*sustainability*

*Article*

# Blockchain Technologies and Digitalization in Function of Student Work Evaluation

**Goran Bjelobaba [1], Marija Paunovic [2], Ana Savic [3,*], Hana Stefanovic [4], Jelena Doganjic [5] and Zivanka Miladinovic Bogavac [6]**

1 Department for e-Business, Faculty of Organizational Sciences, University of Belgrade, 11000 Belgrade, Serbia; gbjelobaba@gmail.com
2 Faculty of Hotel Management and Tourism, University of Kragujevac, 36210 Vrnjacka Banja, Serbia; majap@rcub.bg.ac.rs
3 School of Electrical and Computer Engineering, Academy of Technical and Art Applied Studies, 11000 Belgrade, Serbia
4 Comtrade Information Technology School of Applied Studies, 11000 Belgrade, Serbia; hana.stefanovic@its.edu.rs
5 Milenijum Osiguranje Insurance Company, JSIC, 11000 Belgrade, Serbia; doganjic.jelena75@gmail.com
6 Faculty of Business and Law, University "MB", 11000 Belgrade, Serbia; zivankamiladinovic@gmail.com
* Correspondence: ana.savic@viser.edu.rs

**Abstract:** Following COVID-19, new accreditation standards include digitization, entrepreneurship, social inclusion and the circular economy. Blockchain can help to simplify difficult accreditation processes that ensure worldwide teaching, learning, practice and business communication excellence. The paper proposes a Collaborative Learning and Student Work Evaluation (CLSWE) model based on blockchain technologies (BCTs) encompassing selected concepts from the scientific research peer-review process. BCTs are used to develop a safe platform for storing and exchanging data about students' projects and evaluations. The CLSWE model offers the possibility of improving cooperation between higher-education institutions and companies that seek the "employable skills" of proactive students. Before implementing the CLSWE model, a questionnaire was conducted to survey lecturers about their attitudes related to the potential application of BCTs. The results of the surveys are encouraging and reveal a desire and willingness to introduce BCTs in education. A project scheme with the main functionalities of the model and a description of the roles of the prominent participants was designed. A platform with a database created in the MySQL language for the testing model was built. This research also contributes to higher education literature in terms of the sustainability of the education process and collaborative learning with BCTs.

**Keywords:** blockchain technologies; collaborative learning; digitalization; education process; peer assessment; QR code

**Citation:** Bjelobaba, G.; Paunovic, M.; Savic, A.; Stefanovic, H.; Doganjic, J.; Miladinovic Bogavac, Z. Blockchain Technologies and Digitalization in Function of Student Work Evaluation. *Sustainability* **2022**, *14*, 5333. https://doi.org/10.3390/su14095333

Academic Editors: David González-Gómez and Jin Su Jeong

Received: 9 February 2022
Accepted: 18 April 2022
Published: 28 April 2022

**Publisher's Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



## 1. Introduction

Collaborative learning is an exchange of ideas that enables and improves the interaction between two students (student–student) coping with the learning material on a network. When we imagine individuals seemingly completely focused on the screens and keyboards of their devices, we most frequently have a preconception that they are using those learning devices by themselves. However, such images of individual learning accompanied by electronic tools frequently do not reflect the hidden reality. In reality, students often use their computers to interact with others, and it is frequently their peers whom they interact with [1]. These ideas arise from learning technology known as collaborative learning. Essentially, the collective learning ideas proposed in this paper are models based on blockchain technologies, which can be used to promote cooperation amongst students working in online environments [2]. Collaborative learning principles arise from a well-established approach to education, have a specific meaning and are specifically applied in practice.

Since the early 1970s, there has been an idea that students learn through participation in evaluating work completed by other students of the same class (in the same study year or attending the same subject). By participating in their peers' work and projects, students acquire specific types of knowledge by considering the set problems, checking the obtained results, researching the literature used and taking part in two-way communication. Considering the fact that students are active in reasoning and are functionally active [1], such collaborative learning processes enable students to develop and learn a methodology and develop critical thinking intellectually. Given the nature of the process, there is a knowledge transfer between students. Collaborative learning is closely connected with information processing, which makes it suitable for environments based on contemporary technology, where the focus is on neither a type of hardware nor software, but on the learning experience. The development of e-education technologies, especially during the shift to e-education during the COVID-19 pandemic, has prompted a search for new approaches to collaborative learning oriented toward practical and project work.

By applying collaborative learning methods, models used for the improvement of the teaching process in electronic education should enable the relevant, authentic, transparent and safe evaluation of student work [2], especially in the context of systems with a large number of students, such as MOOCs (Massive Online Open Courses) or e-learning systems [3–5]. In traditional approaches to mass subjects in higher education, the evaluation of students' knowledge is typically performed by testing. The outcome is information about whether a student has or has not passed the test. There is often no clear information about the material that a student has learned from and how successful they were. Furthermore, there is no information on whether the student has been trained to apply scientific material to solve problems in practice. This segment is evaluated through seminar papers and projects, particularly in engineering disciplines, where a concrete project is expected as a learning result. For this reason, students must be enabled to learn in a project-oriented manner, which should be more dominant than the reproduction of what has been discovered [6]. To provide a quality education process, it is necessary for students to work on practical projects and research and to develop their problem-solving abilities and critical thinking [7–11], with this being accompanied by the quality evaluation of student work [12–14].

Blockchain has a high potential to achieve sustainability in business and industrial practices as it offers resources to extend the life cycle of a given product and maximize the use of resources, contributing to sustainability. Blockchain technology is efficiently applied in many sectors, including education. Although blockchain technologies are rarely involved in education, current research indicates their potential in the education sector [15]. Although the use of BCTs in education is in its initial phase, blockchain-based applications are rapidly being developed in different fields of education, including collaborative learning environments with a high security level for all participants [16–18]; the management of competencies and learning outcomes; copyright management [19]; student examinations and examination systems [19,20]; the assessment of students' professional capabilities, which can be used by companies when employing them [21–23]; lifelong learning [23]; online education [24]; and the issuance and verification of diplomas, transcripts, and certificates [25,26], which can be shared between individuals and organizations for verification [27,28]. The EduCTX credential recording transfer platform used amongst partner higher-education institutions to eliminate an intermediary [29] and the data management of educational systems [30] are examples of this approach. Applying blockchain technologies in education encompasses intermediary-free data management and verification without jeopardizing authenticity while simultaneously providing constant availability and confidentiality with complete transparency.

During both their education and professional work, each individual goes through a series of education programs and courses to acquire skills and appropriate certificates issued by different educational institutions. The authors [31] highlight the necessity for the existence of the records of these certificates to be easily authenticated by an employer. This research study considers the advantages of digitalization using blockchain technology and the automation of intermediary-free data verification in the education sector. Similarly, Sharples and Domingue [18] proposed applying blockchain systems for sharing checkable records, i.e., verifiable pieces of information relating to students' awards and records. The authors also offer a kind of currency connected with the reputation established by an educational institution.

Apart from the more reliable assessment of students' competencies, in accordance with the needs of the market, i.e., employers, the proposed model also offers an efficient way for students to self-evaluate during the teaching process. It simultaneously presents an invitation to educational institutions better adapt their educational programs to the market's needs.

*Introduction of the Proposed Model*

This paper proposes the Collaborative Learning and Student Work Evaluation (CLSWE) model based on blockchain technologies, which encompasses the concepts selected from the scientific research paper peer-review process and by applying and adapting good practices from the services such as Publons and arXiv. Students' work and project evaluation will be improved through collaborative learning analogous to the scientific research paper peer-review process. In the proposed model, blockchain technology will be used to develop a safe platform for storing and exchanging data about students' projects and works, student evaluators, peer reviewers from practice, and evaluations. The problem of ensuring data authenticity and non-retractability that may appear in a process such as this can be secured with the help of the proposed model by applying blockchain technologies.

The application of open-science concepts in the educational context will enable better students to work with greater quality and transparency of the whole process. Moreover, their application will also become a part of the career development process. Through their participation in collaborative learning and evaluation of the works of their peers, students use a similar way of thinking and the procedures used in the scientific paper peer review process [32–36]. They simultaneously acquire new types of knowledge within the learning and methodology domains, the ability to think critically and analytically, communication skills, and teamwork, as well as academic and socially responsible behaviour. By participating in the work evaluation process, students build credibility by performing the tasks in a high-quality manner, and those evaluating such works in the best way are acclaimed.

The proposed model also enables connecting with partner higher-education institutions and collaborative learning amongst students at different faculties. The application of blockchain technologies also allows for participation in evaluating student work to become a part of the career development process. Evaluations and evaluated projects will be available to the interested employers. Given the fact that employers have no access to quality students, ensuring them the access to such students from the early schooling years on would pique their interest in participating in this process. The employers who take part in the blockchain collaborative learning and student work evaluation network will be enabled to access future personnel and acquire benefits depending on points, i.e., an internal cryptocurrency [37–39]. Points will be acquired through participation in the student work evaluation process and transaction verification. They will be spent on additional services within the framework of the system and connecting with better students.

## 2. Collaborative Learning

Collaborative learning is an educational approach implying the use of learning improvement groups through joint work. It implies groups of two or more students who work together on problem solving, task solving or learning new concepts. This approach actively includes students in the analysis and synthesis of information and concepts instead of promoting their learning by heart and remembering facts and figures. Students have the possibility to cooperate between themselves on projects where they have to act as a group in order to understand the concepts presented to them [40]. By defending their attitudes, reshaping their ideas, listening to other participants' points of view, and articulating their standpoints, students acquire a more complete understanding of working in a group than they would be able to do working individually [33].

Collaborative learning takes into consideration the different learning premises, which all have one thing in common—to not only present pieces of information to students, but also to make them actively construct knowledge in interaction with other students [35]. For example, collaborative learning can be performed in pairs (dyads) of students, e.g., in the reciprocal teaching process, in small groups of, say, four students or with those attending the course as a whole.

When speaking about collaborative learning in the sense of the roles inside an organization and software development, the group of junior programmers has the task of learning a new framework and then developing a part of the program while using it. Each programmer has his/her part of the development code, but their work will only be a success if they all learn and properly perform their part of the code. Although each person has their own separate role in the work being carried out, the group as a whole has a share in the success of others [16]. In a joint learning process, individual participants also have to take responsibility for the learning results and success of their team, but their roles, resources and organization are left to themselves. There is no organizer who would be applying engagement rules, so the group has to direct itself on its own.

Moreover, a lot of research was conducted in the collaborative learning field and on the practical model itself. Although collaborative learning covers a broad range of participants, fields and learning manners for the needs of this paper, the focus will be on network learning. Generally, collaborative learning itself has numerous positive effects on the participants' cognitive and affective variables [32]. Nowadays, the research studies on collaborative learning in connection with online learning are worthy of significant attention on the part of the professional public, which can be seen in the Internet databases of the International Association for Studying Cooperation in Education (IASCE).

Collaborative learning can also be defined as a set of principles and techniques intended to assist students in cooperation with other peers and other people [41]. In practice, hundreds of different collaborative learning models have been developed so far, a large number of which provide teachers and students with a plethora of ideas about how to take further steps towards raising the probability that student-to-student interaction will achieve its potential. Furthermore, there is a note of optimism that collaborative skills and attitudes developed by students in the interaction process with their peers will serve students throughout their lives, both in the lifelong learning process and in any other context they may find themselves in.

There are several collaborative learning models based on principles such as heterogeneous grouping, collaborative teaching skills, group autonomy, maximum interaction between students, equal possibilities of participation, individual responsibility, positive interdependence, and cooperation as values. Research studies suggest that collaborative learning is connected with improved cognitive and affective outcomes.

Teaching collaborative skills may especially be important in online environments, such as discussion panels, email, and social networks, for the reason that these environments represent new challenges requiring a variety of skills appropriate in face-to-face environments [42].

Group autonomy is a significant principle. Students quite often tend to excessively depend on their teachers, neglecting their and their peers' abilities. The group autonomy principle encourages students to first look to their group peers when they need help or when they want feedback. In order for students to adopt the lifelong learning concept, they have to assume some roles that used to be considered the teacher's exclusive domain, such as assistance and feedback provision roles. Taking on these roles allows students to learn while also encouraging peer-to-peer interaction. When students are assisting one another according to their respective possibilities, teachers may offer assistance exceeding the students' current abilities [35].

The collaborative learning literature offers a lot of ideas for promoting group autonomy since it may be especially important in IT environments, so much more than in classrooms, because it is less likely that teachers will immediately be available for assistance. In online environments, when students face difficulties, they may contact their peers instead of giving up or waiting for a few hours or even longer for their teachers' help.

The collaborative learning principle of maximum interaction amongst students refers to maximizing the two aspects of interpersonal interactions.

First, the number of student-to-student interactions increases in group activities, especially when there is a small number of members in each group. A similar situation happens on occasions when certain students interact with only a small number of their peers instead of the group as a whole.

Second, the usefulness of student-to-student interactions increases when students use higher-order reasoning skills [43]. The "magic" of collaborative learning actually lies in the quality of student-to-student interactions. These reasoning interactions promote harder learning, greater processing depth, and greater engagement in students [44]. Therefore, the greater the number of these quality student-to-student interactions, the better.

Information technologies offer a lot of new and attractive peer-to-peer interaction tools. Together with different software, information technologies provide the tools that offer all group members equal opportunities to participate. For example, unlike face-to-face discussions in which some group members may have difficulties being heard, asynchronous network communication enables students to exchange their ideas without needing to compete for their place in the conversation. The other ideas promoting equal possibilities for participation include colour coding. This concept demonstrates the contribution of each person to the graphic presentation, a table or a text, or of the group members randomly selected to share their respective groups' ideas. Moreover, some pieces of software enable students and teachers to track the distribution and quality of divergence in their groups.

Individual responsibility is reflected in the fact that the individual responsibility principle exerts pressure on the members to achieve their equitable share in groups as long as there is an equal possibility of participation, which tends to offer all group members an opportunity to play important roles in their groups. Therefore, individual responsibility can be perceived as the opposite side of equal participation. Students should use the offered opportunities to contribute to their groups as best they can [36]. A significant benefit is that collaborative learning theories and IT tools offer ideas for promoting individual responsibility. For example, groups may appoint who should do what and when and track if that has been completed. Apart from that, the same software that promotes equal possibilities of participation by tracking every group member's participation can also inform group peers and teachers about who does and does not perform the entrusted work in the group. Including peers in a grading process is one of the two ways to overcome the difficulties often encountered in the process of grading. Most often, lecturers impose the difficulties on themselves for the purpose of grading, forgetting the fact that students are in a better position to supervise their peers' contributions; the other way implies students learning together, but grading each other themselves, e.g., after they have been working together on solving a set of online problems, they work on yet another set of similar problems on their own.

Positive interdependence is the collaborative learning principle that most prominently encourages sharing amongst students. When students feel positively interdependent on their team peers, the group feels their outcomes are positively connected. Positive interdependence can also stimulate motivation for learning since students not only learn for themselves but also learn for the welfare of their teams. Cooperation as a value is built on positive interdependence, with a tendency to convey positive feelings and attitudes of a small group of students to the whole generation, educational institution, city, nation, world and beyond.

## 3. Blockchain Technologies in Education

A blockchain is a decentralized and distributed database in which data cannot be modified or deleted and which enables transaction verification. Transaction-related data are saved on different computers in a network, which are interconnected using the peer-to-peer protocol, where each node shares the same data copy, i.e., a digital register (Digital Ledger) [45]. Data exchange in a blockchain is performed according to predefined rules. Changes are forwarded to all the nodes so as to update the local copy of the data. After a transaction has been saved and confirmed by all the network nodes, it is no longer possible to apply the data of that transaction. This transaction confirmation process is called mining and is based on some of the consensus algorithms based on which an agreement is made between nodes when adopting a new block. A high safety level is ensured in a blockchain since the transactions made are anonymous. Each transaction or digital event performed in the blockchain network is only verified if it is agreed upon by the majority of users participating in the process [46].

The digitization and application of blockchain technologies in higher education institutions provide students with the opportunity to participate in the education sector transformation and gain confidence in the use of the modern technologies necessary for their future jobs. The advantages offered by the application of blockchain technologies in different domains include safety, decentralization, transparency and unchangeability [47]. Blockchain technology prevents abuses in the sense of forging and denying content since it saves complete records in data blocks in sequences with timestamps, where old and new data blocks cannot be deleted, whereas a cryptographic algorithm prevents the unauthorized imputation of data and reduces the possibility of fraud [24]. Due to these characteristics, blockchain technology is used in different sectors, such as finance [48], business operations [38], the health system [49], tourism [50], the energy sector [51], the public sector [52] and education [31,53].

The elimination of the central authority from the database structures is one of the most important and the most powerful aspects of the blockchain system. Coding all important data records in a blockchain is performed with the help of cryptographic techniques. Cryptographic techniques enable consistent data and record integrity. A blockchain consists of three layers: the protocol layer, the network layer, and the application or business layer. Each layer adds different components to the blockchain in order for it to develop.

The application of blockchain-technology-based collaborative learning has been created with the aim of increasing the value of student interactions carried out via electronic devices and diverse software tools. The availability of Web 2.0 [47] and the tools based on the cloud, such as Google documents, Popplet and Prezi, enables more users to create, write, edit, and comment on shared documents, in which way individuals are offered a cooperation platform.

When devising the activities of project-oriented collaborative learning, teachers have to define what students are expected to learn from that activity [54]. This is called the project goal (e.g., learning a certain topic or acquiring cooperation skills). A kind of interaction directed by the support measures for achieving this goal is connected with the goal of such joint activity, yet not identical to it. For example, the learning activity *goal* can be the acquisition of new types of knowledge of the content. In order to achieve this goal, the teacher may include students in the mutual teaching process, where students come one after another to explain something to their peers. So, the teaching support goal is to generate a specific kind of interaction between students. Although only a few teaching frameworks differentiate these dimensions, considering these aspects separately enables a more precise teaching process design [55].

Through the collective writing process, or the process of project task solving as per phases, students will recognize the values of cooperation, aware that the quality and success of their report depend on the contributions made and the feedback provided by individual students. Technology enables collaboration in real-time, where students' feedback and comments can be viewed immediately. Moreover, with computer science in the cloud, cooperation between students is invisibly carried out on different devices, such as tablets, smartphones and computers, and students can cooperate wherever they may be and at the right time.

Activities such as asking questions that provoke students to think require that students should verbalize their thoughts (thinking aloud). This enables the other group members to watch the decision-making processes and internalize them by imitation (recognition modelling). Thinking aloud can also provoke new discussions when the group members gather ideas and discuss them. Students must explain and clarify their ideas using concept illustration examples (the development) and create explicit connections between the notions (the organization) during the argumentation. If students fail to make their ideas understandable to others, they may identify the gaps in their knowledge. In return, this may cause the collaborative learning processes to be directed towards filling these gaps. Students also have to reconcile the cognitive differences arising from opposed standpoints regarding the topic discussed during the argumentation.

### *3.1. Methodology*

The CLSWE model's theoretical framework is grounded in systematic literature review as a convenient resource for leading edges of research and determining starting points for further research on the theme. Further, before implementing the proposed CLSWE model, a questionnaire was conducted to survey lecturers with 130 respondents about their attitudes to the potential application of blockchain technologies in education. Purposeful sampling was used in this research. Results are presented in Section 4.

In the proposed CLSWE model (Figure 1), the first thing to do is to mention all the network participants, as illustrated in the figure below. Lecturers coming from different higher-education institutions assign tasks, seminar papers and projects in their respective subjects to students. To improve the efficiency and quality of student work evaluation, the approach proposed in this paper implies that the students attending the same subject, the senior students or the students in higher-level studies, are participants in collaborative learning and student work and project evaluation.

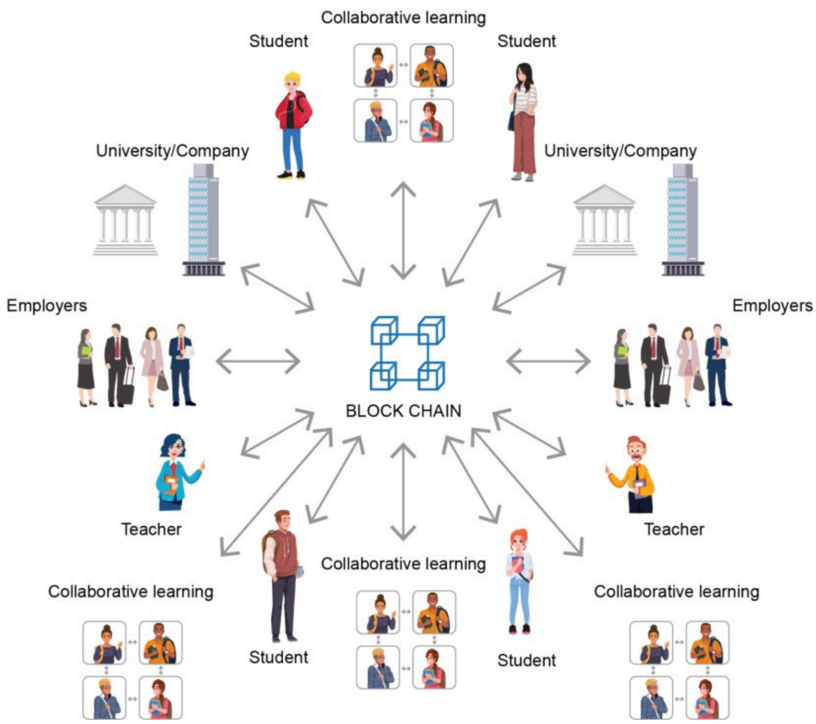


**Figure 1.** Model of collaborative learning using blockchain.

Another student evaluates every seminar paper and project, and the information about the quality of the paper is provided quantitatively and descriptively on a prescribed evaluation form. In that way, all participants in this process can see the recommendation for and evaluation of a seminar paper or a project. The proposal for each student should evaluate their colleagues' work. Teachers determine rules on the minimum and the maximum number of evaluations for their subject. According to HEI accreditation of the Republic of Serbia, the practical student groups are limited to 35. Being in a position to give their recommendation for and provide an assessment of the evaluation of student work, students contribute to the determination of the quality of the evaluator. In this way, the evaluation of student work becomes an integral part of the learning process. Participation in evaluating other students' seminar papers and projects is a mandatory part of the learning process, i.e., it is one of the pre-exam obligations.

The obligation of participation in collaborative learning within the framework of the education process stimulates in students the acquisition of knowledge in the fields studied within the framework of the subject in which a seminar paper or a project was prepared and evaluated, leading to the better connection of the adopted types of knowledge in the fields studied within the framework of the given subject, the adoption of the knowledge of the used technologies and structures, analytical skills, critical thinking, and motivation for working on projects. In that way, the competencies of collaborative learning participating students are improved. A student evaluator has to continuously demonstrate his/her interest in the evaluation process, which positively influences his/her reputation concerning the teachers and participants in practical work.

A student evaluator's reputation can be raised in a few ways:

- based on the practical work grades given by the professors or the grades given by the lecturer;
- based on the grades given by the evaluated students who can provide feedback on the quality of the review they have received;
- based on the grades given by the other students who have access to the project and evaluation;
- based on the grade offered by a businessperson as the party interested in a particular project.

In the proposed model, the reputation of students as evaluators is not crucial, but the key is for a student as the evaluator to adopt new types of knowledge. The knowledge grade is certainly generated traditionally, and the teacher is the person who does that. Reputation is significant for additional services, i.e., establishing connections with employers. Reputation is also needed at the keyword identification level, enabling a better selection of evaluators in the future. Reputation influences the importance of the institution and the teachers as well. This approach offers a more realistic picture of students' acquired types of knowledge and skills, differently from only the formal checking of knowledge. The student is interested in making his/her competencies, i.e., reputation, be recognized by professionals in practice.

Employers will have information about students' practical work results and how others have evaluated the project. A reviewer form of practice, in addition to student evaluators, may be engaged for student work and projects [14]. The evaluator's competencies will be mapped concerning the seminar paper or project topic via the keywords to select a competent evaluator. The information about the quality of the review will be saved for each reviewer. In this manner, cooperation between higher-education institutions and the company is improved. Applying an approach such as this may enable companies to better select personnel "at source".

### *3.2. Blockchain Network Modelling*

A model has been proposed by integrating the mentioned ideas, as illustrated in Figure 2. The blockchain-based evaluation model is of a permissioned blockchain [20], i.e., the limitation is related to transaction execution and overview only on the nodes that participate in the system. In contrast, the system owner determines the participants and nodes participating in the consensus mechanism. There are a few technology platforms that can fulfil the requirements of the proposed model, i.e., platforms that meet the set conditions needed for a permission network of participants. Furthermore, each participating member in the system is configured as a valid peer from a specific higher education institution (or company) with a proven identity. In this way, the requirement for data protection regulations is also met.

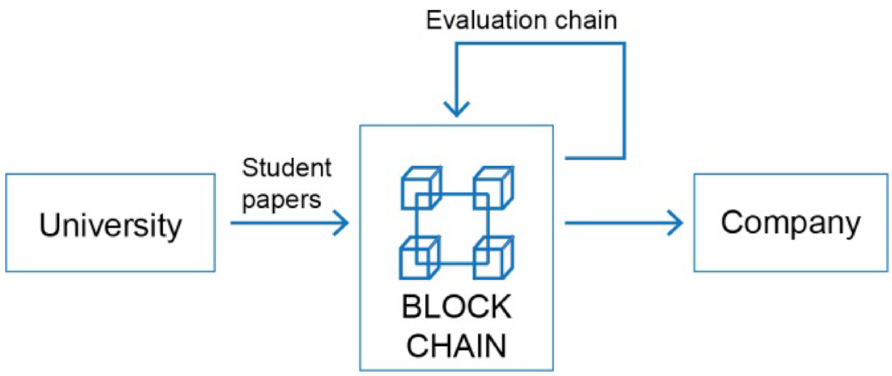


**Figure 2.** The proposed model.

By teachers' assignment of tasks, afterwards followed by the part of collaborative learning with evaluation, i.e., by filling out the evaluation form, a consensus is made, and the assets in the ledger are updated, which means that the assessment has been completed and accepted and ultimately the evaluation is approved smartly and automatically, reducing the need for human interaction. This is very significant for institutions with a large number of students. For example, the critical functionality of the Hyperledger Fabric implies offering the configuration of the number and type of the combination of the endorsers needed for considering one transaction as valid [56]. Via this functionality, i.e., via the part of the consensus algorithm, the teacher and the student have their copy of the ledger and the uploaded intelligent contracts, so that the approval procedure is the execution of smart contracts and sending the outcome results further in the network to check the integrity and reach a consensus.

System transactions are stored in the blockchain as the central system point, and all the participants involved in the system interact with the blockchain. It is essential to highlight that the first layer is a relational basis and can be understood as the system participant management layer. Within the framework of this segment, access points are determined together with roles and privileges, and collaborative learning is simultaneously being performed as well. The second layer contains transactions. Evaluations, i.e., matching the evaluator and the subject matter of evaluation, are performed in the blockchain database. The process starts when the teacher assigns a student a certain task.

According to the proposed model, the student must demonstrate knowledge about solving tasks and evaluating other papers. Tasks with evaluation are saved in the database and are agreed upon by the teacher. In the student's interest, the assessment is as good as possible. If there is no consensus, the student will lose their reputation.

The database evaluation is managed autonomously and uses a distributed timestamp server on a peer-to-peer network. To simplify interoperability between businesspersons (companies) and the evaluation part of the system based on the blockchain solution, it is proposed that this part should be accessed directly through the integrational layer, which is part of the system. Sequences of the evaluation blocks are chained for each second block sequentially (Figure 3).

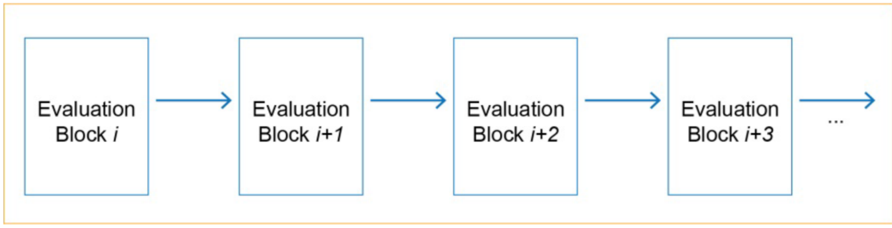


**Figure 3.** The evaluation blocks.

Based on the above illustration, the scheme is designed as follows:

1. The evaluation blockchain is a growing list of evaluation blocks.
2. The evaluator: the student who completes the evaluation form. The evaluator does not have to be publicly known to all the chain participants but only to those with appropriate privileges (e.g., professors).
3. The Public Key Infrastructure (PKI) is a set of procedures that manage critical encryption.
4. The evaluation database: This is the evaluation form database. After data about evaluating a student's paper are recorded, neither side can deny or change them.
5. Miners: Miners are responsible for dealing with student work

The first block is called the Genesis Block. Each block contains the evaluator ID, the evaluation, the evaluator's signature, the timestamp and the hash of the previous block, shown in Figure 4 and illustrated as follows:

1. the evaluator ID is randomly assigned to the participant:
   - the teacher ID
   - the student ID
   - the businessperson ID
2. The evaluation form assesses the work (a seminar paper, a project task, and so on) completed by the student.
3. The evaluation signature: the evaluation form is marked with the evaluator's signature, simultaneously prohibiting other participants from becoming knowledgeable of who has been given a vote, i.e., how a participant has voted. The evaluator uses his/her private key to sign the form, which is further used to evaluate the work.
4. ID reputation.
5. The timestamp.
6. The hash from the previous block: the SHA-256 algorithm for calculating the previous block's hash value is used.

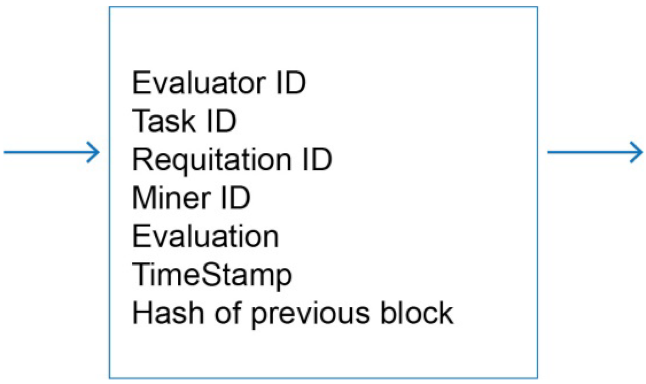


**Figure 4.** The evaluation block.

The blockchain-based evaluation scheme set in this way is resistant to data modification.

*3.3. QR-Coded Recording RSA Authentication*

The RSA authentication of the QR-coded recording leading to the link of the institution at which the lecturer is engaged is envisaged in the proposed collaborative learning and evaluation of student work (CLSWE) model, e.g., for the "lecturer" role as shown in Figure 5. First, the hash value of the recording was determined by applying the SHA (Secure Hash Algorithm) hash function, after which that value was coded by applying the RSA (Rivest–Shamir–Adleman) algorithm using the private segment of the key [57]. The RSA algorithm is based on the complexity of the problem of the factorization of the product of two big prime numbers whose selection is brought into compliance with the requirements for the practical application of public-key cryptography. The sender side is presented in green, while the received side is shown in yellow. The authentication at the sender side is completed in a few steps. First, a hash value of the message (the institution's website) is calculated using MD5 (Message Digest 5 Algorithm). Then, this hash value is encrypted with the RSA private key. Finally, it is encoded into a QR code. The receiver of the QR code decrypts the signed hash value with the public key. Then, the receiver calculates the hash value of the message and compares both hashes. If hashes are equal, the message is authenticated.

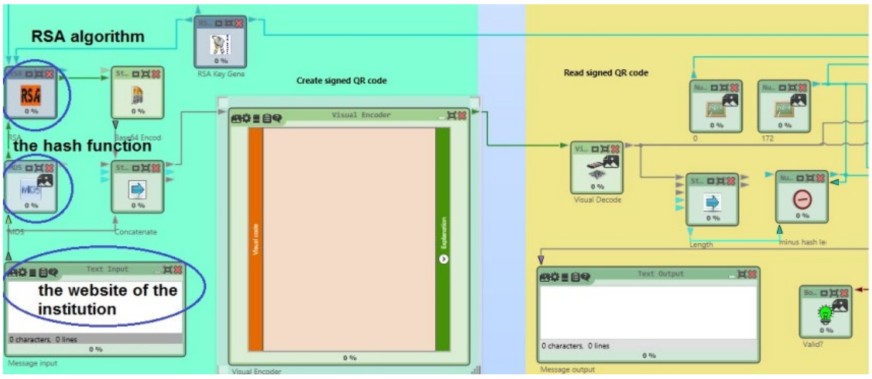


**Figure 5.** The RSA-algorithm-based authentication system model.

The RSA-signed message is then translated into a QR (Quick Response)-coded recording, as shown in Figure 6 (RSA–the hash function–the institution's website).


**Figure 6.** The RSA-signed QR-coded recording generation.

On the receipt side shown in the right-hand part of the image (the yellow colour), the signed hash values of the recording are decoded by applying the public interest of the key, whereas in the lower window, the link to the website of the institution appears, as shown in Figure 6.

Cryptography with a public key was chosen because it ensures confidentiality, which is essential for the data transmission and storage process, authentication, and the digital signature, which guarantees integrity and non-repudiation, unlike cryptographic systems with symmetrical keys, which do not provide this service [58]. The digital signature is a service that should enable the integrity of a message and non-repudiation. The integrity of a statement implies that the party receiving a message can be sure that the message has not been modified during the transmission (along the transmission path); should such a message be modified, however, the same can unambiguously be detected [58]. Non-repudiation is a service that the receiving party may use as indisputable evidence that the message has been received from exactly one particular person.

In the case of the RSA digital signature, by using the public part of the key (N, e) and the private part of the key d, the digital signature S of the message M is obtained as follows: $S = M^d$ (mod N). Number N results from the multiplication of two big prime numbers, p and q. This number is a few hundred digits, so factorization is a challenging problem. In the simulation model presented in Figures 5 and 6, the CrypTools generator of random primes is used. The exponent e is mutually prime with $(p - 1)(q - 1)$. Therefore, it is assumed that e is a prime number, as is usually taken in practice. To calculate S, the private part of the key d must be known to the user, which means that RSA decoding and RSA digital signing are essentially the same operations. $K_e$ stands for the encryption key, while $K_d$ stands for the decryption key.

The basic idea of the RSA algorithm is to find the function $C=E(M, K_e)$ that modifies the message M (the open text) into the cypher sign C, which requires that the function $E(M, K_e)$ should be one-way. The message is coded before the sending process by applying this function. The person on the receipt side needs to have a possibility of using the inverse function $M = D(C, K_d)$ knowing the secret value $K_d$ to obtain the message M from the cypher sign C. Simultaneously, each M should imply the following: $M = D(E(M, K_e), K_d)$, i.e., some one-way function with a trap needs to be found.

Increasing the safety boundary of the RSA algorithm requires an increase in the critical length, given that number factorization algorithms are constantly improved. Since the coding and decoding time is proportionate to the third degree of the required distance, the consequence implies that the RSA algorithm becomes ever slower with increased security requests. Given the development of quant computers, it is expected that the determination of the secret part of the RSA algorithm key will be possible to solve. However, for the ongoing experiments mentioned by the authors, MD5, RSA and SHA are quite adequate. Much better possibilities are offered by applying blockchain technology to provide a non-repudiation service and data tracked ability.

In the first phase of the model implementation, a website with the database created in the MySQL language was built for the purpose of testing the proposed model, and it is the first layer in charge of managing the system participants; access options with the roles and privileges are defined, together with simultaneous collaborative learning.

In Figure 7, the application's homepage is shown, whereas in Figure 8, the objects–connections model is demonstrated with the marked primary keys (PK) and foreign keys (FK).

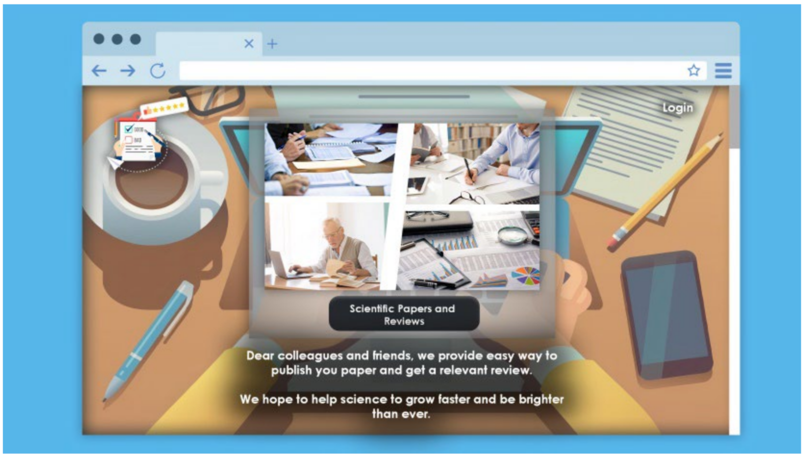


**Figure 7.** The homepage of the application.

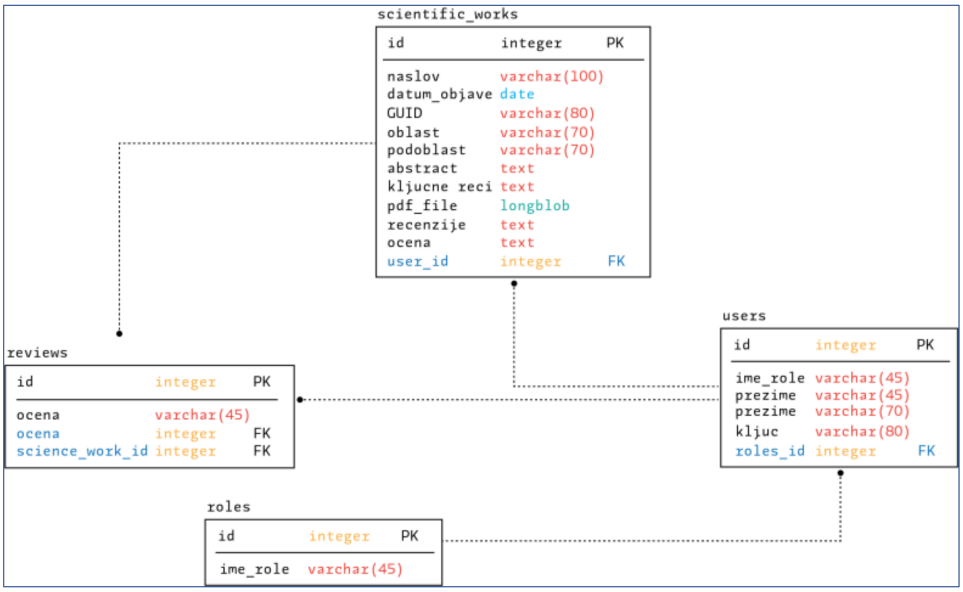


**Figure 8.** The objects–connections model.

Each paper in the database has the following parameters defined:

- the title and GUID,
- the author/authors (GUID)
- the scientific field and subfields,
- the abstract,
- the key words,
- the pdf-format document,
- the reference review list, and
- the mark generated based on the reviews.

Every user can have an overview of the scientific paper list as per fields without logging in, selecting a paper, reading the article online, or downloading it in pdf format.

The user may register as the "Author" or the "Reviewer".

The "Author"-type user has the following parameters defined:

- the name, surname and GUID,
- the list of the papers,
- the mark is generated from the papers' reviews, recalculated with every following review.
- The "Reviewer"-type user has the following parameters defined:
- the name, surname and GUID,
- the list of the reviews, and
- the mark.
- There is a possibility of browsing the paper base as per:
- the author,
- the scientific field (optional),
- the title, and
- the keywords, with the option of sorting them given the review rating.

There is a possibility of uploading a review for a scientific paper that has the following parameters defined:

- the name of the document and GUID,
- the author's name (GUID),
- the reviewer's name (GUID), and
- the review in the following format: a written form, a mark; I recommend YES/NO.

There is a possibility of presenting the list of authors as per the ranking and stating the field in which the paper is published and an overview of the list of reviewers per ranking.

Registered users' rights are as follows:

- "Author" role, with the right to upload a paper and assign the same to an appropriate category;
- "Reviewer" role, with the right to conduct a review of documents (everyone can achieve a thought, open);
- "Administrator" role, with the possibility of manipulating users and eliminating problems on the application;
- "Content Administrator" role, with the right to manage, add and delete fields and subfields.

## 4. Evaluation

Before implementing the proposed model, a study was conducted related to the potential application of blockchain technologies in education. The research instrument is a survey questionnaire intended for lecturers of higher education institutions in Serbia. The role of the lecturers in HEIs is crucial for the implementation and application of blockchain technologies for several reasons. First of all, they play the part of educators and, as such, transfer basic knowledge to students. This role is very important in the stages of the adoption of new technologies due to the lack of previous experience and practice. Secondly, they have the function of evaluators, which cannot be fully transferred to the students, but the lecturers give their final judgment. Therefore, lecturers must have a positive attitude toward the affirmation and application of blockchain technologies in collaborative learning at HEIs. In addition, adequate knowledge and awareness of the benefits of blockchain technologies and their application in higher education are needed. This is why pilot research on the application of blockchain technologies in higher education should start with lecturers as leaders and why their opinions and attitudes are essential. The population for this research was made up of higher education system lecturers. The sample consists of 130 participants, representatives of the HEI lectures network of the Republic of Serbia (see Table 1)

**Table 1.** Demographic characteristics of the respondents.

| **Distribution of Respondents by Gender** | | | | |
|---|---|---|---|---|
| Female<br>68 | | Male<br>61 | | Other<br>1 |
| Distribution of respondents by age intervals (in years) | | | | |
| 20–30<br>11 | 30–40<br>25 | 40–50<br>34 | 50–60<br>37 | Over 60<br>23 |
| Distribution of respondents by working experience in high educational systems | | | | |
| Up to 5 years | 5–10 years | 10–20 years | 20–30 years | Over 30 years |
| 27 | 34 | 28 | 18 | 13 |

In this quantitative research study, a survey method has been applied. The instrument used for this research was a questionnaire based on closed-ended questions. Responses are offered through three-point and five-point scales to reliably confirm or reject the views and opinions of the respondents. The questionnaire contains 13 questions. The first group of three questions served for collecting demographic data. The other questions were designed to examine the participants' familiarity with blockchain technologies and intended to collect data on the intentions of university lecturers for blockchain implementation.

Data collection was performed using an online questionnaire uploaded to Google Drive. The link to the questionnaire was forwarded to the HEI lecturer sample, set to the active teaching forums. This online questionnaire was anonymous. The research was applied because it has a practical focus on problem-solving and implications for practice related to the potential application of blockchain technologies in education. The data were analyzed on a quantitative and qualitative level based on the collected data. The research was conducted in July 2021. As an assessment of the scale for risk assessment, a Likert scale was used as a principle for assessing or measuring attitudes. The HEI lecturers were asked to answer the extent of claims about the application of blockchain in the higher education system. A Likert scale was used, which offers fixed-choice answer formats and is designed to measure attitudes and opinions on an ordinal scale. In this way, it is assumed that the intensity of perspective, view and attitude towards the phenomenon under examination is linear. By applying the ordinal scale with increasing numbers to present agreement or disagreement, the attitudes and opinions related to the blockchain can be measured and quantified in the way that was performed in the analysis of results. In this method of grading, freedom of opinion is allowed, and polarisation of responses is avoided.

Although the questionnaire was targeted and delivered to HEI lecturers, it was anonymous to reduce social pressure and annul the provision of socially desirable responses. The demographic characteristics of the respondents are given in Table 1.

Q 1: "Have you ever met the application of blockchain technologies in education during your previous work practice?" The question aimed to determine how well this concept is known to lecturers. This issue is not further clarified for this indication, as is the case in the following points. Only 12.8% of the total number of respondents replied positively, which can be interpreted in that only that some of the respondents had a clear idea and knowledge of what blockchain technologies are and had some experience in their application. Almost half, i.e., 48.8% of respondents, stated that they had NOT encountered the application of these technologies during their work so far. However, we should not ignore the fact that there may be a smaller share of those among them who know what blockchain technologies are but have not used them before. The third, not-that-tiny group consists of respondents who could neither confirm nor deny personal experience with certainty: 38.4% of them. The reason lies in the fact that many respondents are not familiar with the daily application of such established technology.

The second question aims to examine openness to the possibilities offered by blockchain technologies.

Q 2: "Would you use the opportunity of blockchain technologies in the process of evaluating the work of your students, where the data on student learning, including learning time, course files and test results, could be tracked, recorded on the blockchain in chronological order, and each data record can be timestamped? (without a possibility to delete or change the data, so the accuracy of the data is protected and guaranteed) ". More than half of the respondents, 54.7%, would express readiness to use the possibility of technology to have insight into the time and manner of student learning in mastering the material. A partial enthusiasm of 26.6% represents a significant openness to this possibility. Eighteen point eight percent (18.8%) of respondents are not ready to use this opportunity, which may be due to the belief that the time spent learning does not necessarily mean mastering the material.

Q 3: "Do you support decentralized sharing of educational resources, for example, that students in learning and obtaining final certificates can use resources and courses from other faculties?" The question may indicate a consequent change in education that would erase the boundaries of individual institutions and the acceptability for that to happen. In general, using other resources rather than the required literature is viewed favourably since it shows students' additional commitment and openness to acquiring further knowledge in specific subjects. The vast majority of 82.8% expressed support for this action, while neutrality remained at 10.9%. Only 6.3% of respondents have a negative attitude. The limiting factor is the critical validation of data acceptability.

The responses were expressed on a five-point scale, with 1—the lowest and 5—the highest.

Q 4: "How would you assess the potential of blockchain technologies in education, where a topographic algorithm adopted by encryption prevents data changes (facts and inaccuracies)?" Forty-two point five percent (42.5%) of respondents rated the possibility of applying technology that prevents data change, adding facts and inaccuracies, and 31.5% of them with a score of 4. Such a high score indicates respondents' recognition of these problems as prevalent ones in education systems. In addition, nearly a fifth of the respondents gave a medium grade, and only a small number opted for low rates.

Q 5: "How would you assess the potential of blockchain technologies in education to transform the keeping of records of certificates and credentials of students in learning institutions?" This question received a high average grade, with an average of 3.95 from the total number of respondents that such an application of the blockchain would greatly facilitate and protect the process of certification and accreditation of educational results. A total of 37% of respondents rated this possibility with the highest score, while 30.7% rated it 4, and almost a quarter of the total number of respondents rated it with a score of 3. The lowest score was recorded in 6.3% of respondents with two, and only 1.6% of respondents gave the lowest grade.

Q 6: "Do you think that the use of blockchain technologies in education would reduce cases of abuse in education?" The issue was related to the prevention of manipulation, changes and deletion of information from educational systems, and awarding undeserved certificates. The biggest problem associated with this topic in the literature is awarding undeserved diplomas. Namely, the application of blockchain technologies is based on the "principles of the registrar" and does not allow changing or falsifying the data necessary for certification. In practice, it means that someone who did not attend lectures, perform exercises, take colloquial exams, fulfil pre-exam obligations, or study and master the material cannot pass the exam and finally obtain a diploma. Responses have a high level of agreement, with a positive response from 61.4% of respondents.

Q 7: "How certain do you assess the scenario of education based on blockchain technologies, through the complete digitalization and decentralization of education, the issuance of educational certificates, and the emergence of the concept of lifelong learning?" Observing the polarization of attitudes, it was noticed that almost two-thirds of the respondents believe that blockchain will have its application in the realization of education, with 29.9% of them believing that it will be very fast, and 36.2% are not sure when it will happen in the future. In contrast, one-third of respondents do not rate this venture as known and 23.6% doubt that it will be realized, 7.1% believe that it is uncertain that it will ever happen, and 3.1% of respondents believe that this will never happen.

Q 8: "Do you agree with the statement that a lack of trust in technology and a lack of knowledge on how to exploit the potential of blockchain-in-education solutions can lead to the slow adoption of such innovations in the market?" Responses: 2% partially agree, uncertainty expressed in 14.1%, partial disagreement 3.9%, and as much complete conflict. In interpreting this distribution of responses, it is necessary to point out that there is always resistance to adopting new technologies. Still, it is usually more intense in societies of lower technological development.

Q 9: "What types of blockchain technologies in public education should exist?" Responses were offered: public, private and limited access. Interestingly, 36.2% of respondents choose "public", which would mean that anyone, regardless of age, nationality or other affiliation, can access any education system globally. Only one fifth, i.e., 20.5% of the respondents, replied that these systems should be private, giving a distinct possibility of control and selecting who can access them and under what conditions. Finally, 43.3% of respondents stated that they should be of limited access, which coincides with the optimal views expressed in the theory of implementation of blockchain technologies in education [45].

Q 10: "Please choose from the offered areas of focus of blockchain technologies in education, which you consider the most significant contributions to the quality of education."

Several options, which were not final, were offered, of which the following were singled out:

- Democratization of higher education,
- Continuous lifelong learning,
- Globally standardized certification and credentials of students,

- Decentralized sharing of educational resources,
- Prevention of cases of abuse and manipulation in education,
- Blockchain solution incubator,
- Something else.

According to the number of options related to the focus on blockchain technologies in education, in first place was "prevention of abuse and manipulation in education" with 57.5%, followed by "globally standardized certification and student credentials" with 55.1% of the total number of votes. "Decentralized sharing of educational resources" won 48.8% of the number of votes, "lifelong learning" followed with 45.7%, then "democratization of higher education" with 41.7%. Significantly lower levels of choice are recorded for the "blockchain solution incubator" with 18.1% and the option of something else was 8.7%.

Table 2 shows the mean and the standard deviation (SD) of the score on the Likert scale for the distribution of lecturers' responses. In that way, quantification of the result shows the lecturers' average perception and standard deviation to understand the variability in the answers.

**Table 2.** Statistic summary (IBM SPSS Statistics ver.25) for the distribution of lecturers' response.

| Question | Mean | Modus | Median | Std. Error of Mean | Min | Max | Standard Deviation |
|---|---|---|---|---|---|---|---|
| Q1 | 2.2538 | 2 | 2 | 0.05912 | 1 | 3 | 0.67412 |
| Q2 | 1.7231 | 1 | 1 | 0.07567 | 1 | 3 | 0.8628 |
| Q3 | 1.2769 | 1 | 1 | 0.05676 | 1 | 3 | 0.64718 |
| Q4 | 4.0769 | 5 | 4 | 0.0871 | 1 | 5 | 0.99312 |
| Q5 | 3.9538 | 5 | 4 | 0.08795 | 1 | 5 | 1.0028 |
| Q6 | 4.4923 | 5 | 5 | 0.06575 | 1 | 5 | 0.74964 |
| Q7 | 3.8308 | 4 | 4 | 0.0908 | 1 | 5 | 1.03533 |
| Q8 | 2.1231 | 2 | 2 | 0.09006 | 1 | 5 | 1.02689 |

## 5. Discussion

Human resources with digital and competitive intelligence skills drive the circular economy [59]. The education sector plays a vital role in ensuring students are equipped with the fundamental skills and knowledge to apply circular thinking in their chosen careers. The transition to a circular economy is dependent on how individuals and organizations learn to innovate and apply what they have learned in the real world.

As highlighted in [60], there is a need for decentralized HEIs together with proactive students "as opposed to the former solely degree-focused and affluent consumers of educational offerings" [60] (p. 1). One of the steps towards fulfilling the goal of decentralized education could be the ideas implemented in the CLSWE model, with proactive roles of students. The problems and criticisms stated in the literature [61] regarding the implementation of blockchain technologies in education over the years and the development of these technologies have been largely resolved. However, some challenges remain related to privacy and transparency of data, costs of implementations, limitations of the regulatory framework and respective public (state) institutions, and the competencies of teaching staff and their willingness to use new technologies. Although BC brings improvements in digitalized sustainable education, blockchain technology cannot be applied to all parts of the education process and all countries at this stage of development. Since 2016, many education institutions have implemented blockchain technologies in different parts of the education process [62].

The idea of the proposed model can also help to overcome some of the issues addressed in the study by Petousi and Sifaku [63]. The authors explored the narratives of the scientists and researchers who have caused harm by the misconduct in their published research papers. As a complex phenomenon, misconduct can be viewed in a "narrower context, i.e., fraud, fabrication, forgery, plagiarism or unethical practices, or through a broader context such as conflicts of interest, inadequacy in methodology and expertise, lack of mentoring and oversight, etc." [63] (p. 150) The application of open-science concepts in the educational context will provide for a better quality of students' work, and transparency of the whole process. A student's reputation as an author or evaluator can be monitored through the proposed model and blockchain technology and the consensus mechanism it brings. As a result, this will further impact the importance of both the institution and teachers. A similar methodology could be applied to the general scientific community, scientists, researchers and scientific institutions. Their work could be observed through their authorship of scientific articles or their role as reviewers (see, for example, [64,65]).

Some papers [60,63,66] proposed introducing cryptocurrency or sustainability tokens in the proposed education models through blockchain technology, which could be implemented in the CLSWE model. The introduction of cryptocurrency would help maintain and develop the system, but it also brings specific problems in implementation, such as regulatory policies. One of the obstacles to the faster introduction of these technologies is the slow adoption of regulatory policies in this domain in many countries, which is further reflected in their implementation.

The limitations of this research are twofold: The first limitation is that the testing phase of the CLSWE model is conducted in one HEI in the technical field of science. Therefore, the perception and technical skills of the teaching staff are similar, as well as their education, and the homology error is inevitable. Another limitation was shown through the interviews, which reflected the low level of knowledge of blockchain technology among teachers in different HEIs.

According to the research, only a small number of HEI lecturers are familiar enough with blockchain technologies to apply them (mean 2.25, SD 0.67). Due to the unique and brand new technology, there are still some technical challenges and limitations for HEI lecturers, along with the characteristics of immutability, revealing personal privacy and scalability issues affecting both students and lecturers and HEIs themselves. Nevertheless, more than half of the respondents would express readiness to use the possibility of technology to have insight into the time and manner of student learning in mastering the material. According to the research results, there is a need to solve all the challenges. Therefore, blockchain-based educational projects can solve many issues because blockchain is a safe, fast, cost-efficient way to structure records and data such as college degrees, e-learning certificates, etc. The support for decentralized sharing of educational resources may indicate a consequent change in education. The existing fear is based on the fact that blockchain enables the existence of products and services that could disrupt the education system. The potential of blockchain technologies in education is highly scored, where a topographic algorithm adopted by encryption prevents data changes.Such a high score indicates that the respondents recognize these problems as very common in educational systems. This study represents the attitudes and motivations related to blockchain applications in HEIs, including decentralization, traceability, and a consensus mechanism that can be used to address the issues of educational institutions. One of them is an optimistic assessment that the application of the blockchain would greatly facilitate and protect the process of certification and accreditation of academic results and reduce the number of cases regarding abuse in education (mean 4.49, SD 0.75).

There is a strong belief in blockchain education implementation's future. Uncertainty and dilemmas remain among the respondents only regarding the time of its implementation (mean 3.83, SD 1.04). The readiness to introduce blockchain technologies in HEIs exists, but a necessary condition for it is systematic education.

An overview of the theoretical basis of collaborative learning and student work evaluation is presented in the paper.

## 6. Conclusions

The lack of funds for implementing the new technologies is the main problem in many education institutions, especially in low-income countries and developing countries where funding for education is still relatively low. New technologies require allocating significant funds for these needs, including technical and educational conditions. Additionally, blockchain technology generally brings high operating costs and high power consumption. Some of the solutions proposed in this model can reduce or alleviate these issues. By merging several faculties or universities, the operational costs of implementing the answer can be reduced, which may imply a demand for a more active role of the respective state institutions, both in creating data protection policy and assisting in funding. Another possibility for a more environmentally sustainable CLSWE model is to implement some green blockchain solutions consensus mechanism [66] based on minimal computational power.

The industry in all areas is increasingly paying attention to the skills of its employees and potential employees, especially in light of I4.0 digitalization and the need for educated and professional staff. The proposed model defines the role of a company/employer through the availability of a reputation service overview, i.e., access to the best students at the source. The role of professionals could be even more significant. Experts could be of great importance in pointing out current topics and underscoring the shortcomings of the proposed solutions. In this way, they can help teachers adapt educational programs to the market's needs. The Dual Education System has been introduced in many countries or is in the process of being presented by state institutions, which can be a good starting point for better cooperation between HEI and companies, but also as an opportunity for broader use of the proposed model or some ideas from this project.

Blockchain-technology-based collaborative learning and evaluation of the student work model are proposed. The paper's contribution is reflected in presenting a new blockchain-technology-based collaborative learning and assessment of a student work model. The developed model aims to provide a better quality student work evaluation, stimulate project-oriented education, and improve the quality of the educational process. The application of blockchain technologies ensures data authenticity [67,68]. A new methodological approach to student work evaluation was also developed based on the selected research paper reviewing the concepts. At this stage of development of the proposed model, teachers report on more efficient work and faster and more successful completion of project tasks. Two groups of students, the experimental and control, were monitored to analyze students' achievements. The results of this analysis will be presented in the following work of the authors. In this way, future research will be complemented by more data sources. Further research studies are also expected concerning integrating the developed model with formal learning systems in the faculty where the project is implemented and with partner HEIs. There is also a tendency to aspire to a more open base.

**Author Contributions:** Conceptualization, G.B., M.P., A.S., J.D. and Z.M.B.; methodology, G.B. and A.S.; software, H.S., Z.M.B. and M.P.; validation, G.B., M.P., A.S., J.D. and Z.M.B.; formal analysis, G.B. and Z.M.B.; investigation, G.B., M.P., H.S., J.D., A.S and Z.M.B.; resources, G.B. and M.P.; data curation, G.B.; writing—original draft preparation, G.B., M.P. and A.S.; writing—review and editing, G.B., J.D., A.S. and MP; visualization, A.S., J.D. and Z.M.B.; supervision, M.P.; project administration, G.B. and J.D. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** Not applicable.

**Acknowledgments:** The authors extend their appreciation to the department for e-business, the faculty of organizational sciences, and the University of Belgrade for technical support.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Topping, K.J. Peer Assessment. *Theory Pract.* **2009**, *48*, 20–27. [CrossRef]
2. Saurabh, S.; Sanwar Hosen, A.S.M.; Byungun, Y. Blockchain Security Attacks, Challenges, and Solutions for the Future Distributed IoT Network. Available online: https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9323061 (accessed on 1 June 2021). [CrossRef]

3. Xu, J.; Li, Q.; Liu, J.; Lv, P.; Yu, G. Leveraging Cognitive Diagnosis to Improve Peer Assessment in MOOCS. *IEEE Access* **2021**, *9*, 50466–50484. [CrossRef]
4. Piech, C.; Huang, J.; Chen, Z.; Do, C.; Ng, A.; Koller, D. Tuned Models of Peer Assessment in MOOCs. *arXiv* **2013**, arXiv:1307.2579. [CrossRef]
5. Luo, H.; Robinson, A.C.; Park, J.-Y. Peer Grading in a MOOC: Reliability, Validity, and Perceived Effects. *Online Learn.* **2014**, *18*, 454–460. [CrossRef]
6. Vu, T.T.; Dall'Alba, G. Students' Experience of Peer Assessment in a Professional Course. *Assess. Eval. High. Educ.* **2007**, *32*, 541–556. [CrossRef]
7. Mok, J. A Case Study of Students' Perceptions of Peer Assessment in Hong Kong. *ELT J.* **2011**, *65*, 230–239. [CrossRef]
8. Han, Y.; Wu, W.; Yan, Y.; Zhang, L. Human-Machine Hybrid Peer Grading in SPOCs. *IEEE Access* **2020**, *8*, 220922–220934. [CrossRef]
9. Garcia-Loro, F.; Martin, S.; Ruipérez-Valiente, J.A.; Sancristobal, E.; Castro, M. Reviewing and Analyzing Peer Review Inter-Rater Reliability in a MOOC Platform. *Comput. Educ.* **2020**, *154*, 103894. [CrossRef]
10. Stefanovic, H.; Savic, A.; Veselinovic, R.; Bjelobaba, G. An Application of Visual Cryptography Scheme with Digital Watermarking in Sharing Secret Information from Car Number Plate Digital Images. *Int. J. Eng. Invent.* **2021**, *10*, 1–11.
11. Hovardas, T.; Tsivitanidou, O.E.; Zacharia, Z.C. Peer versus Expert Feedback: An Investigation of the Quality of Peer Feedback among Secondary School Students. *Comput. Educ.* **2014**, *71*, 133–152. [CrossRef]
12. Formanek, M.; Wenger, M.C.; Buxner, S.R.; Impey, C.D.; Sonam, T. Insights about Large-Scale Online Peer Assessment from an Analysis of an Astronomy MOOC. *Comput. Educ.* **2017**, *113*, 243–262. [CrossRef]
13. Paré, D.E.; Joordens, S. Peering into Large Lectures: Examining Peer and Expert Mark Agreement Using PeerScholar, an Online Peer Assessment Tool. *J. Comput. Assist. Learn.* **2008**, *24*, 526–540. [CrossRef]
14. Liu, F.; Zhu, W.-d.; Chen, Y.-w.; Xu, D.-l.; Yang, J.-b. Evaluation, Ranking and Selection of R&D Projects by Multiple Experts: An Evidential Reasoning Rule Based Approach. *Scientometrics* **2017**, *111*, 1501–1519. [CrossRef]
15. Bhaskar, P.; Tiwari, C.K.; Joshi, A. *Blockchain in Education Management: Present and Future Applications. Interactive Technology and Smart Education*; Emerald Group Holdings Ltd.: Bingley, UK, 2020; pp. 1–17. [CrossRef]
16. Hori, M.; Ohashi, M. The Adaptive Authentication in the Collaborative Systems: Applying the Time Authentication into the Certified Originality of Digital Contents. *Lit. Inf. Comput. Educ. J.* **2018**, *9*, 2873–2877. [CrossRef]
17. Bdiwi, R.; Runz, C.D.; Faiz, S.; Cherif, A.A. A Blockchain Based Decentralized Platform for Ubiquitous Learning Environment. In Proceedings of the IEEE 18th International Conference on Advanced Learning Technologies, ICALT 2018, Mumbai, India, 9–13 July 2018; Institute of Electrical and Electronics Engineers Inc.: Piscataway, NJ, USA, 2018; pp. 90–92. [CrossRef]
18. Sharples, M.; Domingue, J. The Blockchain and Kudos: A Distributed System for Educational Record, Reputation and Reward. In *Lecture Notes in Computer Science*; Springer: Berlin, Germany, 2016; Volume 9891, pp. 490–496. [CrossRef]
19. Zhao, W.; Liu, K.; Ma, K. Design of Student Capability Evaluation System Merging Blockchain Technology. *J. Phys. Conf. Ser.* **2019**, *1168*, 32123. [CrossRef]
20. Ito, K. *A Critical Examination of the Application of Blockchain Technology to Intellectual Property Management*; Palgrave Macmillan: London, UK, 2019; pp. 317–335. [CrossRef]
21. Williams, P. Does Competency-Based Education with Blockchain Signal a New Mission for Universities? *J. High. Educ. Policy Manag.* **2019**, *41*, 104–117. [CrossRef]
22. Duan, B.; Zhong, Y.; Liu, D. Education Application of Blockchain Technology: Learning Outcome and Meta-Diploma. In Proceedings of the International Conference on Parallel and Distributed Systems—ICPADS, Beijing, China, 14–16 December 2021; pp. 814–817. [CrossRef]
23. Mikroyannidis, A. Blockchain Applications in Education: A Case Study in Lifelong Learning. In Proceedings of the 12th International Conference on Mobile, Hybrid, and Online Learning (eLmL 2020), Valencia, Spain, 21–25 November 2020; pp. 21–25.
24. Sun, H.; Wang, X.; Wang, X. Application of Blockchain Technology in Online Education. *Int. J. Emerg. Technol. Learn.* **2018**, *13*, 252–259. [CrossRef]
25. Xu, Y.; Zhao, S.; Kong, L.; Zheng, Y.; Zhang, S.; Li, Q. ECBC: A High Performance Educational Certificate Blockchain with Efficient Query. In *Lecture Notes in Computer Science*; Springer: Berlin, Germany, 2017; Volume 10580, pp. 288–304. [CrossRef]
26. Alammary, A.; Alhazmi, S.; Almasri, M.; Gillani, S. Blockchain-Based Applications in Education: A Systematic Review. *Appl. Sci.* **2019**, *9*, 2400. [CrossRef]
27. Han, M.; Wu, D.; Li, Z.; Xie, Y.; He, J.S.; Baba, A. A Novel Blockchain-Based Education Records Verification Solution. In Proceedings of the SIGITE 2018 19th Annual SIG Conference on Information Technology Education, Fort Lauderdale, FL, USA, 3–6 October 2018; Association for Computing Machinery, Inc.: New York, NY, USA, 2018; pp. 178–183. [CrossRef]
28. Skiba, D.J. The Potential of Blockchain in Education and Health Care. *Nurs. Educ. Perspect.* **2017**, *38*, 220–221. [CrossRef]
29. Turkanović, M.; Hölbl, M.; Košič, K.; Heričko, M.; Kamišalić, A. EduCTX: A Blockchain-Based Higher Education Credit Platform. *IEEE Access* **2018**, *6*, 5112–5127. [CrossRef]
30. Bore, N.; Karumba, S.; Mutahi, J.; Darnell, S.S.; Wayua, C.; Weldemariam, K. Towards Blockchain-Enabled School Information Hub. In *ACM International Conference Proceeding Series*; Association for Computing Machinery: New York, NY, USA, 2017. [CrossRef]

31. Mahankali, S.; Chaudhary, S. Blockchain in Education: A Comprehensive Approach–Utility, Use Cases, and Implementation in a University. In *Blockchain in Education*; IGI Global: Hershey, PA, USA, 2020. [CrossRef]
32. Ali, H. The Effect of Collaborative Learning and Self-Assessment on Self-Regulation. *Educ. Res. Rev.* **2015**, *10*, 2164–2167. [CrossRef]
33. Laal, M.; Laal, M. Collaborative Learning: What Is It? *Procedia Soc. Behav. Sci.* **2012**, *31*, 491–495. [CrossRef]
34. Laal, M.; Ghodsi, S.M. Benefits of Collaborative Learning. *Procedia Soc. Behav. Sci.* **2012**, *31*, 486–490. [CrossRef]
35. MacDonald, J. Assessing Online Collaborative Learning: Process and Product. *Comput. Educ.* **2003**, *40*, 377–391. [CrossRef]
36. Kollar, I.; Fischer, F. Peer Assessment as Collaborative Learning: A Cognitive Perspective. *Learn. Instr.* **2010**, *20*, 344–348. [CrossRef]
37. Hyvärinen, H.; Risius, M.; Friis, G. A Blockchain-Based Approach Towards Overcoming Financial Fraud in Public Sector Services. *Bus. Inf. Syst. Eng.* **2017**, *59*, 441–456. [CrossRef]
38. Morkunas, V.J.; Paschen, J.; Boon, E. How Blockchain Technologies Impact Your Business Model. *Bus. Horiz.* **2019**, *62*, 295–306. [CrossRef]
39. Mettler, M. Blockchain Technology in Healthcare: The Revolution Starts Here. In Proceedings of the 2016 IEEE 18th International Conference on e-Health Networking, Applications and Services (Healthcom), Munich, Germany, 14–16 September 2016; IEEE: Piscataway, NJ, USA, 2016; pp. 1–3. [CrossRef]
40. Malekigorji, M.; Corbett, D.; Hanna, L.-A.; Hall, M. An Investigation of Chinese Students Academic Performance, and Their Views on The Learning Experience, Associated with Flipped Team-Based Learning. *Lit. Inf. Comput. Educ. J.* **2018**, *9*, 2788–2799. [CrossRef]
41. Johnson, D.; Johnson, R.; Stanne, M. *Cooperative Learning Methods: A Meta-Analysis*; University of Minnesota: Minneapolis, MN, USA, 2000.
42. Johnson, D.W.; Johnson, R.T.; Johnson, H.E. *The Nuts & Bolts of Cooperative Learning*, 2nd ed.; Interaction Book Co.: Minneapolis, MN, USA, 2007.
43. Chiang, V.; Leung, S.; Chui, C.; Leung, A.Y.M.; Mak, Y.W. Building Life-Long Learning Capacity in Undergraduate Nursing Freshmen within an Integrative and Small Group Learning Context. *Nurse Educ. Today* **2013**, *33*, 1184–1191. [CrossRef]
44. Järvel, S.; Hurme, T.R.; Järvenoja, H. Self-Regulation and Motivation in Computer-Supported Collaborative Learning Environments. In *Learning Across Sites*; Routledge: London, UK, 2010; pp. 330–345.
45. Rauchs, M.; Glidden, A.; Gordon, B.; Pieters, G.C.; Recanatini, M.; Rostand, F.; Vagneur, K.; Zhang, B.Z. *Distributed Ledger Technology Systems: A Conceptual Framework*; Cambridge Centre for Alternative Finance, Cambridge Judge Business School, University: Cambridge, UK, 2018. [CrossRef]
46. Chatterjee, R.; Chatterjee, R. An Overview of the Emerging Technology: Blockchain. In Proceedings of the 2017 3rd International Conference on Computational Intelligence and Networks (CINE), Odisha, India, 28 October 2017; IEEE: Piscataway, NJ, USA, 2017; pp. 126–127. [CrossRef]
47. Paunovic, M.; Savic, A. Blockchain in Tourism and Bc Model for Education of the Students in Tourism Sector. *TISC* **2022**, *in press*.
48. Petrović, L.; Stojanović, D.; Mitrović, S.; Barać, D.; Bogdanović, Z. Designing an Extended Smart Classroom: An Approach to Game-based Learning for IoT. *Comput. Appl. Eng. Educ.* **2021**, *30*, cae.22446. [CrossRef]
49. Radenkovic, B.; Despotovic-Zrakic, M.; Bogdanovic, Z.; Barac, D.; Labus, A.; Naumovic, T. A Distributed IoT System for Modelling Dynamics in Smart Environments. In Proceedings of the 2020 International Conference Engineering Technologies and Computer Science (EnT), Virtual, 24–26 June 2020; pp. 47–53. [CrossRef]
50. Rashideh, W. Blockchain Technology Framework: Current and Future Perspectives for the Tourism Industry. *Tour. Manag.* **2020**, *80*, 104125. [CrossRef]
51. Andoni, M.; Robu, V.; Flynn, D.; Abram, S.; Geach, D.; Jenkins, D.; McCallum, P.; Peacock, A. Blockchain Technology in the Energy Sector: A Systematic Review of Challenges and Opportunities. *Renew. Sustain. Energy Rev.* **2019**, *100*, 143–174. [CrossRef]
52. Akaba, T.I.; Norta, A.; Udokwu, C.; Draheim, D. A Framework for the Adoption of Blockchain-Based e-Procurement Systems in the Public Sector. In *Lecture Notes in Computer Science*; Hattingh, M., Matthee, M., Smuts, H., Pappas, I., Dwivedi, Y.K., Mäntymäki, M., Eds.; Springer International Publishing: Cham, Switzerland, 2020; Volume 12066. [CrossRef]
53. Ullah, N.; Al-Rahmi, W.M.; Alzahrani, A.I.; Alfarraj, O.; Alblehai, F.M. Blockchain Technology Adoption in Smart Learning Environments. *Sustainability* **2021**, *13*, 1801. [CrossRef]
54. Rummel, N. One Framework to Rule Them All? Carrying Forward the Conversation Started by Wise and Schwarz. *Int. J. Comput. Collab. Learn.* **2018**, *13*, 123–129. [CrossRef]
55. Holstein, K.; Aleven, V.; Rummel, N. A Conceptual Framework for Human–AI Hybrid Adaptivity in Education. In *Artificial Intelligence in Education*; Springer: Berlin, Germany, 2020; pp. 240–254. [CrossRef]
56. Dodevski, Z.; Filiposka, S.; Mishev, A.; Trajkovik, V. Real Time Availability and Consistency of Health-Related Information across Multiple Stakeholders: A Blockchain Based Approach. *Comput. Sci. Inf. Syst.* **2021**, *18*, 927–955. [CrossRef]
57. Menez, J.; van Oorschot, P.; Vanstone, S. *Handbook of Applied Cryptography*, 5th ed.; CRC Press Series on Discrete Mathematics and Its Applications; CRC Press: Boca Raton, FL, USA, 2001.
58. Klima, R.E.; Sigmon, N.P. *Cryptology Classical and Modern*, 2nd ed.; Chapman and Hall: London, UK; CRC Press: Boca Raton, FL, USA, 2019.

59. Ilić, M.P.; Ranković, M.; Dobrilović, M.; Bucea-Manea-țoniş, R.; Mihoreanu, L.; Gheța, M.I.; Simion, V.E. Challenging Novelties within the Circular Economy Concept under the Digital Transformation of Society. *Sustainability* **2022**, *14*, 702. [CrossRef]
60. Son-Turan, S. Fostering Equality in Education: The Blockchain Business Model for Higher Education (BBM-HE). *Sustainability* **2022**, *14*, 2955. [CrossRef]
61. Bartolomé, A.R.; Bellver, C.; Castañeda, L.; Adell, J. Blockchain in Education: Introduction and Critical Review of the State of the Art. EDUTEC. *Rev. Electrónica Tecnol. Educ.* **2017**, *61*, 1–14. [CrossRef]
62. Min, L.; Bin, G. Online Teaching Research in Universities Based on Blockchain. *Educ. Inf. Technol.* **2022**. [CrossRef]
63. Petousi, V.; Sifaki, E. Contextualising Harm in the Framework of Research Misconduct. Findings from Discourse Analysis of Scientific Publications. *Int. J. Sustain. Dev.* **2020**, *23*, 149–174. [CrossRef]
64. Chen, G.; Xu, B.; Lu, M.; Chen, N.-S. Exploring Blockchain Technology and Its Potential Applications for Education. *Smart Learn. Environ.* **2018**, *5*, 1. [CrossRef]
65. Mackey, T.K.; Shah, N.; Miyachi, K.; Short, J.; Clauson, K. A Framework Proposal for Blockchain-Based Scientific Publishing Using Shared Governance. *Front. Blockchain* **2019**, *2*, 19. [CrossRef]
66. Varavallo, G.; Caragnano, G.; Bertone, F.; Vernetti-Prot, L.; Terzo, O. Traceability Platform Based on Green Blockchain: An Application Case Study in Dairy Supply Chain. *Sustainability* **2022**, *14*, 3321. [CrossRef]
67. Kuleto, V.; Bucea-Manea-Tonis, R.; Ilić, M.P.; Martins, O.M.D.; Ranković, M.R.; Coelho, A.S. The Potential of Blockchain Technology in Higher Education as Perceived by Students in Serbia, Romania, and Portugal. *Sustainability* **2022**, *14*, 749. [CrossRef]
68. Bucea-Manea-Ţoniş, R.; Martins, O.M.D.; Gheorghiță, C.; Kuleto, V.; Ilić, M.P.; Simion, V.-E. Blockchain Technology Enhances Sustainable Higher Education. *Sustainability* **2021**, *13*, 12347. [CrossRef]