Chapter

Blockchain-Based Educational Certificates: A Proposal

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Abstract

The development of science and technology is very fast and even increases year by year, especially in the education system. However, in practice, a lot of learning systems continue to employ traditional methods and thus, learning becomes a less active process. Thanks to the technological improvements that have taken place over time, the concept of Blockchain could be integrated in the educational sector. Although mainly used for digital currencies, it seems that it could significantly impact healthcare, pharmaceutical industry/drug supply chain management, and now, the educational sector. Hence, Blockchain is used by the majority of current systems as a secure mechanism for confirming and transferring student data, academic credentials, and databases of educational organizations. Thanks to Blockchain, which gives students a powerful tool to manage and share their learning success, employers can rely on trustworthy, realistic representations of students' potential based on academic achievement (trusted verification). This chapter aims to define the concept of Blockchain, both in general terms and within the educational system. It also aims to carry out a case study among students and establish correlations between their answers.

Keywords: Blockchain, educational certificates, students, Blockchain applications, educational sector, fake diploma problems, bitcoin, technology

1. Introduction

The advancement of science and technology is extremely rapid and even gets faster every year, particularly in the field of education. The most significant and cutting-edge technologies of the past 10 years are Blockchain and internet of things. A better understanding of Blockchain technology has made it possible for the education sector to use its comprehensive characteristics to the advantage of students, teachers, organizations, employers, and lifelong learners. The complicated field of document verification requires a number of difficult and time-consuming techniques to authenticate. The most significant records that universities offer to students are educational certificates. Fake certificates can be easily produced, though, because the issuance procedure is not very clear and verifiable [1].

Blockchain technology can be extremely important in this new environment since it can give systems the required foundation for secure and impenetrable operations. Blockchain is a digital ledger that stores and verifies data and information. In some institutions, Blockchain applications are currently being used for a range of purposes, including issuance and storage of certificates and diplomas, assessment of learning outcomes, support and management of academic degrees, protection of intellectual property, collaboration between students and their professors, learning accreditation, payment for studies, the creation of an academic passport (portfolio), and administration of the educational process [2].

2. Blockchain-based educational certificates, present, and future. Fake diploma problems

2.1 About Blockchain

2.1.1 What is Blockchain?

As it is written in Ref. [3], in 2008, Blockchain was introduced as a new technology. It began as a peer-to-peer database for recording Bitcoin cryptocurrency transactions [4]. The main objective, as it is said in Ref. [5], was to reduce any intermediaries and to allow clients to access their business directly, that is why Blockchain was created as a decentralized network of peer nodes. Each entity:

- can have a copy of the ledger of transactions;
- when it obtains agreement from the others in the network, it can create an item for its own repository;
- can verify that the ledger it possesses is identical to those throughout the network on a regular basis;
- broadcasts to the rest of the network any transaction made by its users.

The Blockchain is a distributed database or public ledger that stores a list of all digital events or transactions that have occurred and is fundamentally shared among all participants. Only if the majority of the participating parties decide, a transaction can be valid. Moreover, it is impossible to remove or change data unless with the agreement of all or the majority of the network participants, once it has been confirmed and inputted, exactly as it is said in Ref. [6],—an analogy in nontechnical terms; it is very easy for anyone to steal a cookie from a cookie jar that is kept in a hidden place than to steal from a jar that is placed in a market place, where thousands of people are keeping an eye on.

2.1.2 How does it work?

The name Blockchain is not by chance: A "chain" of separate "blocks" of data is often used to characterize the digital ledger. A new "block" is formed and attached to the "chain" as new data are uploaded to the network. This requires that all nodes update their Blockchain ledgers in order to be identical.

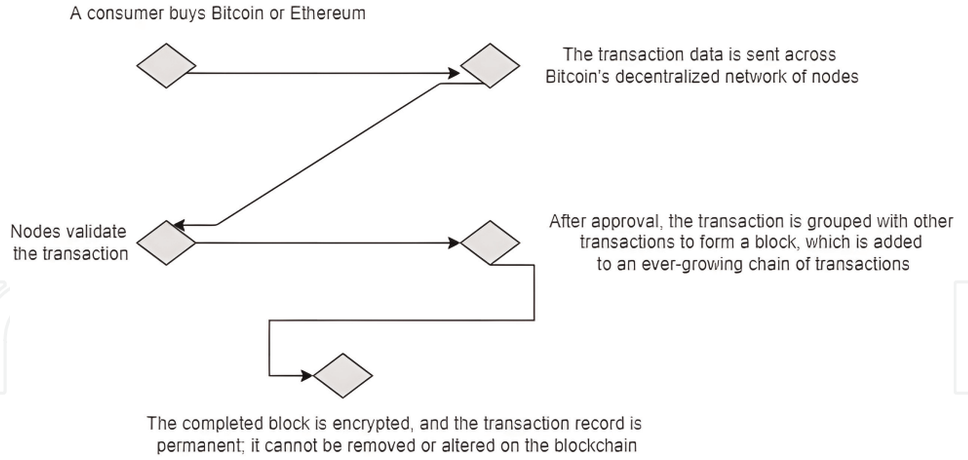

Figure 1.
An example of how Blockchain is used to verify and record bitcoin transactions [7].

The reason Blockchain is considered extremely secure is because of the way these new blocks with informations are formed. Before a new block can be added to the ledger, most nodes must verify and certify the legitimacy of the new data. An independent database or spreadsheet (the methods used before Blockchain), on the other hand, allows a person to make changes without supervision [7].

Figure 1 [7] shows an example of how Blockchain is used to verify and record Bitcoin transactions.

2.1.3 The importance of Blockchain

Blockchain has a number of qualities that make it useful. The success of Bitcoin, whose capital market presently stands at 191 billion USD [8], demonstrated the robustness and promising aspects of Blockchain. According to Ref. [6] and the UK government's office of research, Blockchain secures data records, lowers operational expenses, and increases transaction transparency.

The following are some of the interesting aspects, benefits, and significance of Blockchain, as it is mentioned in Ref. [6]:

- **Networked existence**: At the same moment, different users (nodes) on the Blockchain network store the same Blockchain data. Even if one node fails or loses data, other nodes in the network have a copy of the Blockchain and can continue to update it. The Blockchain can be recopied from other nodes. These feature guards against data loss, record tampering, and cryptocurrency costs unnecessary.

- **Decentralized nature**: Blockchain's decentralized nature eliminates the need for central authority and middlemen, making it more ideal for applications. Blockchain enables systems to be self-contained and devoid of the hazards that come with relying on middlemen and central authorities. Private Blockchains, on the other hand, can be partially or totally centralized while still benefiting from the other Blockchain features.

- **Data security and integrity**: Blockchain is secure in the sense that any changes to data in any block are discovered by a change in the block hash, which differs

from the previously recorded hash in the next block. To be successful, a malicious user must change the block data for all computers on the network, which is essentially impossible in a large network. As a result, data on Blockchain is protected against alteration in this regard.

- **Traceability and transparency**: Because Blockchain records are time-stamped and saved on all complete nodes on the network, everyone can check and see all activity and transactions. All of a node's activity and transactions can be tracked if its address is known. Blockchain becomes visible and traceable as a result of this. It is also a useful platform for auditing and public services because it is suitable for fraud detection.

- **Efficiency**: Because middleman subsystems are removed, Blockchain allows systems to work autonomously with greater efficiency. This is one of the advantages that many companies and countries are hoping to obtain from Blockchain technology.

- **Verifiability**: The legitimacy of a record may be checked thanks to Blockchain's encryption. This may be difficult to do in other databases since it necessitates cryptographic technologies, such as Blockchain's digital signature.

- **Interoperability**: Blockchain provides a secure data-sharing platform that allows separate parties to share the same data and synchronize their services.

- **Cost savings**: Using Blockchain saves a lot of money because it eliminates the need for intermediary systems. Banks might save $20 billion each year if they used efficient Blockchain. One of the reasons why some banks and businesses seek to integrate Blockchain into their systems in order to save money is because of this economy.

Border control, government identity, insurance, shipping, real estate, advertising, waste management, energy, tourism, and a variety of other problems can all be solved with Blockchain technology. It is made up of numerous algorithms that are kept in the ledger and are used to detect faults. It also determines which block the error happened in.

2.1.4 Types of Blockchain

Due to the wide range of interests in Blockchain applications, the technology is divided into four categories: public, private, hybrid, and consortium Blockchains, as can be seen in the following **Figure 2**.

For a better view of these four categories of Blockchain, in the **Table 1**, there are the advantages, disadvantages, and some use cases of each one:

2.2 Applications of Blockchain

Blockchain was originally employed in cryptocurrencies, with Bitcoin being the first to demonstrate its success. There are numerous Blockchain applications today, as summarized in the following **Figure 3**:

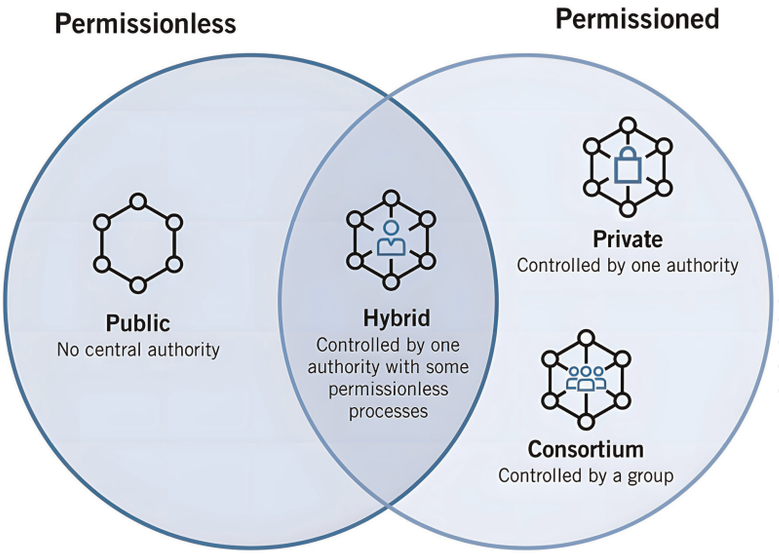

Figure 2.
Types of Blockchain [9].

	Public	Hybrid	Consortium	Private
Describe	No central authority.	Controlled by authority with some permissionless processes.	Controlled by a group.	Controlled by one authority.
Advantages	Transparency Independence Trust	Access control Performance Scalability	Access control Scalability Security	Access control Performance
Disadvantages	Performance Scalability Security	Transparency Upgrading	Transparency	Trust Auditability
Use case	Document validation Cryptocurrency	Medical records Real estate	Banking Research Supply chain	Supply chain Asset ownership

Table 1.
Differences between types of Blockchain [10].

To be more specific, the following list will explain a little bit about the importance of the use of Blockchain in the most important domains [6]:

- Cryptocurrencies;
- Smart contract;
- Healthcare management;
- Insurance;
- Banking and finance;
- IoT industry;
- Decentralized data storage;

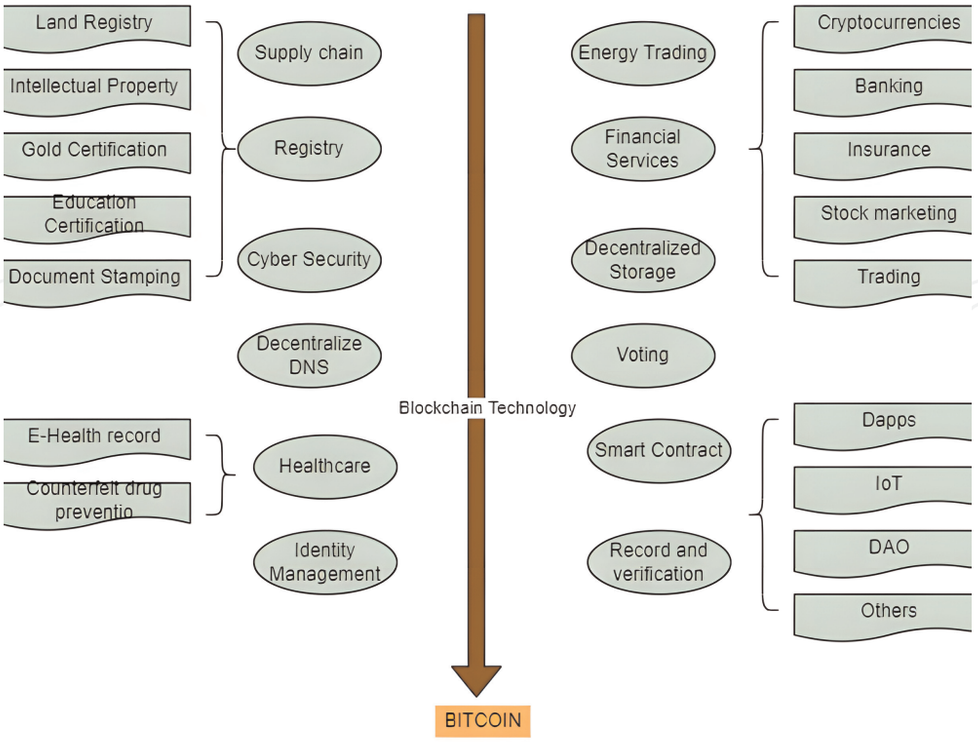

Figure 3.
Blockchain applications tree [6].

- Intellectual properties and document stamping;
- Digital identity management;
- Project management;
- Cybersecurity;
- Asset registry and tokenization.

2.3 Advantages and disadvantages of using Blockchain

According to Ref. [11], Blockchain technology has been portrayed as a disruptive technology that provides unprecedented levels of security, which is required and wanted not only by the IT and finance industries but by all industries in general, making it a very adaptable technology.

Despite its many advantages, Blockchain technology is far from flawless, and it has advantages and problems in its deployment, much like every revolutionary technology.

Advantages:

- Higher accuracy of transactions,
- No need for intermediaries,
- Extra security,

- Efficient transfers,
- Decentralization,
- Network distribution,
- Resistant and resilient.

Disadvantages:

- Limit on transactions per second,
- High energy costs,
- Potential for illegal activity,
- Risk of asset loss,
- Private keys,
- Unemployment,
- Storage.

And there are also some characteristics of the Blockchain network that can be both an advantage and a disadvantage, such as:

- Immutability of information,
- Anonymity.

2.4 Educational sector

The education sector is undergoing a technological transition; yet, there are numerous challenges with this. Virtual classrooms are taking over traditional classrooms. The real question is how might Blockchain technology help educational institutions and students' study more effectively [12].

This topic can be answered in a variety of ways; however, it will focus on three major segments to describe the advantages of Blockchain solutions and for whom it is beneficial:

- Educational institutions (universities, start-ups, and nongovernmental organizations) that are searching for solutions to improve the efficiency and security of student data storage and management;
- Learners who would benefit from more interesting, dependable, and long-term methods of accumulating, attesting, and sharing information;
- Employers who want to assess the validity of students' talents and credentials in a trustworthy and secure manner [12].

It is worth emphasizing that the application of Blockchain in academia is still in its early stages, which has an impact on the availability and quality of research on the subject. The majority of existing solutions employ Blockchain as a secure system for validating and distributing personal student data and academic diplomas, along with educational organizations' databases.

2.4.1 Blockchain technology for educational sector

After some research, it is clear to say the best way to explain how Blockchain could be implemented in the educational sector is to divide the interests, the same as it is explained in Ref. [12].

a. Enhancing security and efficiency for educational institutions, corporations, and students

   Blockchain technology has the potential to protect students' data by ensuring their identification, privacy, and security. As previously stated, Blockchain ensures integrity through its hash chain, which provides security and authenticity. Students, for example, cannot change past educational certifications stored on the Blockchain. Furthermore, because Blockchain does not store data, but rather a hash of it, privacy is assured. Before being stored on the Blockchain, the data might be encrypted if desired.

   As it is mentioned in Ref. [13], a variety of Blockchain-powered efficiency applications, including record-keeping applications, such as digital credentials and intellectual properties, simplifying diploma verification, and fast and reliable student payments. Not only do these technologies save money and time for educational institutions, but they also save time and money for companies and individual students.

b. Integrating trust and transparency

   Employers may be assured that job applicants have the required abilities to succeed in the industry, since Blockchain guarantees that students cannot falsify their grades, degrees, or certifications. Blockchain becomes a trust anchor of one truth for credentials‖ as it is said in research "Tapscott and Kaplan, 2019."

   Moreover, this anchor gives job searchers and companies the option to make better matches. In general, because distributed ledger technologies enable learning and protect academic records, they improve interactions between "universities, companies, companies, and their relationships to society" by integrating trust and transparency into skill transactions and sharing procedures.

c. Learners' empowerment (self-sovereignty)

   The data (credentials, skills taught, etc.) linked with a student's identification is owned by the student, not by a central administration like a university. Students can keep their lifetime learning data (both inside and outside of the classroom), fully own it, and decide who has access to it.

> Furthermore, even when students benefit from Blockchain "wallets," where they can store and share all of their learning data with various parties (students being complete owners of their identity-related data), they still benefit from the support of their professors, ensuring that they are not alone in their learning journeys.

Moreover, Blockchain can facilitate the most important element for educational institutes, such as

- Decentralization;
- Immutability;
- Smart contracts;
- Payment registry;
- Security;
- Transparency.

2.4.2 Blockchain-based educational certificates. Challenges reduced by Blockchain. Fake diploma problems

Students' educational qualifications become public and simply shareable with companies and universities for opportunities for future personal growth. Employers can base on reliable, realistic representations of students' potential based on academic accomplishment thanks to Blockchain, which provides students with an empowering tool to manage and share their learning achievement (trusted verification).

The following are some of the challenges that Blockchain can alleviate:

- It has the ability to establish an environment in which students' personal databases can be modified and subsequently stored. The Blockchain gives institutions access to data, which is a lot more precise, and any changes do not have to be as time-consuming;
- It can be seen in the development of an open-source environment. This can provide a place to store all of the documents that a student will need during his or her course of study, as well as provide an air of validity for students to carry less documents in their luggage, so offering an alternate mode of education;
- One key benefit of this technology to the educational backdrop is that it provides each student with a unique id, which aids students in matching up their information, and in the event of any project confusion between two students, it can be readily resolved. The ability to see the grades in real time can be a huge benefit;
- The issue that the schools/universities face is the high number of incidences of fraud and fraudulent diplomas offered to pupils. The fundamental objective of Blockchain technology is to get to a point, where every block is a proven block, so

that if there is any fraud, the necessary information is sent directly to the higher authorities, who may take swift action.

2.4.3 The advantages of using Blockchain in an educational environment

As it is mentioned in Ref. [6], the main advantages of using Blockchain in an educational environment are:

- It gives its customers the opportunity to check the veracity of a record against the Blockchain without involving the issuing organization.
- It works to eliminate the practice of issuing certifications on paper. Educational establishments' qualifications can be reliably and permanently recorded via Blockchain. Further developments could include automating certifications, transferring credits, or even preserving a complete record of a student's accomplishments throughout their academic career.
- Implementing Blockchain technology can drastically cut the costs incurred by educational institutions in maintaining data. It also enables the reduction of liability risks that are common while handling records.
- The records are open to the public and easily verified.
- Enhancing learners' interactivity.
- Supporting learners' career decisions.
- Improving the management of students' records.
- Enhancing trust.
- Identity authentication.
- Enhancing accountability and transparency.
- Better control of data access.
- Enhancing students' assessments.
- High security.

3. Analysis of the status quo of digital education recognition

3.1 Analysis of current state-of-the-art of the European digital education recognition using Blockchain in comparison to best practices in the world

As it is said in Ref. [14], the European Blockchain Partnership (EBP) was established after EU member states and Norway signed a declaration with the goal of

providing digital public services that meet the requisite degree of digital security and maturity in today's society.

In future, all public services will use Blockchain technology. Blockchain is a great opportunity for Europe and member states to rethink their information systems, promote user trust and the protection of personal data, help create new business opportunities, and to establish new areas of leadership, benefiting citizens, public services, and companies. The partnership launched today enables member states to work together with the European Commission to turn the enormous potential of Blockchain technology into better services for citizens‖ declared Mariya Gabriel, the commissioner for Digital Economy and Society, in 2018.

Many industries and colleges in Europe and beyond are becoming increasingly interested in Blockchain technology. Blockchain, a relatively new discovery in computer science, is a worldwide, cross-industry, and disruptive technology that is expected to drive global economic growth for another few decades.

When discussing a topic like Blockchain, it is natural to start with themes, such as technological transformation, digital economy, competency industries, and innovation system. This enables people to comprehend the context in which digital disruption occurs.

However, the socioeconomic forces that produce interest in technology (or alter in reaction to it) may be as essential, if not more so, than the digital technology itself. The most successful digital company concepts put people first and digital technology second. Within the educational setting, the phrase is quickly becoming associated with the ability of individual students to own, manage, and share information about their credentials without relying on the education sector as an authorized middleman.

Blockchain technology is perfect for securing, sharing, and verifying learning achievements as a new infrastructure. In the case of certificates, a Blockchain can maintain a list of the certificate's issuer and receiver, as well as the document signature (hash), in a public database (the Blockchain) that is replicated on thousands of computers all over the world [14].

3.1.1 Results of case studies on the application of Blockchain technology in education

As early Blockchain literature frequently refers to "self-sovereignty," or an individual's ability to own and control his or her own identity online, within an educational context, the term is quickly becoming synonymous with the autonomy of individual learners to own, manage, and share details of their credentials without relying on the education institution as a trusted intermediary [14].

3.1.1.1 Open University UK

Imagine a scenario where every learning activity is registered on the Blockchain, including informal learning, together with informal feedback. All assignment test scores will be mapped on learning environments across Europe. Europe-wide analytics could then be developed from the ground up. The best lecturers in Europe by the subject could be easily identified. Learning would become that much more interactive and reputations built on more tangible matrices‖, declared Professor Domingue.

Professor Domingue suggests that the EU consider funding the development of an EU-wide Blockchain for educational experiments. Funding would be made available for more innovative projects on the same Blockchain. It should organize an education

program as well as a series of informational meetings for various stakeholders. For example, colleges should use Blockchains to communicate with other colleges and universities and in different EU countries, fostering collaboration [14].

3.1.1.2 University of Nicosia

The University of Nicosia (UNIC) has declared a number of "world firsts" in its commitment to maximizing the potential of Blockchain in education. UNIC claims to be the first university to [14]:

- accept Bitcoin as payment for any degree program at the university since October 2013;
- has a course about cryptocurrency, called, Introduction to Digital Currencies‖ since January 2014;
- offer an approved academic degree program in digital currency—a Master of Science in Digital Currency—taught online in English (from March 2014, with the first students graduating in June 2016);
- using its own in-house software platform, award academic certifications on the Bitcoin Blockchain since September 2014.

"It would be hugely valuable if high schools around the world had some common standard for accreditation and recognition. We cannot have 40 standards on a Blockchain. How does this become useful to higher education—which is being fed by secondary education? How can we get everyone to subscribe to the same standard? If any one institution like ours is doing it—it is limited; if a nation-state or all higher education institutions and schools in a country come on board—that would be very useful," claimed Mr. Polemitis.

In conclusion, it appears that Blockchain technology will likely be implemented by most EU member states. Some EU members will try to develop a national strategy for its use, and others are already testing specialized Blockchain applications.

Given the expense of implementing Blockchain technology, it is evident that, despite the excitement around the technology, it can only be applied to select use cases from a technical standpoint. As a result, a Blockchain-based application should only be used if it fits a specific set of requirements [14].

4. Methodology for collecting data

The further case study is based on finding out the perspective of students regarding the adoption of Blockchain technology in the education system. It is important to know the students' opinion, in order to find out their knowledge of Blockchain technology, but also the advantages and disadvantages that they consider in using such technology.

The research methods used are the following: a documentary study on the topic, secondary analysis of statistical data, and quantitative research by the method of distributing a questionnaire. The research method used is empirical, which is using

primary quantitative research. This research was conducted on the basis of a structured questionnaire.

The questionnaire consisted of 10 questions, and its completion resulted in 147 responses from respondents. It was distributed online and was addressed to students at the Faculty of Automation and Computers, Polytechnic University of Bucharest. During the questionnaire, mainly quantitative questions were used (using the Likerd ordinal scale), but also qualitative questions were to find out the year in which the students first heard about the concept of Blockchain technology and in what context. Also, at the beginning of the questionnaire, questions were used to find out information about the respondents (gender and study program).

Quantitative questions (using the ordinal Likerd scale) were mainly used during the questionnaire. Respondents' responses were rated on a scale of 1 to 5 as follows: 1 = not important, 2 = low, 3 = medium, 4 = high, and 5 = very high.

The software used to analyze statistical data and find out the final results was SPSS (statistical package for the social sciences).

5. Analysis of data

At the basis of the work, there were five hypotheses that were analyzed. To summarize the results, five Figures will be presented (for each hypothesis). Each subpoint on the left will be represented by a color. On the right side, each subpoint will include the colors of the elements with which there is a correlation.

H1 - *The use of Blockchain technologies in the education sector influences the need for Blockchain knowledge in different fields.*

In order to be able to analyze H1, the 11 subpoints from question 5 (the level of use of Blockchain technologies in different cases in the educational system) and the 7 subpoints from question 6 (the level of knowledge about Blockchain technologies of different professions) will be taken into account. **Figure 4** shows the synthesis of hypothesis 1:

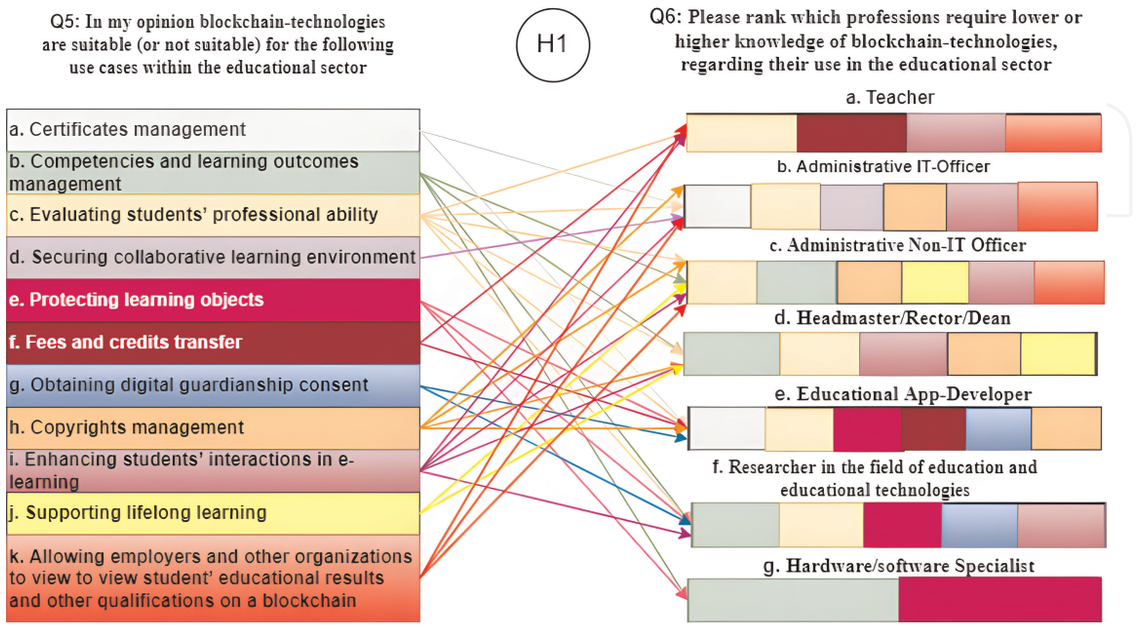

Figure 4.
Synthesis of hypothesis 1.

Between H1 elements, there were both weak positive correlations (statistically significant at a 95% confidence level) and reasonably positive correlations (statistically significant at a 99% confidence level). Thus, the following examples of *weak positive correlations* between the elements are mentioned:

- between the use of Blockchain technologies for certificate management and the need for high knowledge of the IT administrative officer,
- between the use of Blockchain technologies for securing a collaborative learning environment and the need for high knowledge of the administrative IT officer.

The following examples of *reasonable positive correlations* between the elements are mentioned:

- between the use of Blockchain technologies for protecting learning objects and the need for high knowledge of the researcher in the field of education and educational technologies,
- between the use of Blockchain technologies for fees and credits transfer and the need for high knowledge of the educational app developer.

H2 - *Issues to consider before including Blockchain technologies in the education sector influence the use of Blockchain technologies.*

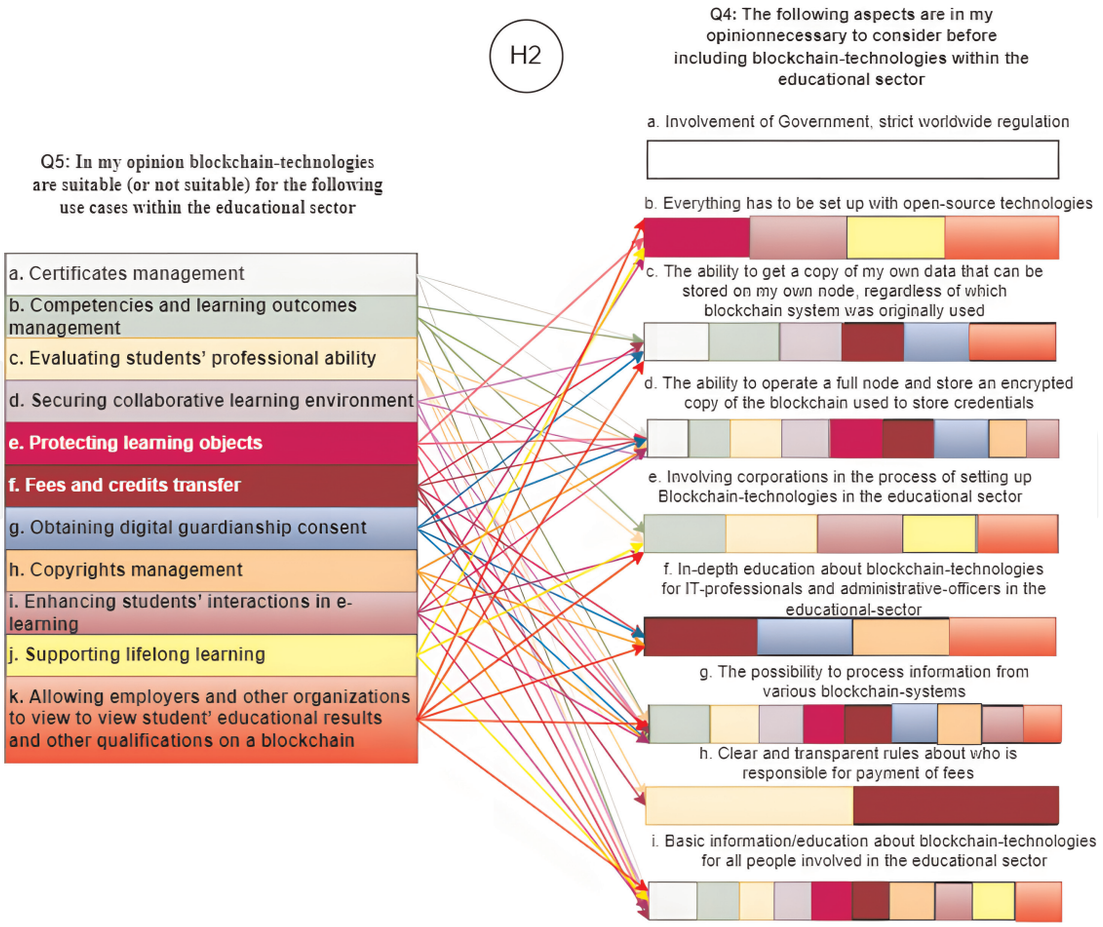

Figure 5.
Synthesis of hypothesis 2.

In order to be able to analyze H2, the 11 subpoints from question 5 (The level of use of Blockchain technologies in different cases in the educational system) and the 9 subpoints from question 4 (Issues to consider before including Blockchain technologies in the education sector) will be taken into account. **Figure 5** shows the synthesis of hypothesis 2:

Between H2 elements, there were both weak positive correlations (statistically significant at a 95% confidence level) and reasonably positive correlations (statistically significant at a 99% confidence level). Thus, the following examples of *weak positive correlations* between the elements are mentioned:

- between the use of Blockchain technologies for competencies and learning outcomes management and the need to consider "the ability to get a copy of data that can be stored on nodes, regardless of which Blockchain system was originally used" before including Blockchain technologies in the education sector,

- between the use of Blockchain technologies for securing a collaborative learning environment and the need to consider "the possibility to process information from various Blockchain systems" before including Blockchain technologies in the education sector.

The following examples of *reasonable positive correlations* between the elements are mentioned:

- between the use of Blockchain technologies for evaluating students' professional ability and the need to consider "the possibility to process information from various Blockchain systems" before including Blockchain technologies in the education sector,

- between the use of Blockchain technologies for protecting learning objects and the need to consider "basic information/education about Blockchain technologies for all people involved in the educational sector" before including Blockchain technologies in the education sector.

H3 - *Knowledge of Blockchain technologies in different professions influences the benefits of adopting Blockchain technologies.*

In order to be able to analyze H3, the 7 subpoints from question 6 (the level of knowledge about Blockchain technologies of different professions) and the 9 subpoints from question 7 (the benefits of adopting Blockchain technologies in education) will be taken into account. **Figure 6** shows the synthesis of hypothesis 3:

Between H3 elements, there were both weak positive correlations (statistically significant at a 95% confidence level) and reasonably positive correlations (statistically significant at a 99% confidence level). Thus, the following examples of *weak positive correlations* between the elements are mentioned:

- between the need for high knowledge of the teacher and better control of data access,

- between the need for high knowledge of the headmaster/rector/decan and enhancing learners' activity,

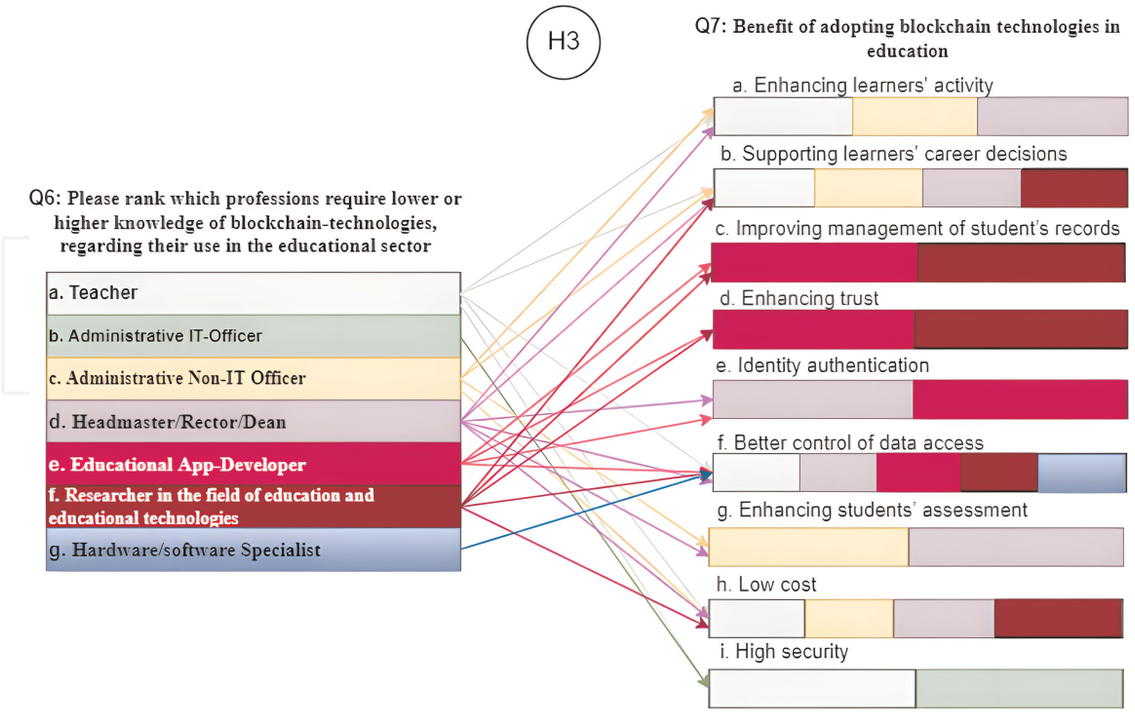

Figure 6.
Synthesis of hypothesis 3.

- between the need for high knowledge of the headmaster/rector/decan and identity authentication,
- between the need for high knowledge of the educational app developer and improving the management of students' records.

The following examples of *reasonable positive correlations* between the elements are mentioned:

- between the need for high knowledge of the teacher and the enhancing learners' activity,
- between the need for high knowledge of the teacher and the high security,
- between the need for high knowledge of the educational app developer and the enhancing trust,
- between the need for high knowledge of the researcher in the field of education and educational technologies and supporting learners' career decisions.

H4 - *Issues to consider before including Blockchain technologies in the education sector influence the benefits of adopting Blockchain technologies.*

In order to be able to analyze H4, the 9 subpoints from question 4 (issues to consider before including Blockchain technologies in the education sector) and the 9 subpoints from question 7 (the benefits of adopting Blockchain technologies in education) will be taken into account. **Figure 7** shows the synthesis of hypothesis 4.

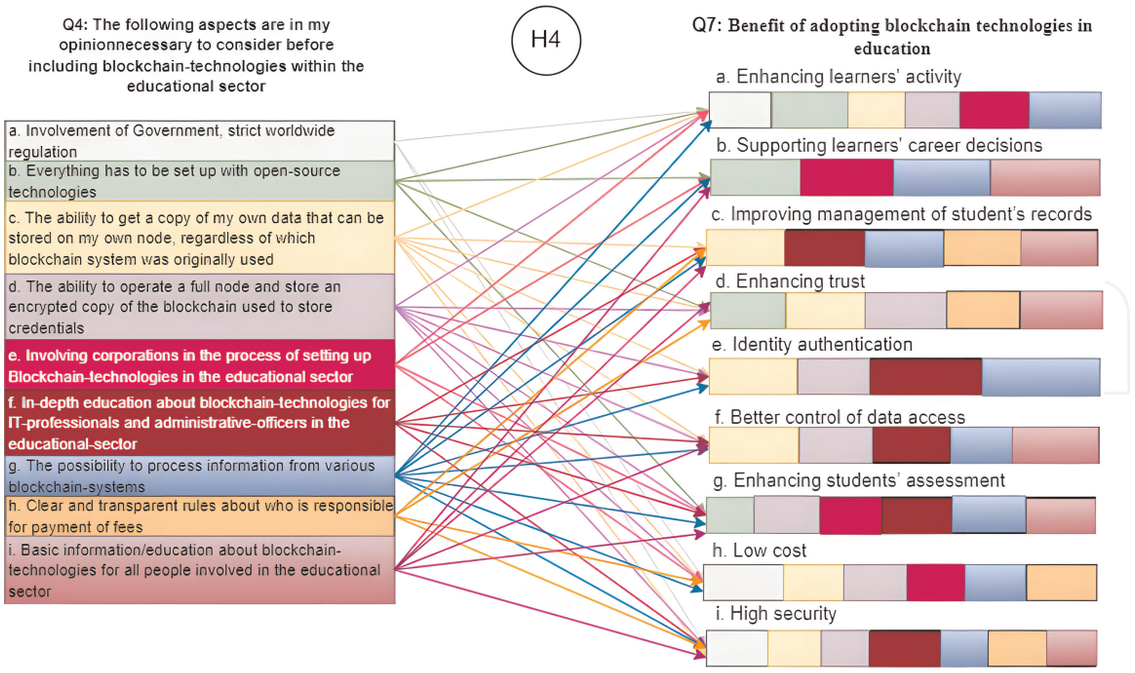

Figure 7.
Synthesis of hypothesis 4.

Between H4 elements, there were both weak positive correlations (statistically significant at a 95% confidence level) and reasonably positive correlations (statistically significant at a 99% confidence level). Thus, the following examples of *weak positive correlations* between the elements are mentioned:

- between the need to consider "involvement of Government, strict worldwide regulation" before including Blockchain technologies in the education sector and enhancing learners' activity,

- between the need to consider "everything has to be set up with opensource technologies" before including Blockchain technologies in the education sector and enhancing trust.

The following examples of *reasonable positive correlations* between the elements are mentioned:

- between the need to consider "involvement of Government, strict worldwide regulation" before including Blockchain technologies in the education sector and the low cost,

- between the need to consider "the ability to operate a full node and store an encrypted copy of the Blockchain used to store credentials" before including Blockchain technologies in the education sector and the enhancing trust,

- between the need to consider "the ability to operate a full node and store an encrypted copy of the Blockchain used to store credentials" before including Blockchain technologies in the education sector and the high security.

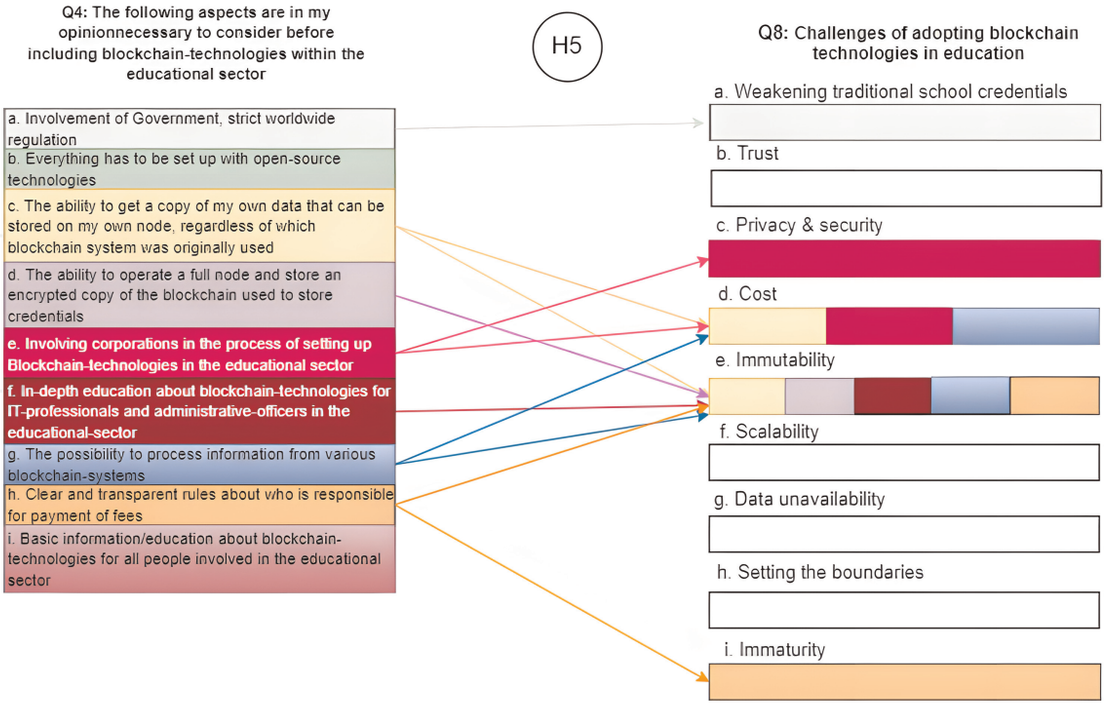

Figure 8.
Synthesis of hypothesis 5.

H5 - *Issues to consider before including Blockchain technologies in the education sector influence the challenges of adopting Blockchain technologies.*

In order to be able to analyze H5, the 9 subpoints from question 4 (issues to consider before including Blockchain technologies in the education sector) and the 9 subpoints from question 8 (challenges of adopting Blockchain technologies in education) will be taken into account. **Figure 8** shows the synthesis of hypothesis 5.

Between H5 elements, there were both weak positive correlations (statistically significant at a 95% confidence level) and reasonably positive correlations (statistically significant at a 99% confidence level). Thus, the following examples of *weak positive correlations* between the elements are mentioned:

- between the need to consider "the ability to get a copy of data that can be stored on node, regardless of which blockchain system was originally used" before including blockchain technologies in the education sector and immutability,

- between the need to consider "involvement of Government, strict worldwide regulation" before including Blockchain technologies in the education sector and weakening traditional school credentials,

- between the need to consider "involving corporations in the process of setting up Blockchain technologies in the educational sector" before including Blockchain technologies in the education sector and privacy and security,

- between the need to consider "the possibility to process information from various Blockchain systems" before including Blockchain technologies in the education sector and cost,

- between the need to consider "involving corporations in the process of setting up Blockchain-technologies in the educational sector" before including Blockchain technologies in the education sector and cost,

- between the need to consider "clear and transparent rules about who is responsible for payment of fees" before including Blockchain technologies in the education sector and immaturity.

The following examples of *reasonable positive correlations* between the elements are mentioned:

- between the need to consider "the ability to operate a full node and store an encrypted copy of the Blockchain used to store credentials" before including Blockchain technologies in the education sector and immutability,

- between the need to consider "the possibility to process information from various Blockchain systems" before including Blockchain technologies in the education sector and immutability,

- between the need to consider "clear and transparent rules about who is responsible for payment of fees" before including Blockchain technologies in the education sector and immutability.

6. Development of a pilot model using Blockchain concept for "record keeping" of students' degrees, certificates, and diplomas based on the previous analysis. Simulation of a case study

A pilot model using Blockchain concept for "record keeping" of students' degrees, certificates, and diplomas must take into account:

1. **Inputs:**

   - personal data (e.g., name, gender, date of birth, educational institution, etc.),

   - diplomas (e.g., engineering degree, etc.) and certificates (e.g., BA certification, etc.).

2. **Outputs:**

   - the hash of identity stored on Blockchain,

   - the hash of certificate stored on Blockchain.

Figure 9 shows a pilot model for "record keeping" of students' degrees, certificates, and diplomas.

Figure 10 shows the simulation of a case study.

Such a pilot model can bring numerous benefits for both students and institutions. The following benefits of the model are mentioned:

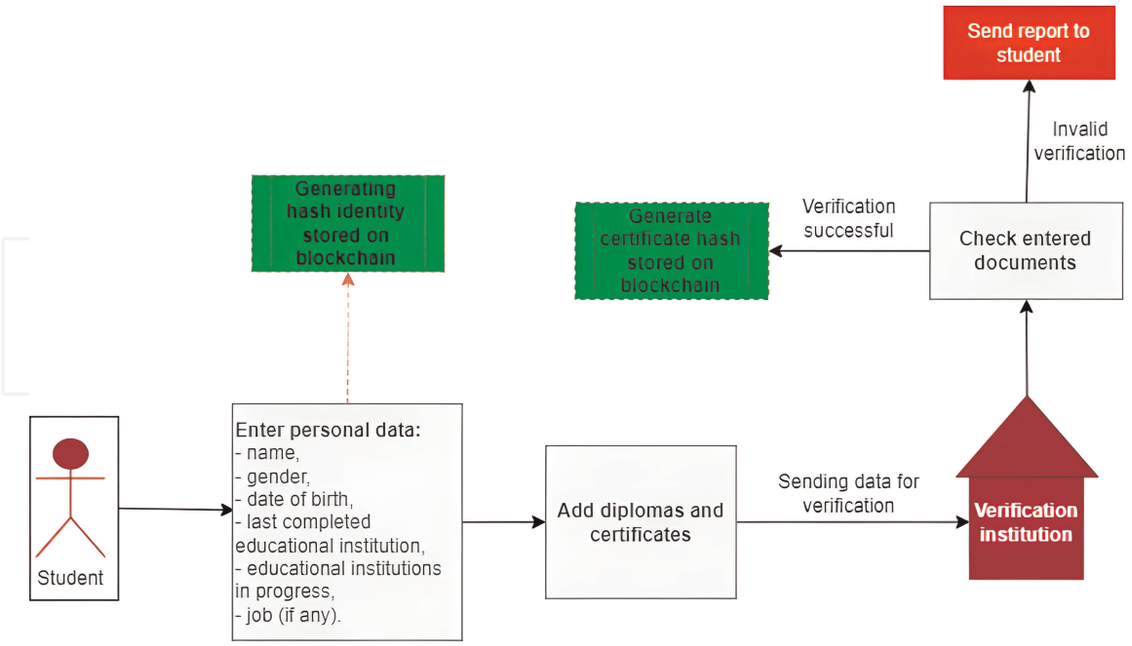

Figure 9.
Pilot model.

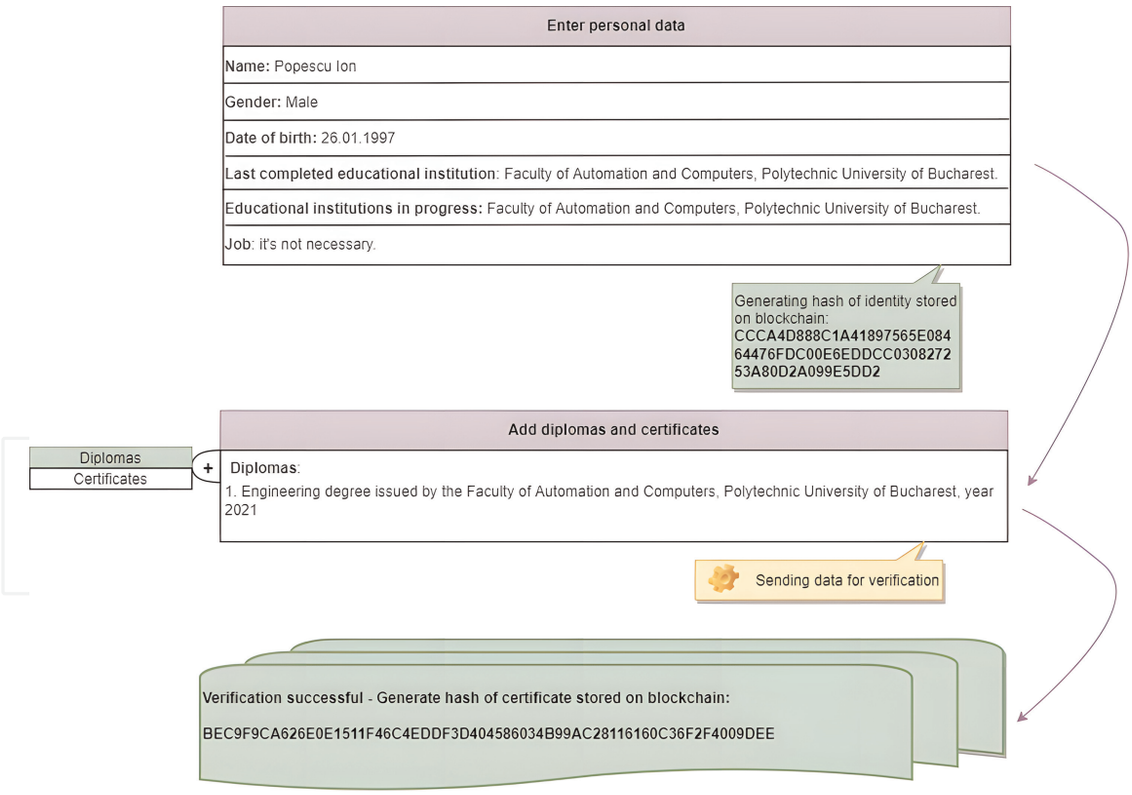

Figure 10.
Simulation of a case study.

- increased efficiency due to the simplicity of verifying the correctness of data and diplomas/certificates (reduced verification time),
- information confidentiality (due to hash generation),

- increasing confidence (the entered data cannot be falsified),
- protecting student data (by ensuring security with Blockchain technology).

In addition to the previously mentioned, students can use this data stored on Blockchain at the time of employment, increasing in this sense the trust in front of the employer.

7. Conclusions

The Blockchain is a distributed database or public ledger that stores a list of all digital events or transactions that have occurred and is fundamentally shared among all participants. Blockchain technology is perfect for securing, sharing, and verifying learning achievements as a new infrastructure. In the case of certificates, a Blockchain can maintain a list of the certificate's issuer and receiver, as well as the document signature (hash), in a public database (the Blockchain) that is replicated on thousands of computers all over the world.

Regarding the case study presented, it can be seen that all five hypotheses are validated. Thus, it can be said that the first link is between the use of Blockchain technologies in the education sector and the need for Blockchain knowledge in different professions. A second link is between the issues to be considered before including Blockchain technologies in the education sector and the use of Blockchain technologies. The third link is the knowledge of Blockchain technologies in different professions and the benefits of adopting Blockchain technologies. The fourth link is between the issues to be considered before including Blockchain technologies in the education sector and the benefits of adopting Blockchain technologies, but also a link between these issues and the challenges of adopting Blockchain technologies in the fifth hypothesis. Thus, the different subpoints that constitute the elements of the hypothesis are influenced by the existence of different reasonable correlations, but also weaker correlations.

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