

Article

The Role of Blockchain Technologies in the Sustainable Development of Students' Learning Process

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Abstract: Technological evolution has contributed to considerable changes in the learning methods used today. If a few years ago, before the technological boom, students relied only on their memory capacity, on notes on sheets of paper and written materials (in the form of course materials, books, or textbooks), today the process of learning is significantly facilitated by the means and techniques involved in the use of technology, such as artificial intelligence, smartphones, and tablets, which are rapidly replacing bulky desktop computers and outdated textbooks used in the learning process. Moreover, blockchain technology can also be used as a motivational factor for developing learning abilities by implementing a system that can bring students credit points convertible into cryptocurrencies or online badges. Studies conducted in the field show that students' motivation for learning and creativity is significantly improved with the help of this reward system. In this article, two specialized studies were conducted (in Romania), one on the perception of teachers in the university environment towards the use of new technologies in the learning process (artificial intelligence, smartphones, and tablets), and the other on the perception of students on the technological integration of blockchain (by implementing a system that can bring students credit points convertible into cryptocurrencies or online badges to certify their knowledge) in the learning process and measuring their satisfaction.

Keywords: blockchain; sustainable education; higher education; blockchain in education; blockchain applications; educational technology



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1. Introduction

The concept of blockchain is a relatively recent one that is believed to have appeared with the advent and development of Bitcoin [1]. However, it seems that the first writings on the blockchain and bitcoin system appeared in 2008, under the author's name (or group of authors) Nakamoto [2]. According to these writings, blockchain technology is based on encrypting and storing all the information about a series of transactions generated in a network. In practice, the information about the performed transactions is grouped and stored in the form of blocks, and the blocks are connected in a chain—blockchain [3].

The ability of cryptocurrencies to allow anonymous transactions allows users to trade virtual currency regardless of their geographical location, without revealing either the actual source of income or their own identity. However, cryptocurrency's exact degree of anonymity is subject to debate. Cryptocurrencies, such as Bitcoin, the centralized replicon system based on peer-to-peer public key addresses, do not have an accrediting regulatory body, like a financial institution or a bank that examines and monitors transactions. This

allows potential criminal transactions to be processed through cryptocurrency, as the process of moving money is faster and more efficient due to the lack of passage through regulatory controls or third-party institutions, such as banks. To date, there is no universal regulation that states that any Bitcoin exchange must comply with anti-money laundering and anti-terrorism regulations. As a result, Bitcoin exchange services may be misused for illicit purposes due to their ability to create accounts using false information. Although legislation and regulations are currently being considered to prevent the illicit use of cryptocurrencies and to ensure compliance with taxation, the global nature of these forms of currency makes it difficult to adhere to such legislation without the universal adoption of such measures [4].

Blockchain is a distributed registry created by blocks containing transaction details connected in chronological order to form chains. It is a distributed registry in which blockchain peer-to-peer network participants generate blocks, not the central administrator. The possibilities of using blockchain are recognized in many fields, leading to many developments and studies, and investments are made actively [5]. From the perspective of financial institutions, the emergence of blockchain not only has technical significance—the emergence of a highly efficient database system—but also creates the possibility that if the business model of existing financial institutions or financial intermediaries disappears, the financial services that are based on them may disappear entirely or be partially replaced, and consumer financial transaction patterns may change. On the other hand, the areas of use for blockchain are expected to be expanded to become a means of increasing financial inclusion beyond being a new business model for financial institutions [5].

Users can record and share a shared perspective of a system's state over a distributed network using blockchain (or Distributed Ledgers Technology). This opens up more options for peer-to-peer value transfer, shared credible registries as an immutable source of truth, and securely executable agreements via smart contracts. blockchain is construed as a machine to build trust, speed, transparency, reliability, and effectiveness in automated and peer-to-peer transactions [6].

According to the literature, there are three types of blockchain structures:

Public blockchains, like Bitcoin, are large distributed networks that operate using a native token. Anyone at any level is welcome to engage in this forum. They have open-source code that the community maintains.

Blockchains with permissions: A permissioned blockchain, such as Ripple, regulates the kinds of roles that people can play in a network. They are large distributed systems that also use a native token. The basic code of permissioned blockchains may or may not be open source.

Private blockchains: These are smaller blockchains that do not employ tokens. The number of people who can join private blockchains is limited. Nevertheless, consortia prefer this type of blockchain since its members are trustworthy, and private information may be transferred without difficulty [7].

The potential of blockchain technology has been noticed and used in other industries and services due to the advantages it brings to the working process (shortening the transaction process, protecting copyright by “tokenization”, and the efficient and secure tracking of transactions) [8]. Among the companies and organizations that have implemented blockchain technologies, the literature mentions IBM and Everledger, which use blockchain to track logistics in a transparent and low-cost manner [3].

The article is structured in five parts (the first being the introduction), of which in the theoretical part the evolution of blockchain technologies in the learning process is approached. Numerous specialized articles in the field have been studied in order to be able to outline a clear picture of the benefits that may arise from the implementation of blockchain technologies in general, and the teaching–learning processes in particular. For example, a relevant study highlights the advantages of using blockchain technologies in the education system by implementing transcription systems for certificates and badges obtained by students through blockchain [9]. Another study [10] highlights the benefits

of using blockchain technologies in the teaching–learning process from the perspective of teachers (who would find it easier to protect their intellectual property and store large volumes of scientific materials and course materials) as well as from students (who can easily access course materials, save their data, grades, and certifications in a secure system). Moreover, there have been real-world applications of this technology, such as at the Massachusetts Institute of Technology (MIT). MIT used it to secure and validate the certificates it issued. Another example is Sony Global Education, which collects individual data on its trainees’ abilities and productivity. A third example is the University of Nicosia, the first to use intelligent contracts and accept cryptocurrencies as payment [11].

The next section of this article (materials and methods) explains the types of research conducted, the purpose and objectives for each, as well as the target group categories (the sample on which the research was conducted), and the hypotheses identified in the literature. In this article, two studies were conducted, one of a qualitative type among university professors (to identify their perception regarding the implementation of blockchain technologies in the teaching–learning process), and another of a quantitative type (among students), following which, a PLS-SEM analysis was performed (model made by structural equations) to identify the main advantages of blockchain technologies that can contribute to student satisfaction (in the learning process).

Section 4 (results) presents and explains the results obtained from the two studies and the validated model made using the WarpPLS program.

In the discussion section, elaborated ideas are compared between the results obtained in this article and those obtained in wider research in the field. The last section (the conclusions) highlights the main conclusions and possibilities for further research in the field.

2. The Emergence and Development of Blockchain in the Learning Process

In the learning process, blockchain technologies have emerged as a support for the learning activity, especially as we are in the process of digitization. First of all, due to the storage capacity of blockchain technology, the interests of the educational environment in this direction were focused on “storing” learning materials (course materials and interactive materials in electronic format) in a secure form and with the possibility of sharing them without the need for sophisticated cryptographic calculations [12]. Moreover, there is the possibility of awarding prizes to students (through badges or credits convertible into cryptocurrencies). Presently, digital badges and micro-credentials are used to identify and honor a learner’s accomplishments and specialized abilities [13]. Due to the short lifespan of micro-credentials, benefits such as digital badges are created often, making it difficult to issue and validate the micro-credential promptly.

In addition, it seemed that digital badges could be fabricated by users, making them untrustworthy (a user can create their own digital badge). A micro-credential and digital badging tool that will allow users access to career-oriented courses seems to be the right option to help people keep up with the trend and improve their abilities. Blockchain can thus be included in education systems to address the issue of security. Blockchain’s popularity is growing, and applications outside the banking industry are developing. In education, for example, blockchain is used to produce inviolable accreditation [11].

Furthermore, due to its fixed quality and decentralized nature, blockchain is a perfect technology to integrate into a micro-accreditation system, which can include short courses and digital badges as incentives. In addition, blockchain technology demonstrates a high level of security and transparency, ensuring that data cannot be tampered with and that its records remain intact. This is why this technology is ideal for developing a micro-accreditation system that may be used as an alternative to standard professional development [3].

However, while it can be considered that there are typical databases that can replicate the apparent advantages of using blockchain technologies for storing educational materials, there are several significant differences, which are shown in Table 1:

Table 1. Comparison of blockchain and database.

Blockchain	Database
In blockchain, there is confidence among unknown users since every node has the same priority, and any node may check newly added transactions [10].	Because the administrator is in charge of the data, there is no confidence in the system [10].
Students can provide feedback anonymously without worrying about the reaction of the course holder.	If students provide feedback, the course owner can see who commented and what.
Data uploaded to a blockchain is immutable because all of the data is linked by a hash, which changes if the data is updated [10].	Others with access to the database can edit data, or people can hack the database to change data, and the modifications will be undetectable since there is no proof [10].
Because each user has a copy of the blockchain, the blockchain will continue to exist even if some nodes are gone [10].	If the database crashes, all data will be lost [10].
All students' online achievements (digital badges/certificates) will remain their own [10].	The digital certificate/digital badges will last as long as the database does, which means that if the organization quits hosting the e-learning platform, the student's data would be lost [10].
Without anyone's help, an employer can authenticate a digital certificate/badge on the blockchain system [10].	The administrator should be contacted if any categorization is required [10].
Student record keeping is a time-consuming and expensive task that can be accomplished with minimal effort utilizing blockchain technology [12].	Students do not have access to all the necessary materials through databases.
Personal information (name, identification, address, etc.), course attendance, grades, and degrees and certificates gained are all protected on blockchain platforms and are trustworthy/transparent for all counterparties [12].	Within the databases, the administrator or its owner can access each participant's data or activity.
Professors may use blockchain to secure their intellectual property (IP), such as courses, ideas, innovations, and patents [12].	The intellectual property of the uploaded materials is not ensured through the databases.
Plagiarism is a simple problem to solve. Plagiarized research articles will likewise be immediately detected. Professors will restrict the dissemination of copyright-protected courses on the Internet by encrypting them and storing them in a safe chain. Permitted network users will have access to the data [12].	Uploaded materials and articles are not automatically checked for plagiarism through the databases. Instead, these must be downloaded and passed through a separate software.

Universities should be concerned about the emergence and growth of blockchain technology, which has the potential to turn into “a compelling disruptive innovation”. Furthermore, blockchain technology now addresses the issues that both higher education and society as a whole are now confronting. Blockchain technology has all advantages of decentralized open data, a lack of forgeries, secure data storage, and lower transaction costs linked to data monitoring, control, and verification.

MIT used it to secure and validate the certificates it issued. Another is Sony Global Education, which collects individual data on its trainees' abilities and productivity; a third is the University of Nicosia, the first to use intelligent contracts and accept cryptocurrencies as payment [13].

Other relevant examples of the implementation of blockchain technologies in the teaching–learning process are the following [14]:

1. University of Maryville—one of the first universities to implement blockchain transcripts and diplomas, empowering students and graduates to hold academic credentials;
2. The University of Nicosia’s provision of certified courses via blockchain-based verified certificates;
3. Southern New Hampshire University will offer its College for America students a digital version of their bachelor’s or associate’s degree on the blockchain in addition to a regular paper version.

Although many uses of blockchain technology are still to be considered, we believe that the following specific aspects of education are most likely to be influenced by the adoption of blockchain (by specific aspects of education we mean activities in which the implementation of blockchain technologies are a real advantage) [15]:

- (a) Blockchain technology will begin the demise of the paper-based certificate system. Using blockchain technology, every type of certificate produced by educational institutions, including qualifications and records of success, may be permanently and safely safeguarded. In addition, advanced blockchain implementations might potentially be used to automate the awarding, recognition, and transfer of credits and maintain and verify a comprehensive record of formal and non-formal achievements throughout a person’s life;
- (b) Blockchain technology enables users to automatically check the validity of certificates against the blockchain, eliminating the need to contact the organization that issued them. As a result, educational institutions will likely no longer be required to confirm credentials;
- (c) Other educational settings can benefit from this ability to issue and validate certificates automatically. Thus, one may picture quality assurance authorities issuing certificates of accreditation to schools or teaching licenses to educators, all of which are publicly available and verifiable by any user against a blockchain;
- (d) It may also be used for intellectual property management, such as recording first publications and citations, without requiring a central authority to keep track of these databases. This allows for the automatic tracking of free educational resource consumption and re-use;
- (e) The ability of blockchain technology to enable data management structures in which users have enhanced ownership and control over their data might significantly reduce educational organizations’ data management expenses and liability risk due to data management difficulties;
- (f) Finally, some institutions may adopt blockchain-based cryptocurrencies to ease payments. Because of the potential to create unique cryptocurrencies, blockchain is anticipated to play a significant role in grant- or voucher-based education funding in many nations.

Considering all of these advantages identified in the specialized literature, we considered the research, carried out in this article to adapt and validate the information to the Romanian market, to be valuable.

3. Materials and Methods

3.1. Research among University Professors

This paper presents the results of two studies conducted to highlight the perspective of the members of the education system (teachers and students) on the potential implementation of blockchain technologies.

The first study was conducted among 10 university professors in Romania and was of a qualifying type, using a semi-directed interview guide. Regarding the number of participants in the study, it seems that a lot of specialized studies have concluded that in the case of qualitative research, any number between 5 and 50 participants may be

appropriate [16]. In order to participate in the research, they were asked for their consent and willingness to participate, and subsequently, the interview was applied to them through online survey platforms (their answers being anonymous). Both the interview and the participation proposal were initiated with a short description of the research carried out, presenting its purpose and objectives, and the procedure for obtaining and analyzing the results. For this research, we had the following purpose: to identify the attitude of specialists in the field of education (teachers in the university environment) on the implementation of blockchain technologies in the educational process.

The objectives were as follows:

O1: Determining the degree of knowledge of blockchain technologies;

O2: Determining the perceived benefits regarding the integration of blockchain technologies in the teaching–learning process;

O3: Determining the extent to which teachers would integrate blockchain technologies into the teaching–learning process.

The questions asked in the interview guide were as follows:

Q1: Do you know the concept and functionality of blockchain technologies?

Q2: Do you know the applicability of blockchain technologies in the teaching–learning process?

Q3: In general, do you use technology in the teaching–learning process?

Q4: What advantages and disadvantages do you identify in integrating blockchain technologies in the teaching–learning process?

Q5: What do you think about using blockchain technologies in the teaching–learning process for credits convertible into cryptocurrencies?

Q6: What is your availability regarding the use of blockchain technologies in the teaching–learning process?

Participants were informed that the answers provided were anonymous and would be analyzed only from a contextual point of view to create an overview of their perception.

3.2. Research among Students

The second study was conducted among students at the Academy of Economic Studies in Bucharest to see their views on the use of blockchain technologies in the learning process. A questionnaire was used for this research (quantitative type) for students from undergraduate and master's degree programs. The questionnaire was applied through an online survey platform, and the students agreed to participate in this research. However, they were informed that the answers would be confidential and only be used to analyze the research results.

At the beginning of the questionnaire, two filter questions were asked to ensure that the responding students could provide valid opinions on the implementation of blockchain technologies (Q1: Are you familiar with the concept of blockchain? (If not—stop questionnaire); Q2: can you easily identify features and advantages of blockchain technology? (If yes—continue the questionnaire; if not—stop questionnaire)).

A total of 212 students completed the questionnaire, but after cleaning the database (and maintaining only the variants that passed the filter questions), 116 respondents were obtained. Given that the analysis was performed using the SEM (structural equation modeling) method, the number of respondents is sufficient because the general complexity of a structural model, according to the literature, has no impact on the sample size requirements. The explanation for this is the structural model's asynchronous connection analysis (two early studies systematically evaluated PLS-SEM performance with small sample size and concluded that it had good results). Furthermore, according to simulation research conducted by PLS-SEM is a suitable choice when the sample size is limited since it has greater statistical power in cases with model structures or smaller sample numbers [17,18]. Nonetheless, other writers believe that a calculation rule should be utilized for the sample size used in the SEM-PLS analysis, and the “rule of ten” was the general conclusion reached and adopted in the literature. This rule states that if the most significant variation was

picked between two multiples of 10, the sample size is sufficient (i.e., the number of linkages between variables in the model, or the number of formative indicators used to measure a particular construct, multiplied by 10) [18]. In this article, we uncover 10 linkages between constructs (variables) in the model.

The other questions asked were:

- What are the benefits of integrating blockchain technologies into your education process? (e.g., the interactivity of the learning process, improving/personalizing students' time management, credibility in information sources, increased control over the activities carried out, the possibility of obtaining certifications in digital format, the possibility of international recognition of certifications in digital format, the possibility of providing honest feedback, the possibility of receiving badges attesting the acquired knowledge, the possibility of converting the credits obtained into cryptocurrencies);
- To what extent do you agree with the following statements regarding the increase of the interactivity of the learning process by integrating blockchain technologies? Through this question, the variable "when improving/personalizing students' time management" was defined;
- To what extent do you agree with the following statements regarding the improvement/personalization of students' time management during the learning process by integrating blockchain technologies? Through this question, the variable "improvement/personalization of students' time management" was defined;
- To what extent do you agree with the following statements regarding credibility in information sources by integrating blockchain technologies? Through this question, the variable "student credibility" was defined;
- To what extent do you agree with the following statements regarding the increased control over the activities carried out by integrating blockchain technologies? Through this question, the variable "the increased control over the activities carried out" was defined;
- To what extent do you agree with the following statements regarding the possibility of obtaining certifications in digital format by integrating blockchain technologies? Through this question, the variable "possibility of obtaining certifications in digital format" was defined;
- To what extent do you agree with the following statements regarding the possibility of international recognition of digital certifications by integrating blockchain technologies? Through this question, the variable "possibility of international recognition of certifications in digital format" was defined;
- To what extent do you agree with the following statements regarding the possibility of providing honest feedback on the integration of blockchain technologies? Through this question, the variable "possibility of providing honest feedback" was defined;
- To what extent do you agree with the following statements regarding the possibility of receiving badges attesting to the knowledge acquired by integrating blockchain technologies? Through this question, the variable "possibility of receiving badges attesting to the acquired knowledge" was defined;
- To what extent do you agree with the following statements regarding the possibility of converting loans obtained into cryptocurrencies by integrating blockchain technologies? Through this question, the variable "possibility of converting the credits obtained into cryptocurrencies" was defined.

In this article, the PLS-SEM analysis (modelling by structural equations) of students' perceptions was carried out to identify which variables (advantages of blockchain technology in the learning process) contributed to increased satisfaction with educational services. Furthermore, we wanted to identify, based on the identified advantages of blockchain technologies integrated in the learning process, which of these contribute (or can contribute) to the satisfaction of the student in higher education.

Each of the variables built on the identified advantages of integrating blockchain technology in the teaching–learning process (learning process interactivity, improving/personalizing

students' time management, credibility in information sources, increased control over activities, the possibility of obtaining certifications in digital format, the possibility of international recognition of certifications in digital format, the possibility of providing honest feedback, the possibility of receiving badges attesting the acquired knowledge, and the possibility of converting credits obtained into cryptocurrencies) were built with the help of four descriptive items, customized for each variable part, as follows:

- Increasing the interactivity of the learning process by integrating blockchain technologies contributes to increasing the interest in learning;
- Increasing the interactivity of the learning process by integrating blockchain technologies contributes to simplifying the learning process;
- Increasing the interactivity of the learning process by integrating blockchain technologies contributes to increasing the interest in learning materials;
- Increasing the interactivity of the learning process by integrating blockchain technologies contributes to increasing the time spent studying materials.

Practically, a question constructed using the semantic differential measurement scale was used for each variable constructed following the identified advantages of integrating blockchain technologies in the teaching–learning process. For each answer, the respondents had to choose a variant to measure the degree of agreement with the respective statement (where 5—agree to the greatest extent; 4,3,2,1—agree to the minor extent).

The variable “student satisfaction” was also used as a question constructed using the semantic differential measurement scale (i.e., to what extent do you consider that the following advantages of integrating blockchain technologies in the teaching–learning process can contribute to the formation of satisfaction?). For each answer, the respondents had to choose a variant to measure the degree of agreement with the respective statement (where 5- agree to the greatest extent, 4,3,2,1-agree to the minor extent). In this case, the answer options, respectively, in the construction of the variables were the following: the benefits brought in the use of the materials, the benefits regarding the digitization of the diplomas and certificates obtained, the benefits of the rewards system.

4. Results

4.1. Research among University Professors

The obtained results were analyzed, resulting in the following main ideas:

First, all participants in the study knew about blockchain technologies, their functionality, and the possibilities of integration in the teaching–learning process (the most mentioned idea being that of storing educational materials and diplomas and accreditations acquired by students).

Regarding the question about the use of technology in general in the teaching–learning process, most of the participants in the study answered in the affirmative. However, when asked to what extent they use technology, they answered that they do not have spectacular or unique approaches that could be different from other approaches, but that it is generally based on the mandatory requirements for the proper conduct of teaching activities (use of online video platforms, use of presentation programs, and so on).

The hypothesis from which we started in this research was that there is an affirmative answer to each of the questions asked by the study participants (i.e., everyone knows the concept and applicability of blockchain technologies, understands the advantages and disadvantages of using them in the teaching–learning process, understands the use from the perspective of the benefits brought to the students, and knows how they can integrate them in their activities). In order to elaborate on the hypotheses, the specialized literature was studied to highlight the possibilities of confirming the expectations of this article, thus identifying a series of perceived advantages and disadvantages on the use of blockchain technologies in the teaching–learning process (Figure 1) [17].

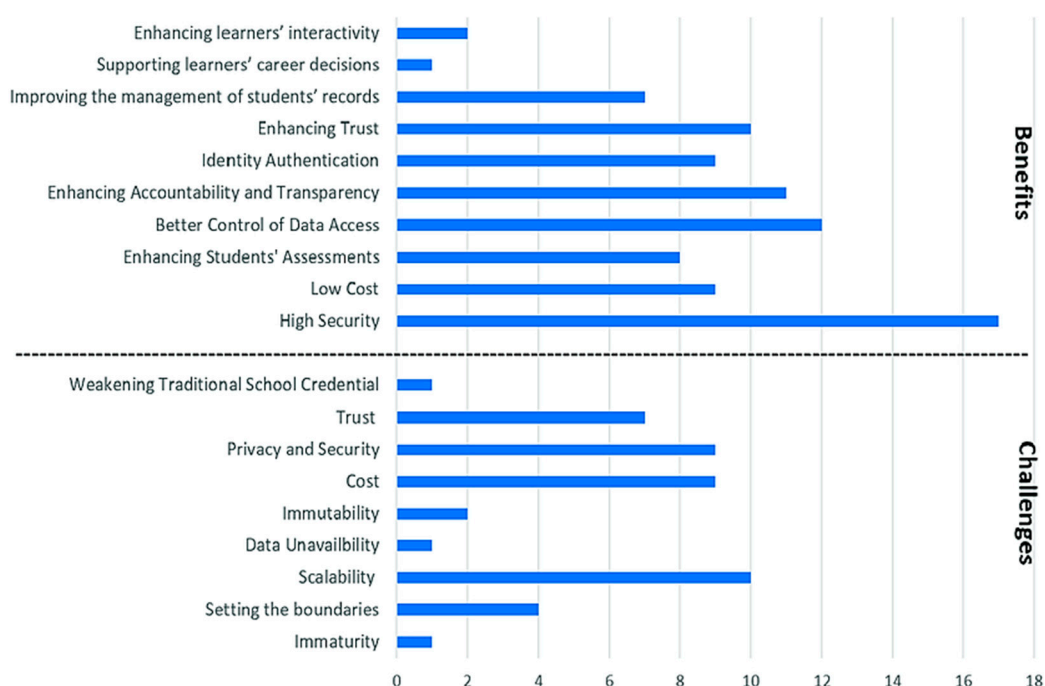


Figure 1. Benefits and challenges of blockchain technologies in education.

The advantages identified in the study were based on students' increased interest, the safe storage of materials, and the provision of copyright. In contrast, the disadvantages identified would be the lack of familiarity with blockchain technologies (and the duration of learning/familiarization) and the costs involved.

Regarding the motivation of students to learn or be trained by offering credits convertible into cryptocurrencies, the participants stated that it would be a good idea and motivating for most of the students, but would be almost impossible from a financial and logistical point of view (at least for the present). Furthermore, they argued that there was a lack of potential for universities to make cryptocurrencies available to students (existing or created) in exchange for credits earned in the learning process.

Regarding their willingness to adopt blockchain technologies in the teaching–learning process, all participants expressed their opinions positively, arguing their answers by presenting the benefits which could be derived for both themselves and the beneficiaries (students).

It can be seen that university professors are open to the integration of blockchain technologies in teaching–learning processes in order to ensure the safety of the study materials used, but also for the benefit of their students.

4.2. Research among Students

The WarpPLS program (version 7.0) was used to perform the analysis by structural equations, in which the database was introduced in excel format, and coded to define the variables and the connections between them. For the ease of use of the program (and because it allows variable names to be longer than seven characters), the variables have been encoded as follows:

- Badges—the possibility of receiving badges attesting the acquired knowledge;
- Certificate—the possibility of obtaining certifications in digital format;
- Int_Cer—the possibility of international recognition of certifications in digital format;
- Control—improving/personalizing students' time management;
- Crypto—the possibility of converting the obtained credits into cryptocurrencies;
- Credible—credibility in information sources;
- Satisfaction—student satisfaction;

- Feedback—the possibility of providing real feedback.

The purpose of modelling by structural equations was to identify the factors (known advantages) that contribute to students' satisfaction following the implementation of blockchain technologies in the teaching–learning process.

The proposed objectives refer to the links that exist between two variables in terms of the power and direction of these links (each “arrow” in Figure 2 represents an objective), and they were formulated as follows: O1: Measuring the direction and intensity of the link between the possibility of receiving badges attesting the acquired knowledge and the credibility granted by the students in the sources of information used; O2: Measuring the direction and intensity of the connection between the possibility of obtaining certifications in digital format and the credibility given by students in the sources of information used; O3: Measuring the direction and intensity of the connection between the possibility of obtaining certifications in digital format and the satisfaction felt by students; O4: Measuring the direction and intensity of the link between the possibility of international recognition of certifications in digital format and the credibility given by students in the sources of information used; O5: Measuring the direction and intensity of the connection between the possibility of international recognition of certifications in digital format and the satisfaction felt by students; O6: Measuring the direction and intensity of the connection between the improvement/personalization of students' time management and the satisfaction felt by students; O7: Measuring the direction and intensity of the connection between the possibility of converting the credits obtained into cryptocurrencies and the satisfaction felt by students; O8: Measuring the direction and intensity of the connection between the satisfaction felt by students and the credibility given by students in the sources of information used; O9: Measuring the direction and intensity of the connection between the satisfaction felt by students and the possibility of providing real feedback; O10: Measuring the direction and intensity of the connection between the possibility of providing real feedback and the credibility given by students in the sources of information used.

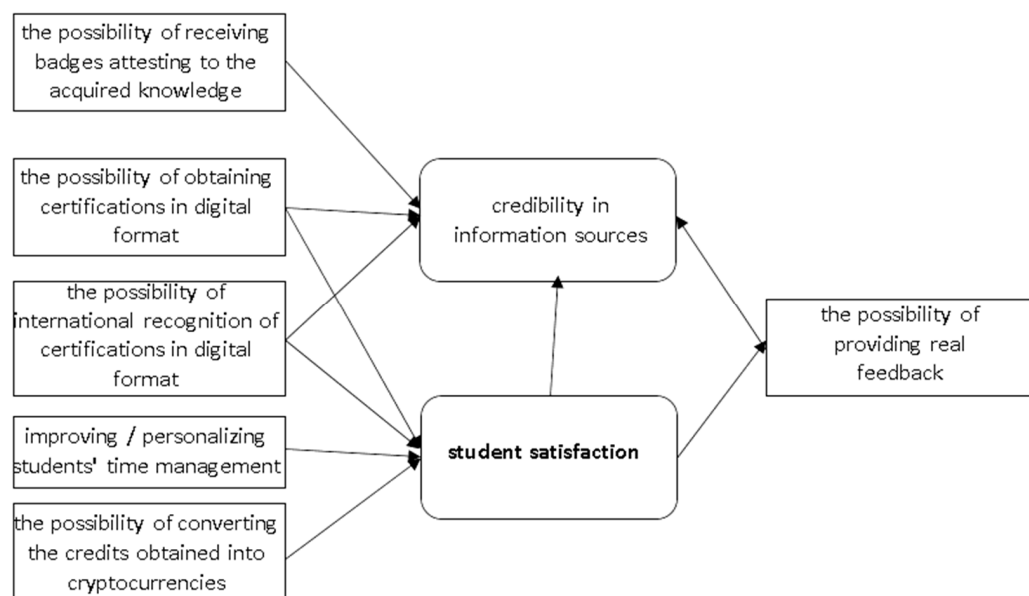


Figure 2. Proposed conceptual model of student satisfaction in terms of the benefits of integrating blockchain technologies into the teaching–learning process.

The hypotheses were established based on the literature, assuming that there was a connection between each of the two variables mentioned in an objective.

Literature used for H1 and H2: Digital badges open up new possibilities for online learning activities and experiences. A badge may become a gamification feature when combined with points and leaderboards, allowing learners to compete with themselves or

others and see how close they are to achieving a goal and earning the associated reputation. Badges encourage sustained involvement in this job, which improves time-on-task and facilitates skill learning via performance [19]. Moreover, through this reward system, students gain more confidence in themselves, the evaluation system, and the information received. In order to have a secure future, continuous learning has to become a crucial element of a person's life.

Furthermore, in order to stay up to date with current developments in rapidly developing businesses, ongoing learning is required. People's needs have been met by introducing micro-credentials, which allow people to attend short career-oriented courses in their own time and at their own speed. However, due to the short lifespan of micro-credentials, incentives such as digital badges are often created, making it difficult to promptly issue and validate the micro-credential. Furthermore, users can digitally fabricate badges, making them untrustworthy [10].

Literature used for H3, H4, and H5: It is considered helpful as all the procedures and documents to be analyzed and selected for subsequent applications would benefit from digitization and the issuance of certificates in electronic format. This is because it is a complex task to request and process verifying documents. It is one of the most significant advantages for graduates because some of the organizations in which they work are situated across the nation and overseas, and the electronic certificate would substantially ease the flow of paperwork [20].

The literature used for H6: The qualities of the virtual classroom that allow interaction between the instructor and the learner are referred to as online learning attributes. Flexibility, utility, structure and organization, perceived use of online platforms, and teacher quality are some of these traits, but one of the most valued was flexibility and time management [21].

Literature used for H7: Blockchain technology can also be a motivational factor for developing learning abilities by implementing a system that can convert students' credit points into cryptocurrencies or online badges. Studies conducted in the field [17] show that students' motivations for learning and creativity are significantly improved with the help of this reward system.

Literature used for H8, H9, and H10: Students' perceptions of feedback in university courses are frequently assessed as part of both internal institutional assessment surveys and national survey instruments that collect information on the quality of students' educational experiences. National surveys have several advantages: they create information that may guide practice changes; they can be used to assess courses based on their quality; and they can affect policymakers' work at a national level and influence budget allocations. However, there is a dispute around the use (or misuse) of such measurements, which is why anonymous feedback from students is thought to contribute to increased satisfaction and credibility of their effects [22].

Figure 2 shows the proposed conceptual model of student satisfaction regarding the benefits of integrating blockchain technologies into the teaching–learning process. To create a representative SEM analysis, it is required to assess the correctness of the data used and the complexity of the variables employed (the quality of the items used and the extent to which each analysis is complete), their consistency, and validity. Evaluation indicators such as Cronbach's alpha and extracted average variants are employed in this way (Table 2).

Table 2. Latent variable coefficients.

	Credible	Control	Certify	Int_Cer	Feedback	Badges	Crypto
Cronbach's alpha	0.667	0.185	0.929	0.529	0.910	0.979	0.981
Average variances extracted	0.789	0.689	0.500	0.605	0.569	0.789	0.966
Q-squared	1000	-	-	-	0.432	-	-
R squared	1000	-	-	-	0.271	-	-

The Cronbach's alpha indicator is used to determine the measurement's dependability, defined as the degree to which it is error-free and consistently produces reliable results. The indicator must be stated as a number between 0 and 1 to offer a measure of internal consistency [23], which is satisfied in the table.

The links between the variables are underlined in the WarpPLS program, and their validity and confirmation are determined in terms of the accuracy of the items on which they were created. As a result, the average validity test derived from the AVE is utilized; if it passes the requirement for categorization in coefficients, it indicates that the measurements are of good quality and may be used to validate the convergence. According to the literature, dependability coefficient values must exceed the 0.5 thresholds and be lower than any other values reported in each column [24].

The results in Table 3 show that the discriminant validity was fulfilled, indicating that the measures were indicative of the definition and usage of variables within the proposed conceptual model.

Table 3. Correlations among latent variables with the square root of AVEs (average variance extracted).

	Credible	Control	Certify	Int_Cer	Feedback	Badges	Crypto
Credible	(0.888) ¹	0.590	0.644	0.543	0.688	0.816	0.422
Control	0.590	(0.828)	0.618	0.070	0.708	0.642	0.779
Certify	0.844	0.618	(0.707)	0.033	0.658	0.439	0.775
Int_Cer	0.543	0.070	0.033	(0.778)	0.460	0.719	0.518
Feedback	0.788	0.708	0.858	0.460	(0.754)	0.836	0.520
Badges	0.816	0.642	0.439	0.719	0.736	(0.888)	0.136
Crypto	0.422	0.779	0.775	0.518	0.520	0.136	(0.983)

¹ The table of correlations among latent variables, according to the author of the WarpPLS program's handbook. To show that their measuring instruments pass generally established standards for discriminant validity testing, they employ the square roots of the average variances extracted on the diagonal. According to the following criterion for discriminant validity testing, the square root of the average variance extracted for each latent variable should be larger than any of the correlations involving that latent variable. The square roots of the average variances retrieved for each latent variable on the diagonal of the table holding correlations among latent variables should be larger than any of the values above or below them in the same column. In other words, the values on the diagonal should be greater than any of the values to their left or right in the same row; given the repeated values of the latent variable correlations table, this indicates the same as the previous assertion. As a result, there is no 1:1 link between the two variables.

The research's major assumptions are based on descriptions of the connections between the proposed model's latent components. First, the binding coefficients (Beta-standardized coefficients) corresponding to each causal link in the model are calculated and evaluated. The value of the Beta coefficients reveals the strength and direction of the correlation between the variables; when the value of the linked Beta coefficient is more than 0.1 at a significance level of $p < 0.05$, the hypotheses are validated.

Except for the finding that beneficiaries' need for specialized medical services does not directly and positively influence their decision to choose specific medical services in

the context of COVID-19, the majority of the proposed hypotheses have been validated, as shown in Table 4 and Figure 3.

Table 4. Validation of the leading hypotheses by the connection β coefficients.

	Main Hypotheses	β	p	Validation
1	<i>The possibility of receiving badges -> the credibility is given to information sources ¹.</i>	0.00	=1.00	No
2	The possibility of obtaining certifications in digital format -> the credibility given to information sources.	0.30	<0.01	Yes
3	The possibility of obtaining certifications in digital format -> the satisfaction felt by students.	0.53	<0.01	Yes
4	The possibility of international recognition of certifications in digital format -> the credibility given to information sources.	1.30	<0.01	Yes
5	The possibility of international recognition of certifications in digital format -> the satisfaction felt by students.	0.10	<0.03	Yes
6	Improving/personalizing students' time management -> student satisfaction.	0.70	<0.01	Yes
7	<i>The possibility of converting the credits obtained into cryptocurrencies -> the satisfaction felt by the students.</i>	0.00	=1.00	No
8	<i>Student satisfaction -> credibility given to information sources.</i>	0.10	<0.06	No
9	Student satisfaction -> the possibility of providing honest feedback.	0.52	<0.01	Yes
10	<i>The possibility of providing honest feedback -> credibility given to information sources</i>	0.00	=1.00	No

¹ Several links between variables are highlighted by italics as they have not been confirmed/validated following the analysis performed.

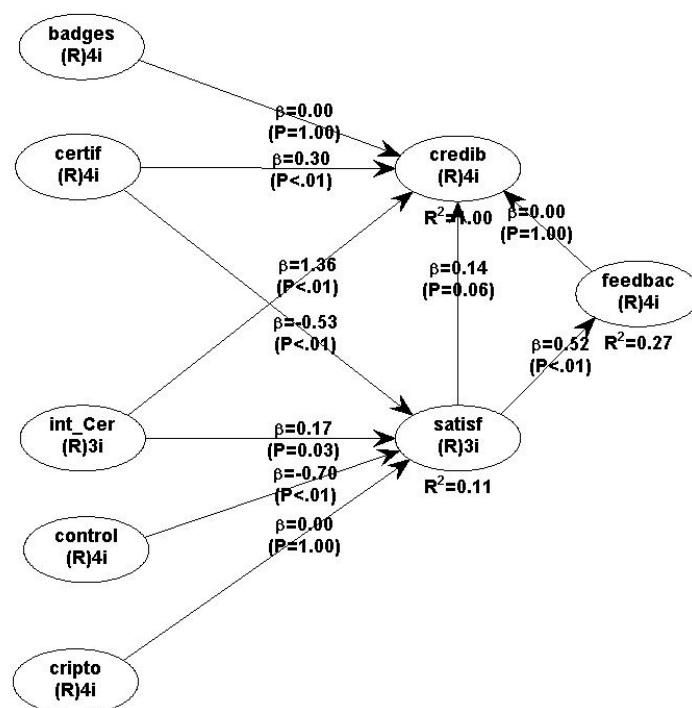


Figure 3. Validated model regarding students' satisfaction with the integration of blockchain technologies in the teaching–learning process.

5. Discussion

This article presents a comprehensive perspective (both from the perspective of teachers and the perspective of students) of the implementation of blockchain technologies in the educational process. First of all, the opinion of the teachers regarding the use of these technologies for the more efficient storage and distribution of educational materials was studied. Such an idea was also addressed in the scientific paper “MOOCsChain: A Blockchain-Based Secure Storage and Sharing Scheme for MOOCs Learning” [9], which proposes the integration of Electronic Learning Record (ELR) platforms, such as Coursera, Udacity, iCourse, Udemy, and others, in blockchain technologies (thus giving rise to the concept of the MOOCsChain) for greater storage security and evidence of loaded materials.

In the qualitative research among the university professors involved in the teaching–learning process, their attitudes toward the implementation of blockchain technologies in the educational process were studied, and some of the results obtained in this article coincide with other mentions in the specialty literature, such as the list of advantages and disadvantages (identified in [1,17,18]). Additionally, regarding the use of technology in general, in this article it emerged that teachers use technology in the teaching–learning processes at an intermediate level, based on the need for practical activities, such as streaming platforms, online video, and presentations, etc.

Regarding the students' opinions in this study, even if a similar study confirms that they would be interested in converting credits into cryptocurrencies [10], the results obtained in this research show the opposite. Moreover, the students participating in this article are more excited and interested in issuing diplomas/certificates of completion in electronic format (especially in an internationally recognized format) than in the offering of regular badges or convertible credit points.

It is important to note, however, that using blockchain in education is still a topic in its infancy, which is what impacts the existence and quality of research conducted on this topic.

Although the amount of research on the uses of blockchain in education has been expanding in recent years, it is still fragmented, and no comprehensive study has yet been undertaken on the issue [17]. Today's blockchain technology may not be mature enough

to scale for all use cases [25]. This is especially concerning for education-platform use cases (such as blockchain record keeping or digital asset use cases). Given the relative newness of blockchain investigation in the education industry, many of the most prominent blockchain-in-education efforts have yet to be thoroughly investigated and recorded [14].

Other sources [26] confirm that blockchain is a distributed ledger system that combines decentralization, traceability, immutability, and monetary qualities with cryptographic techniques and distributed consensus processes. Its monetary qualities can spark a slew of new educational uses. Blockchain technology, for example, can increase students' incentives to study by recognizing that "learning is earning." It can keep a complete and reliable record of educational activities, including procedures and outcomes in formal and informal learning situations. It may also keep track of instructors' teaching practices and performances, which can be used as a benchmark for teacher assessment. In a nutshell, blockchain is promising for both learners and instructors in terms of instructional design, behavior recording and analysis, and formative evaluation.

6. Conclusions

Following the results obtained, we can highlight the fact that both students and professors from the university environment may be interested in using blockchain technologies in the teaching–learning process, with each of the two categories of research participants quickly identifying several advantages that can contribute to the quality of educational services and the satisfaction of the final beneficiaries (students).

It seems that several hypotheses in this study have not been confirmed, namely that badges given online based on acquired knowledge are not a motivating factor that contributes to student satisfaction between the satisfaction they feel in the learning process (using blockchain technologies); that the credibility given to the accessed information is not a direct link (which is probably also due to the lack of knowledge among students about the process of encrypting and securing information within the blockchain); that there is no strong link between the possibility of providing honest feedback (through blockchain technologies which can provide anonymous feedback so that teachers or owners of materials cannot identify who the author is) and the credibility of students; and that the most interesting idea is that converting credit points into cryptocurrencies is not a significant factor in achieving student satisfaction among study participants.

However, the potential for integrating blockchain technologies into the cost of teaching and learning in academia is of interest to both students and teachers, obviously representing a significant technological evolution that can contribute to security, simplification, and efficient education.

The contribution to the literature brought by this article consists of opening the possibility for numerous other similar studies within other universities, and even other countries. First of all, considering the somewhat limited amount of research in the field (implementation of blockchain technologies in education), this article highlights the problems expressed in the opinions of professors and students from the university environment on the usefulness and advantageousness of implementing such technology in education (in the teaching–learning process).

The limitations of this study can be considered to be related to the fact that the research was conducted in a single country (but it is an opportunity for future research).

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