Development of the Learning Management System Concept based on Blockchain Technology

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Abstract
The growth in demand for the use of distance learning technology caused by the COVID-19 pandemic has led to increased use of technologies that provide a continuous learning process. Furthermore, the Russian invasion of Ukraine demonstrated that such technologies could make it possible to conduct the educational process in relatively safe conditions for the parties of the education process. One of the technologies that provides distance learning is the learning management system. While this technology facilitates the educational process, it also allows the accumulation of data, which can pose a threat to the privacy of system users in case of unauthorized access. Also, in the conditions of distance education, educational institutions may face challenges of scalability of these systems, sharing of data on qualifications obtained in such systems, and issues of trust in the acquired education among employers. In this paper, an analysis of existing learning management systems based on both blockchain technologies and traditional ones is carried out, their weaknesses and strengths are analyzed, and tasks that should be solved by a new system based on blockchain technology are formulated. Smart contract and NFT technologies are also considered in the context of their application in the field of education, i.e., smart contracts can be used to rate students' progression and NFT can be used for certificate issuing. As a result of the conducted research, a conception of the system was proposed that uses two types of blockchain networks—hybrid and consortium, which allows solving the issues of scalability, secure data storage, and confirmation of acquired qualifications with the help of a unified blockchain network of the consortium type, which makes it possible to establish criteria for acceptance of new network participants, which allows solving the problem of low-quality suppliers, and also acts as a database to which network participants must add a unified version of the diploma in the form of NFT, which will allow interested party to quickly check the validity of the diploma or certificate. Student data in this conception is stored on the education provider's hybrid blockchain network, which allows sensitive data to be securely stored while allowing third-party access to open data. An analysis of the strengths and weaknesses of the proposed network was also carried out and possible ways of solving some of them were proposed.

Keywords
LMS, learning management system, blockchain, smart contracts, NFT, decentralization, distance learning.

1. Introduction

The COVID-19 pandemic has prompted educational institutions to close their campuses to attendance and find ways to continue providing educational services to ensure continuity of education [1]. The key to the continuation of education was distance learning, which can be organized in different ways. Also, distance learning can be divided into synchronous and asynchronous learning [2]. A great example of asynchronous learning is Massive Open Online Courses or MOOC [3], which were used long before the pandemic and

provided education services for several people around the globe. The main idea of asynchronous learning is that the student has no necessity to join lectures in predefined time slots but has an opportunity to study on their schedule. Synchronous learning, on the other hand, means that students have to join lectures at a specific time, meaning that there is a schedule that students should follow.

Moreover, the number of enrolments for distance learning courses drastically increased between 2019 and 2021 [4] which shows that distance learning has become a more popular way to get education.

Furthermore, the Russian full-scale invasion of Ukraine in 2022 shows that distance learning can be crucial for the continuation of the education process in a relatively safe place [5].

Also, online learning platforms can provide opportunities for people to get the necessary skills for obtaining a new job or switching to another profession.

The crucial component of distance education is the Learning Management System (LMS) [6] which helps to maintain students' data, course information, tasks, lectures, course progression, etc.

Since such systems maintain information about students it means that such system poses information that could be a threat to user privacy if it is stolen [7]. There are different ways to protect data, such as the implementation of complex security systems [8], the usage of automated monitoring of networks for intrusion detection or abnormal traffic [9], or the usage of software baits [10] and decoys [11]. Another way is the usage of ML for developing security strategies [12]. However, using blockchain technology and decentralization can also provide a mechanism for privacy-preserving [13].

Blockchain is a relatively new paradigm for digital data management and learning. Many researchers believe that this is a new megatrend of the digital world [14]. Without a doubt, it plays an important role in the learning process on several levels. For example, it finds application in the organization of education, through the implementation of decentralized platforms containing grades, documents, or diplomas of graduates, or authentication and security of processes related to the verification of knowledge, such as exams.

Blockchain functions at the interface with other technologies such as artificial intelligence, IoT, and Big Data. These solutions are slowly making their way into teaching practice, for example by technically supporting assessment, monitoring, or profiling. Because of this, these methods, despite their undoubted advantages, seem culturally invasive and can raise serious ethical questions.

The traditional transmission and storage of knowledge, primarily through schools and universities, is a time-honored, valuable, and important determinant that represents intellectual development, progress, and the improvement of everyday life. However, on the other hand, to function effectively in a modern, dynamic, and convergent environment, educational institutions should be characterized by openness and high dynamism in the assimilation of new ideas and innovations, especially in the field of ICT [15].

This article examines the possibilities of blockchain and corresponding technologies such as smart contracts and NFT in usage as a system that can handle challenges of the modern education market, such as privacy preservation, knowledge verification, and trust in higher education institutions along with the development of the concept of the system that will provide capabilities to implement a system that will preserve handling of these challenges and provide an opportunity for scalability.

2. Analysis of Learning Management System

The correct organization of distance learning is a necessity during the period of quarantine restrictions and military time in Ukraine from February 24, 2022. The relevance of out-of-class classes is constantly preserved since students for various reasons are unable to attend classes and are forced to study remotely. However, in the era of technologies that are available to almost every person and fit in a smartphone, organizing the educational process is not such a difficult task.

Modern online education requires precise control and management due to its massiveness. Massive open online courses involve many students, and the educational process must be analyzed considering many parameters. For this purpose, any learning

management system provides reporting and analysis tools with the possible subsequent adjustment of courses. However, the popularity of online education is growing, and the number of students is increasing [16]. In some cases, taking an online course is an alternative to classroom study of a discipline, so more methods are needed to collect and analyze various learning data and to manage the educational process.

There are many LMSs [17], including Moodle, Open Edx, Open LMS, ILIAS, etc. Platforms such as Udemy, Coursera, and edX are also well-known representatives of such systems. Although they act as an intermediary between the educational service provider and the educational recipient, they also provide the ability to create courses, manage course and student data, evaluate progress, issue certificates, etc., which qualifies them as an LMS.

One of the key differences between these platforms is that edX and Coursera provide courses from universities and organizations, while Udemy allows almost anyone to create a course, which already raises the specter that such courses can be created by unqualified individuals [18].

Consider two platforms already used in the educational process, in particular, the Moodle and ODEM [19] learning platforms following can be stated about them.

Moodle provides a statistical course report, a grade report, and a student activity report. Thus, with the help of standard Moodle reports, information about grades can be gathered, the date and time of assignments, as well as the progress of learning for specific students. These data make it possible to compile ratings of students, calculate the average score, and analyze various tasks from the point of view of the success of their completion and the time spent by them by different achievers.

ODEM is a decentralized platform based on blockchain and smart contract technologies that allows numerous professional teachers and students to interact directly.

The platform will solve numerous problems in obtaining high-quality education. All lessons, lectures, or seminars can be conducted directly in person, with an individual approach and detailed analysis of errors. Each teacher of the platform has vast experience in the field of education. The ODEM platform is international, that is, it is easy to get the necessary knowledge and education from anywhere in the world.

Each student of the platform has a huge choice of the form of obtaining the information he needs, whether it is a one-day lecture or a whole week-long educational event. Thanks to a single database of teachers and students, the entire community of the platform unites into one ecosystem where everyone agrees on the type of training, time, and payment directly within the platform. The use of the Ethereum blockchain guarantees full transparency and security of all transactions. Table 1 describes the advantages and disadvantages of using ODEM and Moodle in the education sector.

Table 1

Advantages and disadvantages of ODEM and Moodle learning platforms

Analysis process	ODEM	Moodle
Advantages	Increased security through decentralization. Data in the blockchain is distributed across the network, which reduces the likelihood of fraud and makes forgery attempts virtually impossible. Document verification takes moments, not weeks. Educational institutions can quickly check information without going through a bunch of documents. Permanent and immutable records. Documents stored on the blockchain will be stored as long as the system will exist.	Reduction of personnel training costs. LMS courses are cheaper than standard training. Saving time for adaptation and improvement of employee qualifications. Ease of use. All educational content is stored in one system, communication takes place here. No additional programs are required. Service availability. Content management and performing tasks can be done from any device and from anywhere in the world. Unlimited amount of information. Can be stored as many educational materials as needed. Ease of use. Content creation requires no technical skills: the LMS has an educational program builder.

	Diplomas or certificates are accessible and verifiable even decades later.	Extensive analytical skills. The service allows for monitoring the progress of students (individually and in groups), and the impact of training employees on working for the company.
	Moving away from paper systems can reduce costs for universities. Savings can be directed at students.	
Disadvantages	Low level of trust. A technology can only succeed if enough universities and employers trust it.	The system is free, but still need to install it somewhere (need a server or hosting, a domain name). The cloud solution is paid, and this can be an overwhelming and expensive task for a school or university.
	Insufficient scalability. Educational institutions store a lot of data about their students and graduates, which brings back the issue of blockchain scalability. Since each transaction requires P2P verification, the number of blocks required grows as the coverage of the data involved grows, slowing down transaction speeds.	The system consumes a lot of resources, which can increase financial costs. Requires specialists who have the skills to train users of the system. Frequent "crashing" of the site or its very slow operation, which makes it difficult to use resources or the impossibility of accessing the resource at all.
	Legal formalities. Most countries are still carefully formulating their responses to the opportunities and threats inherent in digital assets, with almost no legislation in the field of data digitization in Ukraine.	Inability to transfer personal data and resources from one university to another. Not publicly available to non-registered individuals.
	Costs of time and money. The distributed network eventually helps to save money, but the adoption and implementation of blockchain technology are expensive.	

Considering the tabular results, it can be concluded that the use of blockchain technology based on the ODEM platform is a better solution for educational institutions and students, because it is transparent, easy to use, has a high degree of protection of personal data, and has a base that is stored forever. This platform is unique and incredibly promising. The question of the quality of education in the world is on the edge, and the ODEM project will be able to answer it. The functions and capabilities of the platform are incredibly promising, allowing each user to find the training he needs to the smallest detail, and most importantly, the quality of this education will be at the highest level.

Despite the advantages of ODEM, it still faces the following challenges that should be solved:
- Trust issue.
- Scalability issue.
- Possible privacy issue as students' data stored in common blockchain.

We believe that the development of another type of interaction between parts of the system will help to solve these issues. However, before developing the system, the key features of such a system as smart contracts and tasks of the system should be reviewed in the following chapters.

3. Usage of Blockchain Technology Capabilities in the Education Field

The users may consider the concept of blockchain to be inextricably linked with Bitcoin, mining, and cryptocurrency exchanges. Its scope is much wider. For example, smart contracts can be created and function on the blockchain. If the candidate does not meet certain requirements, the company may suffer losses in the future. This database can save the organization from losses related to the confirmation of the validity of diplomas and certificates [20].

A standard contract is an oral or written agreement with a list of terms. It consists of buying real estate, renting a car, hiring for work, life insurance, admission to studies, and so on. To create such a contract, it is usually necessary to contact intermediaries (lawyers, notaries, banks) so that they monitor the

integrity of the agreement. Their services are not free, and it takes a long time to draw up a contract. If a dispute arises between the parties to the agreement, it is necessary to deal with them in the legal field, which may require additional costs. Previously, this format of interactions was recognized as the best. However, the emergence of a smart contract has shown that it is possible to execute agreements more quickly, profitably, and securely [21].

This format of interaction eliminates intermediaries, which helps to reduce costs and save time. A smart contract is a code, that is deployed to the network and performs itself when predefined conditions are met. The programs operate 24/7, so there are no delays in operation. Participants do not have to argue about the interpretation of this or that provision of the contract. After all, it is based on a program code that cannot be interpreted ambiguously. The probability of errors is reduced to a minimum. The obligation becomes self-fulfilling, which reduces the dependence on the trustworthiness of the counterparty, which reduces the chances of hiding details, not paying, or missing deadlines [22].

The following components are required to create a smart contract:

- Subject of the contract—the program must have access to the goods or services for which the contract is concluded and be able to automatically grant or close access to them.
- Subject of the contract—the program must have access to the goods or services for which the contract is concluded and be able to automatically grant or close access to them.
- Terms of the contract—the terms of the smart contract in the form of an exact sequence of operations that must be signed by all participants.
- Contract participants—the models described above between two people (P2P), a person and an organization (P2O), or a person and a machine (P2M).
- Decentralized platform—the smart contract is recorded in the blockchain of this platform and stored and distributed on its nodes.

The blockchain can provide the presence of these components. Massachusetts Institute of Technology is working on the Issues of protection and validation of certificates, as well as a reputation system with the help of blockchain. The institute released several versions of the Blockcerts program with open-source code, which implements accounting and issuing certificates with the possibility of sharing them with employers [23].

Also, since 2018, MIT has been enabling students to get a digital version of their diplomas on the blockchain as part of an experimental program that makes academic data secure and portable.

The implementation of blockchain technology will allow for the standardization of issued documents, which in turn can standardize education around the globe. The proven knowledge and skills of candidates can be stored in a single database, which will allow candidates to be dynamically selected based on their set of skills and necessary skills for the selected position.

The result of the creation of this database will be the presence of an open market of candidates with proven knowledge. This, in turn, will create a demand for specific competencies and will create tendencies to study certain educational programs, because of which these competencies are formed.

Educational organizations will see a real-time situation of required candidates and will issue relevant educational programs or training courses. As a result, this will reduce the gap between the labor market and the education market, as well as solve the problem of the rapid de-actualization of educational programs operating during the rapid growth of information technologies.

3.1. Capabilities for Certificates and Diploma Validation

Currently, training and confirmation of the validity of a candidate's certificates, diplomas, and certificates for their compliance with the necessary competencies is an expensive and time-consuming process for both educational institutions and enterprises sides. The creation of a validated certificates database can save the organization from losses related to the

confirmation of the validity of diplomas and certificates.

The Japanese company Sony, which created the Sony Global Education service, has been using blockchain technology for issuing certificates since the end of 2017. The company is going to show on its own how this technology will become the future in the field of ensuring the reliability of knowledge gained by education [24].

Sony Global Education believes that individual student performance data in education is as valuable as, for example, a personal credit history. When using blockchain technology, the data will be protected by a digital signature and can be safely transferred to other interested parties. Keeping reliable data will allow you to get a complete history of the acquirer (for example, as a computer test) on a protected platform. Thus, the implementation of blockchain technology in education is already finding its application, and in Fig. 1 an example of the use of a chain of micro-accounting data in relations between a university, a student, and an employer is depicted.
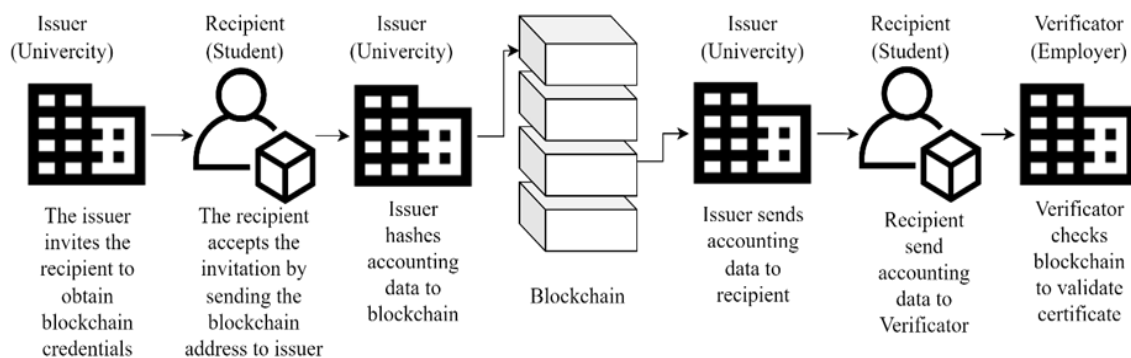

Figure 1: Chain of micro-accounting data

The main idea is the implementation of the possibility of safe storage of certificates, diplomas, and achievements of the applicant, which can solve the following tasks:

- Standardization and/or globalization of education.
- Availability of a reliable, open, and unified market of candidates with proven knowledge.
- Keeping an educational program relevant, and, therefore, the reduction of the gap between the labor market and the education market.

Based on these tasks, the following scenarios of the application of blockchain technology in education can be derived:

- Student identification.
- Accounting of the student's rates.
- Tuition fees.
- Scholarships and incentives.
- Linkage of each newly obtained assessment to goals and knowledge.
- Automated issuance of diplomas and certificates upon achievement of a predefined goal.
- Validation of certificates and diplomas.

- Secured storage and information transfer.
- Conducting tests, surveys, and polls.
- Investment attraction.
- Accreditation and control of an educational institution.

Also, it is a good idea to use smart contracts to sign an agreement between applicants and the university, where the fulfillment of all conditions will result in the receipt of a diploma especially its digital version based on the blockchain. The smart contract includes a list of conditions that the applicant must fulfill to successfully close the agreement: passing university entrance exams, completing all semesters, completing industrial and pre-diploma internships, and defending the thesis.

Therefore, the implementation of smart contracts and blockchain technology will help raise the status of Ukrainian education in the world.

Analyzing the usage scenarios derived, the following key features of LMS based on blockchain can be developed:

- Management of students' academic data.
- Ensuring the integrity of data.
- Ensuring the reliability of data.

These features will be discussed in the next chapters.

3.2. Students' Data Management Capabilities

The use of blockchain technology in information management systems is observed regardless of the field of human activity [25]. Therefore, it is natural that the study of the usage possibility of technology capabilities to maintain academic profiles of students, monitor their data, and enter data according to academic performance becomes a subject of scientific interest. For example, the study [26] proposed a learning management system based on blockchain technology, which allows transferring part of the administrative and academic load from employees of higher education institutions to the system itself by combining blockchain technologies and smart contract technologies [27–28].

Usage of such an approach will allow us to freely obtain data on the student's academic performance and overall educational success. First, this will make it possible to store information about the student's progress in a decentralized manner, which will protect data from the possibility of loss in case of force majeure. Also, the use of blockchain technology makes it possible to increase the level of trust between the parties of the educational process, because such capabilities as the immutability of stored information, as well as the non-existence of users with special rights, such as system administrators, will secure information from unauthorized changes. Moreover, the use of smart contract technology allows for to elimination of or minimizes the human factor when evaluating training results.

3.3. Capability Ensuring the Integrity and Reliability of Information About the Student

The need for secured storage for information about the student is obvious, however, in modern realities, the need to create a decentralized system is quite urgent since the presence of a central point of vulnerability is something unacceptable. The relevance of such a system only increases due to the full-scale invasion of Russia into Ukraine, which forced several Ukrainian higher education institutions to move from the temporarily occupied territories to the territory controlled by Ukraine [29]. Accordingly, the presence of a decentralized system would simplify the process of moving data in force majeure circumstances, as well as minimize the possibility of losing data on students' education, since the decentralized nature of the system would guarantee the absence of a central point of vulnerability and storage of data by nodes of the system which can be located in different regions of the country while maintaining whole copy of data on each node.

Moreover, this approach allows not only to ensure the preservation of data on the part of the higher education institution but also to restore access to the student's lost crypto wallet, which in such systems mainly serves as a place for storing information about the student and its identification. Since the recovery of a lost wallet does not require any actions from the network, only the presence of a seed phrase [30] is required. Thus, this approach will also allow for simplified restoration of access by the student to information about himself in case of loss of the medium with the wallet if the seed phrase is available [31–33].

4. Development of the System Concept

The use of smart contract technology and blockchain in the field of education will require the development of a network that will be available to all parties: the acquirer himself, the provider of educational services, and other interested parties, such as employers. The basis of this approach will be the use of blockchain technology, smart contracts, and NFT. The idea of this approach is that the data about the student, in particular about academic performance, will be stored in the blockchain, and the decision to issue a diploma or certificate of completion of courses will be made by a smart contract concluded between the client and the educational service provider, which will reduce human factor, and such characteristics of the blockchain as immutability and distributedness will make it possible to verify the authenticity of the data in

the network, as well as to confirm the authenticity of the issued blockchain diploma and its data, which will act as an NFT token. Issuance of this blockchain diploma will be carried out by a smart contract, based on the conditions set by the provider of educational services before the start of the education process.

Although this network must be accessible to all parties, it seems logical to use open blockchain network technology. However, considering its properties in the context of a system that processes data that can be classified as personal, the usage of an open network is inappropriate. Also, a fully private network cannot be used since it is crucial to provide access to data for external parties as this is crucial to the validation of diploma or certificate existence.

In this case, it would be wise to use a combination of two types of blockchain networks: hybrid and consortium [34]. Such networks allow us to combine the advantages of such types of blockchain networks as private and open. A hybrid network will be used to build an educational service provider network, and a consortium network will be used to build a common unified network of educational service providers.

The hybrid network should be considered as the network of the provider of educational services that will be responsible for the learning process itself, checking the success of the applicant and saving his data, and the consortium network (the network of providers of educational services) will be responsible for saving the diplomas of a unified type in the blockchain.

This approach will provide several advantages for all parties, for example, as mentioned in the previous sections, the acquirer gets control over his academic data,

the provider of educational services can assure other parties of the authenticity of the data stored in the network about the acquirer's success and the absence of unauthorized changes while ensuring the separation of data into open and data with limited access. Also, the employer will be able to check the authenticity of the data on the obtained qualification, which the employee will provide.

Furthermore, the use of a consortium-type blockchain network for processing data related to the unified blockchain diploma and diploma itself will make it possible to make sure that new network participants, i.e., new providers of educational services, meet the requirements of the network to include them as new nodes of the network. This principle will make sure that new providers who want to become members of the network ensure the quality level of the provided educational services.

The use of a unified type of blockchain diploma will reduce the challenges of scaling the network. The principle of using a unified blockchain diploma should ensure that each education provider will add to the network only a blockchain diploma of the established model, which must contain the minimum amount of data that will ensure the possibility of validating the diploma itself.

Another factor that will reduce system scalability challenges is the use of a separate blockchain network within the educational service provider. The use of a hybrid type of network will allow the provider to determine which data should be classified as open access data and which data should be classified as restricted access data and be prohibited from accessing from external parties.

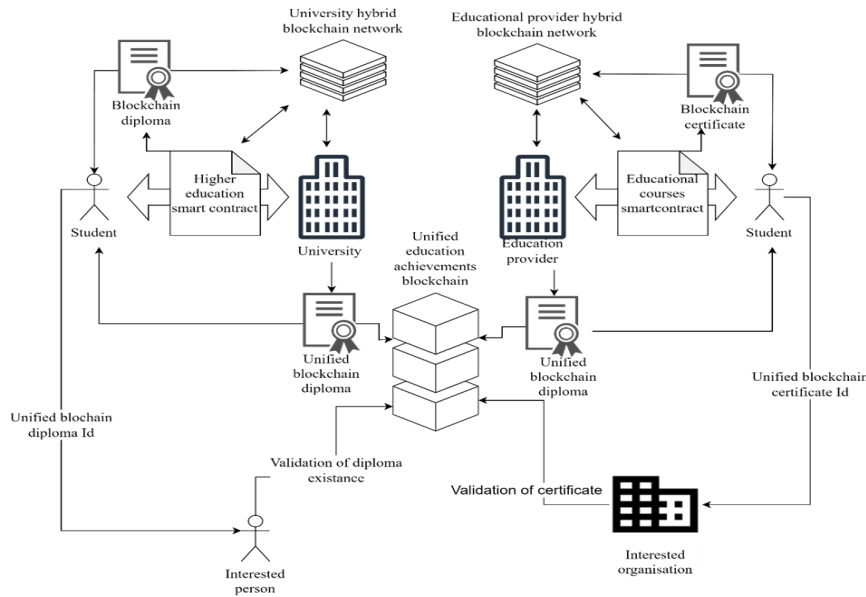In Fig. 2 the concept of such a network is depicted.

Figure 1: The concept of the proposed network

The algorithm of the proposed system will have the following steps:

1. The user receives a crypto wallet.
2. The provider offers the user conditions for obtaining the blockchain version of the diploma.
3. A smart contract is concluded between the user and the provider of educational services.
4. The user's educational data are regularly saved into the network. For example, current control, exam results, completed courses, etc.
5. The smart contract analyzes the data.
6. When the conditions mentioned in step 2 are met, the smart contract decides to issue a blockchain diploma, generates an NFT token that acts as this diploma, adds it to the hybrid blockchain network, and establishes the user as the owner of the diploma.
7. The user receives the generated NFT in his crypto wallet.
8. Based on the generated blockchain diploma, the education service provider generates the unified version of the diploma and adds it to the blockchain network of providers while making the acquirer the owner of the unified diploma NFT.
9. When needed, the user provides the token identifier to an interested party, to verify the information and confirm the user's qualifications.

So, such an algorithm will produce two types of diplomas. The first one will be stored in a hybrid network of education providers to maintain whole information about the owner of the diploma and its owner in a safe place and provide access only for open data, while the unified blockchain diploma will store only data that can be classified as open and will be enough to validate the owner's qualification and diplomas ownership.

The advantages and disadvantages of the proposed system are described in Table 2.

Table 2

Analysis of advantages and disadvantages of the proposed system

Analysis process	Learning management system based on two types of blockchain
Advantages	The acquirer gets control over his data.
	Reducing scalability issues through a unified blockchain diploma and separate blockchain networks for educational service providers.
	Collective control over the unified blockchain network.
	The educational service provider may classify information and process it according to type.
	Possibility of integration of new members into the network.

	Reduction of human intervention in the network through the use of smart contracts.
	Control over education provider quality through establishing criteria to join the network.
	Reduced level of decentralization.
	Reducing the level of transparency of the provider network due to the use of hybrid networks.
	A need to create a blockchain network for every provider of educational services.
Disadvantages	The need to train staff to work with new technologies.
	Risk of high-cost smart contracts for complex conditions
	The increase in blockchain size is dependent on students' data collected.
	Compliance with data protection laws such as GDPR [35], CCPA [36], Law of Ukraine on Personal Data Protection [37].

Such a system can bump into difficulties with its implementation or realization. That's why before its implementation all problematic moments should be considered. A number of them will be connected to blockchain technology disadvantages, such as block sizes, different transaction speeds based on chosen consensus mechanisms [38], etc. Alongside with limitation of blockchain itself, the right ways of using the smart contract technology should be developed.

At first glance, the usage of self-executing code looks excellent for the process of monitoring the education progression of students. For example, a discipline token can be created for each discipline studied at a higher education institution, which the applicant will receive for completing certain tasks and will accumulate their crypto wallet. During the semester control, he will be allowed to exchange tokens as proof of successful study of the discipline. Such evidence can be done in the form of a token of completed discipline. An example of such a token can be NFT, which will contain all the necessary information about the completed course, the student's success rate, the number of ECTS credits, etc. This approach will make it possible to minimize the intervention of intermediaries in the process of monitoring educational achievements, i.e., making unauthorized changes impossible, which in turn will increase the level of trust in the higher education institution itself. However, the disadvantage of this approach will lead to the necessity of creating a system with a large number of smart contracts, which can be expensive, since the creation of contracts and their uploading to the network will require certain costs. For example, there is a gas fee in the Ethereum network, which must be paid to the network every time a smart contract is uploaded, or transaction is created [39]. Also, these contracts will require constant updates, as the curriculum may change, and such changes should be reflected in the blockchain network.

An alternative case of using smart contracts is the generation of special blockchain diplomas upon completion of studies and fulfillment of all conditions for obtaining a diploma, which was mentioned in step 6 of the proposed system algorithm.

At this stage of the development of the higher education system, such diplomas can be considered not as a mandatory part of the completion of studies, but as an additional option that can be obtained in addition to the usual diploma of higher education. The main advantage of this approach is that the number of smart contracts that need to be created will be reduced to one, which will be responsible for creating the blockchain version of the diploma. Also, the costs of processing the transaction and paying for services for creating such a version of the diploma will be borne by the person who wants to create it, and not by the Higher Education Institution itself. Also, the use of smart contracts for these purposes excludes the need to use the administrative resources of higher education institutes, since this process is automatic. For example, the presence of a regular diploma in the Unified State Electronic Database on Education [40] can be a criterion for allowing the creation of a blockchain version of a diploma.

Such disadvantages as a decreased level of transparency cannot be overcome since this is a necessary step to maintain privacy and data safety. But to ensure that the education process is fair the code used to develop each education

provider network and the smart contract in it, should be available for independent audit.

Also, a reduced level of decentralization in unified blockchain networks is necessary to secure the network itself from the acceptance of low-quality education providers.

Another drawback is the speed of transactions. For example, when checking the existence of a diploma in the blockchain network, no transactions need to be made, since it is only necessary to check the presence of data in the network, and when entering data about success, a transaction will be made every time points are received for completing a task, passing an exam, or creating the blockchain version of the diploma. In some networks, bandwidth is as low as in Bitcoin, which can handle only 7 transactions per second [41]. Such disadvantages can be overcome by choosing the right consensus mechanism.

Moreover, new participants of the network will require their blockchain to participate in the network. This can be handled by developing a basic version of a hybrid blockchain network and providing it if they don't have their own.

Furthermore, one of the complicated disadvantages is compliance with data protection rules which can vary from country to country. For EU users the GDPR requirement must be preserved, for users from the USA— CPPA, and for Ukrainian users—the Law of Ukraine on Personal Data Protection, and other laws which can be actual in the rest of the world. That's why making such a system by the mentioned laws can become a time and cost-consuming problem. For example, by GDPR, when the collected data about a person is no longer needed, it should be immediately destroyed. However, one of the main characteristics of the blockchain is that any data saved cannot be deleted, which makes system development tricky in the legislation field, as any inconsistencies with the law can erupt in financial, reputational, and other losses.

5. Conclusions

Developing the concept of blockchain usage in education the advantages of using the technology along with the disadvantages were identified.

First, the use of this technology will increase the level of trust between the parties of the educational process by preventing unauthorized changes to data and will also provide students with the opportunity to control information about themselves while monitoring any changes made to their profiles.

Second, an important aspect of the use of this technology is that it will allow any interested party to verify the data about the diploma, certificate, etc. provided to them since the existence of this data in the blockchain network will testify to its authenticity.

Third, the use of smart contracts will reduce the burden on the administrative part of the education institutes alongside with reduction of the number of errors, as the influence of the human factor will be decreased.

Fourth, such a concept of network will have possibilities for scaling because it provides the possibility to use a unified blockchain diploma for all education providers giving opportunity to store their diploma inside their network. This means that new participators are only required to create a way to produce a unified blockchain diploma and no other changes in their network.

However, the use of technology will also have weaknesses that will affect the possibility of its use in education. In particular, the biggest obstacle in the use of the technology may be the problem of saving information about parties of the educational process in the blockchain network, since such information must be processed according to different data protection rules, which currently are not suitable for blockchain. So additional efforts should be made to store data according to the law. To overcome such issues the usage of networks with lover levels of transparency and decentralization was proposed. This will help to control access to information that may contain the personal data of individuals while still giving access to data that can be qualified as open data.

Another disadvantage of the technology is the price of developing and maintaining such a system network, since smart contracts are not cheap, however, their use is necessary to ensure the operation of the system and minimize human intervention, and their price depends on the complexity and size of the code. In addition, changes in the curriculum will require reflection in the network and, accordingly, changes in the code of the smart

contract itself, which will also incur financial costs for updating it.

Also, over time, the growth of the network itself will lead to an increase in computing power, and will also cause a decrease in the speed of transactions in the network due to the very size of the blockchain. To overcome these problems the usage of separate networks was proposed. This will allow for maintaining a unified blockchain in optimal conditions while all other calculations should be done inside the education provider network.

All in all, the usage of such a system can have a future, but before implementation all weak places should be considered and overcome or their impact should be minimized.

Furthermore, the use of this technology in education will ensure that the data such as a diploma, certificate, degree, etc., that will be provided to the interested party, are reliable, which will allow to confirm the qualification and possession of the necessary skills. Therefore, the implementation of blockchain technology in the field of education can become the foundation for ensuring trust between employers, graduates, and educational institutions by ensuring the transparency of the educational process, which in turn will increase the prestige of higher education institutions in Ukraine.

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