those objects. In particular, it may relate to objects of programming, which emerge every day (Guo et al., 2020).

#### 4. Network of cooperation between students and their professors – new pedagogics

A majority of universities apply the technologically extended classroom-teaching model. New technologies change this approach. Lifelong education is becoming accessible, personalized, and **methodologically urgent**. **“Blockchains provide a platform for students in collaboration, not just tracking people's individual contributions but also rewarding them for results”** (Tapscott, Kaplan, 2019).

“A good model for classroom collaboration is Consensus Systems (ConsenSys), one of the first Ethereum software-**development companies**” (Tapscott, Kaplan, 2019). This development is based on new principles – **those are “dynamic roles rather than traditional job descriptions; distributed, not delegated authority; transparent rules rather than office politics; and rapid reiterations rather than big reorganizations”** (Tapscott, Tapscott, 2017).

One of the problems of individualized education is a vague conventional characteristic of education as a public benefit, since new technologies cause considerable differences from the viewpoint of social diversity, commitments, solidarity, and social relations (Castañeda, Selwyn, 2018).

#### 5. Formation of an academic passport (portfolio)

Blockchain is applied to ensure security of information storage in an electronic portfolio, **which may be formed throughout one's entire life and contain complete, trustworthy, and unchangeable information concerning the holder of that portfolio.** The blockchain-based portfolio formation concept (Klimonov, Popova, 2020; Vakurin et al., 2018) suggests two types of users – a student and an administrator. A student applies a web application to upload his/her achievements to the database by completing the appropriate fields and attaching the necessary documents. The administrator verifies those data. Should the data be confirmed, it is submitted to the blockchain. However, if that blockchain is private, portfolio formation options depend on the capacity of the educational institution where a student studies. As for public blockchains, they **ensure one's rights for authorizing academic certificates in a public book in a reliable and sustainable format** (Budhiraja, Rani, 2020). At the same time, it is necessary to standardize formats of electronic documents to provide their automatic verification. In Russia, it is more difficult to resolve this issue, since application of public blockchains is actually blocked in this country (Khalizev et al., 2018).

#### 6. Payment for studies with a cryptocurrency

The work **“Blockchain Learning: Can Crypto-Currency Methods Be Appropriated to Enhance Online Learning?”** (Devine, 2015) was the first to suggest application of a cryptocurrency to pay for studies, so as to provide broader opportunities for students participating in exchange programs. **This idea was developed in the work “Trustless Education? A Blockchain System for University Grades”** (Rooksby, Dimitrov, 2017). Nowadays benefits for students and universities from circulation of tokens, e.g. to purchase university souvenirs, pay for academic courses, avoid commission when paying for education are under consideration (Zhou et al., 2020).

The work **“TEduChain: A Platform for Crowdsourcing Tertiary Education Fund using Blockchain Technology”** (Rashid et al., 2019) presents a broader view on opportunities of cryptocurrency application in education. The TEduChain is regarded as a platform to create and store agreements between students and sponsors of higher education. Sponsorship is possible in any form: scholarships, donations, or loans.

With the TEduChain undergoing the development stage now, BitDegree has already realized the idea when sponsors select **students to support with funding. The sponsors' money is converted into BDG tokens (in correlation 1:1) and stored in a smart contract until a sponsored student has completed his/her studies successfully. “The Blockchain “pay for success” scheme could enable private companies support the development of skills they are interested, by financing individual students”** (Capetillo, 2018).

#### 7. Accreditation of educational institutions

Application of blockchain to verify accreditation is under consideration in the work **“Prospects of Implementation of Blockchain Technology in the Modern System of Education”** (Kirilova, 2018). **Accredited organizations can create and publish “verifiers” on their own web sites,** which will allow any user to upload their diploma and verify whether it was indeed issued by an accredited institution, as well as publish issued diplomas in a public registry. It would allow any third party to check: (1) a diploma that a university issued to a student; (2) whether that university has an accreditation in a public registry; (3) whether the above-mentioned information is true. To implement this technology, an independent trusted party should create a public registry.

**Thanks to the QualiChain project, “school's secretariat will avoid time-consuming processes for degree verification and other administrative issues, given that the pertinent documents will exist in QualiChain, secure and already verified”** (Kontzinos et al., 2019).

#### 8. Administration of the educational process

The QualiChain project concerns not only accreditation of students and educational institutions; it also has a potential for a larger-scale optimization of the educational process at universities, suggesting an efficient design of educational programs.

Obvious application of the blockchain technology in education is storage of performance and credit records (Sharples, Domingue, 2016; Zaslavsky 2018). Nowadays this technology is applied much more widely than before. In particular, the EduCTX platform is based on the concept of the European Credit Transfer and Accumulation System (ECTS) (Turkanović et al., 2019). This platform is used to process and control ECTX tokens as academic credits. Students and

organizations (e.g. companies as potential employers) are users of this platform. The EduCTX platform is integrated with the existing information systems of universities in various countries (Turkanović et al., 2019).

Based on the conducted analysis of reviews, specialized research papers, and university web sites, this article proposes a summarizing table of cases of application of blockchain in higher education.

**Table 6.** Review of fields of blockchain application by various universities

Country	University	Fields of Blockchain Application
Cyprus	University of Nicosia	Issue and storage of certificates and diplomas. Payment for studies with a cryptocurrency.
USA	Massachusetts Institute of Technology (MIT)	Issue and storage of certificates and diplomas. Identification solutions.
	Holberton School of Software Engineering	Issue and storage of certificates and diplomas. Identification solutions.
	University of Texas at Austin	Issue and storage of certificates and diplomas. Network of cooperation between students and their professors – new pedagogics.
	University of New Hampshire	Issue and storage of certificates and diplomas.
	King's College	Payment for studies with a cryptocurrency.
	University of California	Issue and storage of certificates and diplomas.
Great Britain	Open University	Issue and storage of certificates and diplomas. Network of cooperation between students and their professors – new pedagogics. Accreditation of educational institutions.
	University of Southampton	Issue and storage of certificates and diplomas. Network of cooperation between students and their professors – new pedagogics.
	Woolf of University	The first blockchain university. Issue and storage of certificates and diplomas. Identification solutions. Payment for studies with a cryptocurrency. Administration of the educational process.
Malta	Malta College of Arts Science and Technology	Issue and storage of certificates and diplomas.
Slovenia	University of Maribor	Issue and storage of certificates and diplomas. Administration of the educational process.

Greece	Aristotle University of Thessaloniki, Athens University of Economics and Business, Democritus University of Thrace	Issue and storage of certificates and diplomas. Identification solutions.
UAE	Universities in Dubai	Issue and storage of certificates and diplomas. Formation of an academic passport (portfolio).
Bahrein	University of Bahrein	Issue and storage of certificates and diplomas.
Australia	University of Melbourne	Issue and storage of certificates and diplomas.
Mexico	Central New Mexico Community College	Issue and storage of certificates and diplomas.
Singapore	Ngee Ann Polytechnic	Issue and storage of certificates and diplomas.
China	Zhejiang University, Shenzhen University, Chinese Academy of Sciences	Protection of intellectual property.
Canada	20 % of all universities in Canada	Issue and storage of certificates and diplomas.
Russia	Synergy University	Since 2020. Issue and storage of certificates and diplomas. Network of cooperation between students and their professors – new pedagogics.
	<b>Penza State University</b>	Since 2020. Issue and storage of certificates and diplomas.

Thus, we have identified and classified the main fields of reviews and specialized research related to application of the blockchain technology in higher education; this paper presents the countries and the universities that implement this technology as a single table.

To implement and apply this innovative technology in education efficiently, it is necessary that the society was aware of this technology and was prepared to apply it. We regard the academic community as a vanguard of innovative economy, so our survey has been conducted to determine how well representatives of this community are informed of opportunities to apply the blockchain technology in higher education.

112 representatives of 12 Russian higher educational institutions have participated in our survey: Astrakhan State University; Baikal State University; Buryat State University; Volgograd State University; the Volzhsky Institute of Economics, Pedagogy and Law; Far Eastern Federal University; the Gubkin Russian State University of Oil and Gas; Kazan Federal University; Moscow State University; the Moscow State Institute of International Relations (MGIMO); Saint Petersburg State University; Sochi State University.

**The respondents' minimal age is 36. Their maximal age is 68. The average age of the respondents is 47.9.**

**Since we were interested in measuring the respondents' awareness/unawareness of the blockchain technology, we applied inferential statistics to reveal the percentage of those who are aware of it.**

We checked the hypothesis that over 50 % of faculty staff of Russian university are unaware of the blockchain technology and opportunities of its application in higher education.

The hypotheses are represented as follows:

**The null hypothesis:  $p \leq 0.5$**

The alternative hypothesis:  $p > 0.5$

Let us determine the significance level at 0.05.

Let us calculate the standard error by applying the formula:  $\sigma_p = \sqrt{p(1-p)/n}$ , where  $p$  is the value assumed by the null hypothesis.

After that, let us calculate the observed z-score:  $\frac{p_1 - p}{\sigma_p}$ , where  $p_1$  is the observed survey value.

Let us compare it with the critical z-score. Should the observed z-score be higher than the critical z-score, let us reject the null hypothesis. Otherwise, we shall not reject it. Applying the observed z-score, let us determine the p-value.

Table 7 presents the obtained results.

**Table 7.** Responses to the question “Do you know about the blockchain technology?”

“Do you know about the blockchain technology?”	Number of responses	Percentage of responses	Observed Z	P-value
Yes	64	57.1	1.501	0.0668
No	48	42.9		

With the significance level equal to 0.05, the critical value of z is equal to 1.645. Since the observed value is smaller than the critical one, we do not reject the null hypothesis and conclude that over 50 % of Russian university professors are unaware of the blockchain technology.

Of those respondents who are aware of this technology, let us determine the percentage of those who are aware of application of this technology in education (See Table 8).

**Table 8.** Responses to the question “Do you know about application of the blockchain technology in education?”

“Do you know about application of the blockchain technology in education?”	Number of responses	Percentage of responses	Observed Z	P-value
Yes	40	62.5 %	2	0.0228
No	24	37.5 %		

With the significance level equal to 0.05, the critical value of z is equal to 1.645. Since the observed value is equal to 2, it exceeds the critical one; so let us reject the null hypothesis and conclude that over 50 % of Russian university professors are aware of the blockchain technology, as well as its application in education.

Table 9 presents the results of asking the respondents the question related to application of blockchain in education.

**Table 9.** Responses to the question related to application of blockchain in education

“What opportunities of application of blockchain in education do you know?”	Percentage of responses
Issue and storage of certificates and diplomas	22.2 %
Identification solutions	16.7 %

Protection of intellectual property	11.1 %
Network of cooperation between students and their professors – new pedagogics	5.6 %
Formation of an academic passport (portfolio)	11.1 %
Payment for studies with a cryptocurrency	16.7 %
Accreditation of educational institutions	5.6 %
Administration of the educational process	11.1 %

Based on responses to this question, one can conclude that a majority of professors believe that the blockchain technology may be applied in three fields: 1) issue and storage of certificates and diplomas; 2) identification solutions; 3) payment for studies with a cryptocurrency.

As for the question related to application of this technology in their educational institutions, representatives of the abovementioned federal universities and Moscow-based universities have responded positively; the rest of the respondents have indicated that they do not know.

Based on the conducted survey of representatives of the Russian academic community, let us conclude that implementation of this technology in education is at its initial stage. The academic community is still insufficiently informed of this technology and its application in education; it does not have many ideas in which particular fields it may be applied.

#### **4. Discussion**

We have limited our Systematic Literature Review by grouping research papers as follows: research literature that determined tendencies in the field of the blockchain technology development; review papers concerning the development of blockchain in higher education; specialized papers concerning the development of blockchain in higher education.

The results of our research prove that blockchain management is a complicated task both from the viewpoint of the general ecosystem and at the platform level. Development of the appropriate policy and its regulation face obstacles, since the blockchain networks operate at the international level and are not attached to only one jurisdiction. Implementation of updates or changes for a general-access block network is a problem of control at the platform level caused by decentralized decision-making that involves many participants. In its turn, centralized implementation of updates may result in security threats.

Russian researchers ([Shamsutdinova, 2018](#)) determine a more complicated problem of implementing blockchain in the system of higher education, emphasizing the technological and organizational aspects. As a key problem, they mention absence of a national blockchain platform, **absence of a centralized controlling structure that would coordinate the “educational” blockchain as a single digital information space**. However, this idea and this attempt to regulate it contradicts the idea and the main advantage of blockchain as a decentralized system. Here one should note that much fewer blockchain projects have been realized in the public sector than in the private sector.

A larger-scale application of the blockchain technology may be hampered with the following factors:

1. The information factor. A majority of representatives of the academic community, as our survey has revealed, are unaware of this technology.

2. The technological factor. Only 86 % of Russian organizations have a broadband access to the Internet, whereas this rate in the EU countries is nearly 100 % ([Abdrakhmanova, Kovaleva, 2019](#)). This fact may become critical owing to external challenges that the educational system currently faces, as well as owing to a high competition in this sphere. In the future, it is possible that competition will be taking place between blockchain platforms, not between universities.

3. The legislation factor. In many countries, using blockchain for applications or a cryptocurrency has a vague legal status. In Russia, despite the decision made by the Ministry of Science and Higher Education of the Russian Federation concerning rejection of paper diplomas of higher education and their conversion into the electronic format in 2020, the legal status of such



diplomas has not still been stipulated officially. It is also planned to prohibit emission and circulation of cryptocurrency since 2020.

4. The organizational factor. The development of this technology reduces expenses for the university administrative staff, so university administrations may resist implementation of this technology.

## 5. Conclusion

The conducted analysis of projects and researches related to the blockchain technology in higher education makes it possible to conclude that this new technology is gaining popularity and conquering the educational space. Its implementation changes the concept of interaction between students and their professors, which makes education more accessible and personalized. An **individual's personal strategy aimed at lifelong education is becoming** an objective necessity now; the blockchain technology provides resources necessary for its realization. At the same time, the blockchain technology may result in unequal opportunities in obtaining online and offline education. One should note that a majority of universities, which have developed educational blockchain technologies, are still using those technologies as a supplement to traditional forms of education.

In Russia, educational blockchain technologies are at the stage of research and implementation of some elements. Pilot projects are expected to start in 2020. Of the application fields described above, two fields will be implemented: issue and storage of certificates and diplomas; personality identification solutions.

The number of researches of the blockchain technology is growing at a significant pace. Quite frequently, technological developments and solutions in this field become a base and a stimulus for academic research. One can state that if several years ago researches suggested some particular fields of applying blockchain in education, nowadays there is a tendency to accumulate the entire range of university functions in blockchain projects: administration of the educational process; storage of information related to degrees, scholarships, **etc.; creation and maintenance of students' and graduates' portfolios; a large-scale application of operations with cryptocurrency** (up to investment projects); realization of opportunities that the new pedagogics provides.

The most important advantages of educational blockchain technologies are formation of a single educational environment, creation of network communities, exchange with technologies and scientific knowledge, and copyright protection of the network participants.

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