The Potential Use of Blockchain Technology in Institutions of Higher Learning

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Abstract: Blockchain technology has great potential for widespread application in education. Although the scope of work on the use of Blockchain in higher education institutions has increased in recent years, it is still a few, and lack methodical review has been carried out on this issue. Therefore, the present study concentrated on the potential use of Blockchain technology in institutions of higher learning. This study also discusses the benefits of Blockchain technology by exploring some of Blockchain's accessible applications for educational purposes. Also, this research used the quantitative method and surveyed academics. The surveys were completed by academics who understood Blockchain well. The investigation of the survey is accessible based on a valid response from 125 academics. A specified investigation of the results of every topic became conducted. This assessment also offers insights into other areas of learning that can gain from Blockchain technology.

Keywords: Blockchain Technology, Blockchain Applications, higher education institutions

1 INTRODUCTION

The Blockchain consists of a sequential series of blocks, which store sets of transaction record packages affixed to the Blockchain. Each block is linked to the prior blocks via a cryptographic link that is exclusive to each block and is provided in the chain over time (Gartner, 2019; Gupta, 2018; García-Bañuelos et al., 2017), where and design is provided in figure 1. Anyone with access rights can trace any previous transaction and the parties involved. This leads to a high level of confidence that all transactions can be linked to its source (Gupta, 2018). The type of information included in each block depends on the use of Blockchain, as well as its purpose.
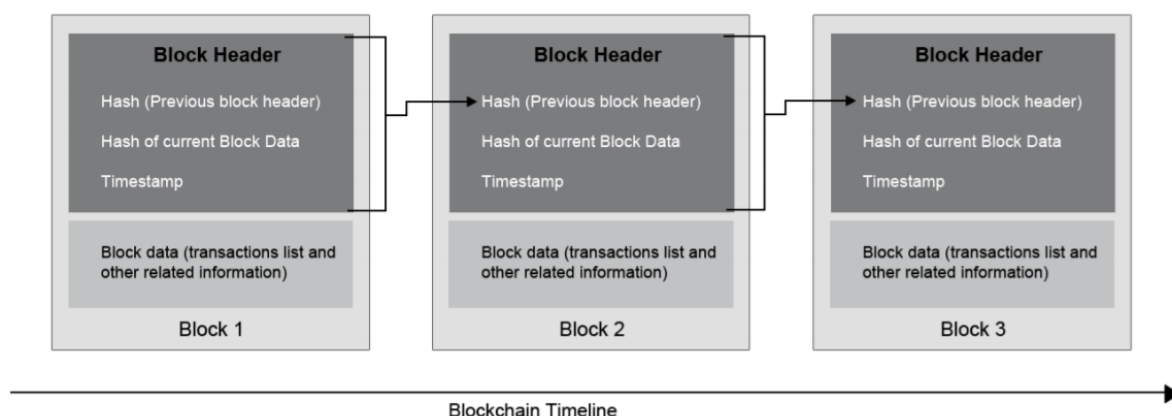

Figure 1: Series of Blockchain

Blockchain technology works with distributed and decentralized ledger technology combined with cryptography to record and store transaction data in a verified, immutable, and inviolable way in blocks that are joined together to form a Blockchain (Harsha et al., 2018; Turkanović et al., 2018; Yaga et al., 2018). Yaga et al. (2018) defined Blockchain as "tamper-evident and tamper-resistant digital ledgers implemented in a distributed fashion", where "at their basic level, they enable a community of users to record transactions in a shared ledger within that community". Blockchain allows users to keep a copy of their information. In the event of an update, all members must be checked and charged. This information can mean transactions, agreements, resources, identities or practically anything that can be defined digitally. Registration is permanent, transparent and searchable, allowing individuals of the community to see the transaction history (Dhillon et al., 2017). Any update is considered as a new "block" added to at the end of the "chain" (Jabbari & Kaminsky, 2018). Blockchain's features and functionality have been unique in many areas, including transparency and reliability. As a result, many blockchain

applications have been implemented in a variety of areas, including education (Memon et al., 2018). Figure 2 represents . the total Blockchain transaction.
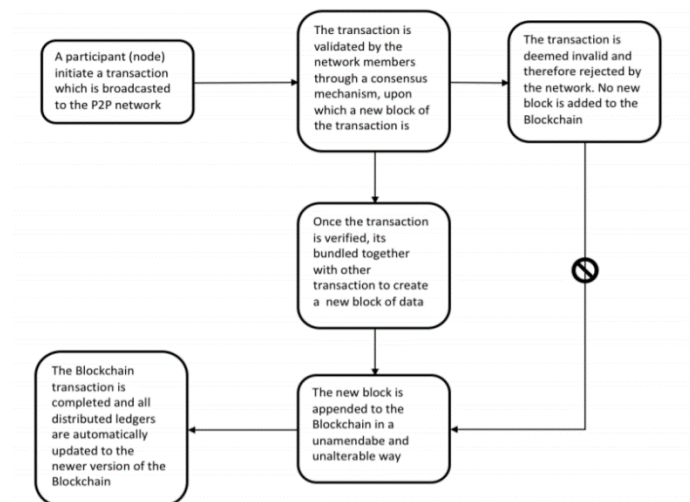

Figure 2: Representation the total Blockchain transaction

According to Gatteschi et al. (2018), Blockchain-based application growth can be divided into three major phases: The Blockchain "1", "2" and "3". The "1" Blockchain was used for copticcurrency and was intended to simplify the simple cash transactions. Then the "2" Blockchain was offered for smart features and contracts. These smart agreements set specific requirements and standards that must be met before being secured in Blockchain. Registrations are made without a third party. Blockchain "3" applications have been established in many areas, such as science, health, and education. The application of Blockchain technology to education is still in the early stages. Nowadays, some educational institutions have started to use blockchain technology. Most of these institutions use it to confirm and exchange academic certificates and/or student learning results (Chen et al., 2018; Alammary et al., 2019). The Blockchain technology reduces the risks of exploitation, it makes it possible to process very sensitive information such as the land register, the polls, the certificates of education, etc. (Svein & Arild, 2017). Nevertheless, field researchers trust that Blockchain technology can offer a lot more and can develop the arena. Based on Nespor (2018), Blockchain can challenge the central role of educational institutions as credential agents and deliver more learning opportunities for students.

The global education industry has undergone a significant transformation over the past decade. The transition from the use of paper and learning materials to online learning modules and digitization has had an impact. In recent years, the global education industry has turned to the Internet rather than offline resources (Jain, 2019). With population growth, there is enormous stress on the education system to produce quality education at reasonable value and advance levels of knowledge. One of the most important features of the Internet is to allow people to share copies of files, documents, and information, not the original. Blockchain can be used to store any kind of files, documents, and information that is important to people throughout life. Blockchain technology can be used to record academic progress in the course (Tapscott & Tapscott, 2016). Linda et al. (2019) reported out that Blockchain technologies have a huge chance to support the suppliers of higher education:

- Reduce costs and reduce deception by dodging manual check transcripts and other documents.
- Promote innovation by providing a platform for collaboration and other opportunities between companies and educational institutions.
- Increase efficiency through "smart contracts" that are automatically executed when certain conditions are met.

Alexander and Anthony (2017) showed that Blockchain technology proposed large multipliers that exceed the probabilities presently offered (see Figure 3). In particular, transferring records in a Blockchain may provide:

- Self-monitoring: Users can classify themselves even if their private data storage and management can be controlled.

- Trust: Workers can rely on infrastructure that provides secure transactions, for example, payment or delivering diplomas.

- Transparency: Workers can make important transactions that each party has the opportunity to complete.

- Survival: Workers can be sure that the record will be permanently collected without the possibility of change or damage.

- Disintermediation: The central control specialist is not required to perform the transaction or maintain the record.

- Collaboration: The capability of the parties to communicate directly with each other without the mediator.
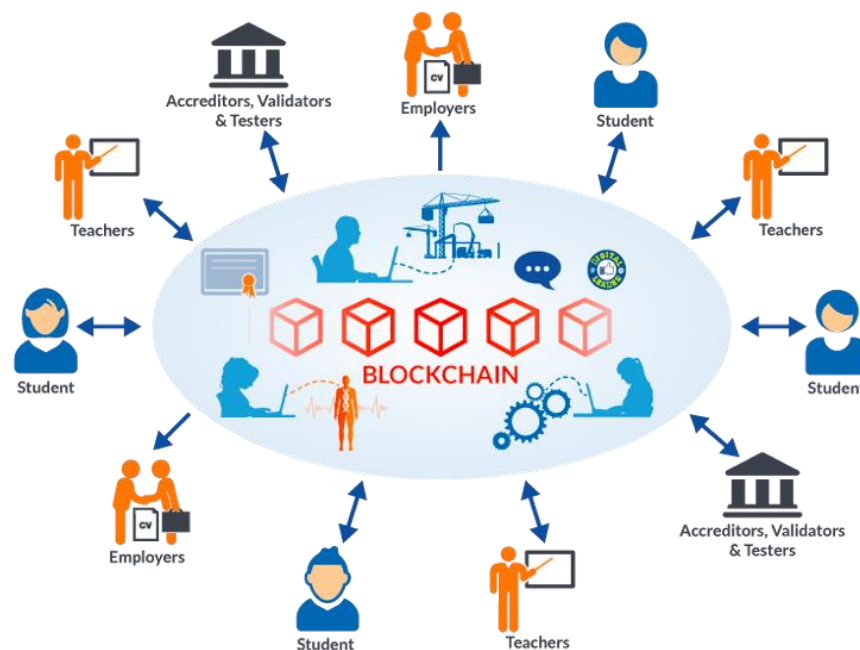

Figure 3: Blockchain is going to make communication in the field of education simpler

Gartner 2019 CIO Survey (2019) showed that 2% of respondents in higher education used Blockchain technology. 18% of respondents planned to implement it over the next 24 months. However, almost half of the respondents (47%) mentioned a lack of interest. Gartner (2019) has identified four ways to apply Blockchain in the higher education sector: improve record-keeping, increase efficiency in existing business processes, create a new market for digital assets, create a disruptive business model, and evaluate projects carefully. Blockchain technology could be used by higher education institutions and community organizations for enhancing learning opportunities; providing an open infrastructure for generating, issuing, analyzing and authenticating certificates, verifying e-portfolios, securing and sharing student records, accessing distributed network applications and data portability, using automatic execution as soon as possible a set of conditions is met, reducing paper processes, helping libraries extend their services by creating improved archiving of metadata, promoting additional digital rights management, and helping to update the community support system for families and students (Tom, 2018). Blockchain can implement lifelong learning, eliminate fake, adopt worker skills and implement standards and requirements (Pamela, 2019). Business Sight Media (2018) reported that the acceptance of Blockchain technology in higher education field have the following benefits:

- Ease of Sharing - With the help of Blockchain technology, students can easily share degrees and certificates related to employers. Both parties who wish to access these documents can view them on platforms that support the Blockchain, but the right to allow someone with access to information remains in the hands of their owners.

- Cost reduction - For transcription wanted by university students, several costs are required. However, with Blockchain technology, these costs are excluded, since the information is easily accessible to everyone

- Eliminates the use of paper - Blockchain can store all data, such as certificates, records of credit transfers, other records related to students throughout life, without resorting to a manual process of documenting on paper.

- Consistency - The Blockchain confirms that the information exchanged is the same for everyone. The information provided cannot be changed by anyone who views or accesses the data.

- Without intermediaries - Using Blockchain, data is stored securely, confirming that intermediaries are not required.

Although the scope of work on the use of Blockchain in higher education has increased in recent years, it is still a few, and no methodical review has been carried out on this issue. Therefore, this research promotes the literature of educational technologies that analyze how to use Blockchain technology in education. The target group of this research is leaders, academic administrators, academics and researchers involved in providing and applying information about this new technology and how it can be used and have a deep impact on education.

2 BLOCKCHAIN TECHNOLOGY APPLICATIONS IN HIGHER EDUCATION INSTITUTIONS

At present, several universities use Blockchain technology in the field of education, and most of them use it to facilitate the administration of academic permissions and a short-term evaluation of learning outcomes (Sharples & Domingue, 2016; Skiba, 2017). Academics, instructors, and designers have considered various roles for blockchains technology in education and training.

Certificates management: Diplomas and transcripts contain confidential information for individuals and should not be easily accessible to others (Jirgensons & Kapenieks, 2018). Therefore, a mechanism to ensure that the information contained in such a document is original is highly necessary, which means that the document is from an authorized source and is not fictitious. Furthermore, the information contained in the document must be confidential so that it can only be viewed by authorized persons. Blockchain technology is used to reduce the number of certificate counterfeits and to improve the security, validity, and confidentiality of graduation certificates (Han, et al., 2018; Nespor, 2018; Pramod et al., 2019; Neethu & Prakash, 2018; Jirgensons & Kapenieks, 2018). Likewise, Han et al. (2018) Blockchain technology is used to provide new blockchain-based educational registers to check and deliver authorized licensed grades. Users can access their data records, and only assigned organizations can enter and accept data stored in the system under specific limited terms and rules. Pramod et al. (2019) have proposed that a student management system uses a decentralized and distributed network in which student data is stored in blocks. These blocks are connected to each other to form a chain of records. Figure 4 below is a brief overview of a simple process to issue and verify a certificate on Blockchain.
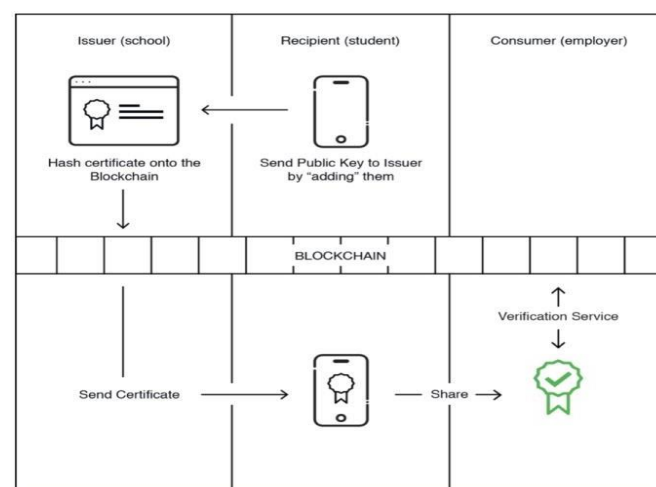

Figure 4: Process to verify and issue official transcripts or certificates on the Blockchain

Management of skills and learning outcomes: More attention has been given to creating Blockchain applications to enhance learning purposes and improve skills acquisition in higher education institutions (Farah et al., 2018). Farah et al. (2018) have put in place a system to track student performance for their multiple learning activities. It is added autonomously with all the suggestions for each action given in the block. So, this training unit can be considered as self-descriptive because it includes all the metadata related to many actions. Using this kind of application leads to a high level of effectiveness. Williams (2019) offered an educational environment for students. The system delivers fast/direct assistance and clear response. The aim was to develop the learning process through the use of diverse skills, encourage critical thinking and solve problems through better cooperation and communication. Liu et al. (2018) used Blockchain technology to connect higher education institutions and employment firms to share all relevant information on recruitment and industry needs. Finally, Ocheja et al. (2018) suggested a Blockchain method to link learning data across multiple platforms, institutions, and educational institutions.

Evaluating students' professional abilities: Assessing students' professional abilities is an important element that connects student professionalism with specific industries for a set of recommendations. Liu et al. (2018) use Blockchain technology to connect higher education institutions with service companies to exchange information needed on recruitment and industry needs. Also, Zhao et al. (2018) have developed an application using Blockchain to evaluate students' professional skills based on their learning outcomes. These skills can be transferred to the relevant industries.

The transfer of fees and credits: The Blockchain can be used effectively to share information and exclude the need for such third parties or intermediaries thanks to a high level of security. Hölbl et al. (2018) have developed a system for the token transfer process. These markers may correspond to any digital form for the learning units, such as diplomas of courses and degrees. Sony Global Education (2017) has developed a Blockchain system for tracking academic results and activity records with the ability to integrate several educational institutions for the safe exchange of results, educational archives and digital records.

Examination review: Higher education institutions have used Blockchain technology to manage student exams, verify answers, maintain integrity, security, and consistency of records (Hoy, 2017; Turkanović et al., 2018). Shen and Xiao (2018) presented a system that uses blockchain technology and Internet resources in an online quiz system to verify student responses. By implementing an authorized Blockchain technique, the safety of the examination work can be considerably enhanced by the use of trusted big ledgers (Alammary. 2019). Mitchell et al. (2019) developed a decentralized system for a review exam. This system was designed with quality assurance standards. Based on their findings, the system has been helpful in managing quality assurance systems. Acharya and Binu (2018) suggested a Blockchain framework to pilot and evaluate peer-reviewed academic tests by automatically creating the certificate after the test is complete.

Storing student's records: Most higher education institutions store student records in special formats (Carmen, 2018). These databases are organized to provide private access to enterprise staff and customized systems on the Internet, without any interoperability. In addition, most higher education institutions have their own system for archiving student records and courses taken by students, as well as keeping them in the institution's database (Kunal, 2017; Tapscott & Kaplan, 2019). Furthermore, most institutions have their own specialized system for storing student records of courses, which maintains its own database data structure. Alternatively, Blockchain archives are kept forever, so that papers such as diplomas and course certificates can be protected and confirmed if the user has access to an institution's record storage system (see Figure 1). Using Blockchain technology, students can share a web link with their credentials with upcoming businesses, allowing them to check them without communicating with the university (Hallie, 2018; Konstantinidis et al., 2018). Identity verification requires a lot of manual intervention and offers many possibilities for falsification of data. In the digital process, the identity of the student is only confirmed once (Alexander & Anthony, 2017; Andrew, 2018). Instead of storing student IDs, the Blockchain stores information about the document. Using Blockchain, students and candidates can identify themselves online (Alammary et al., 2019).

Intellectual property protection: Most Professors in higher education institutions publish research as one of their academic duties. In a traditional system, it is hard to distinguish whether alike academic studies are being carried out when professors begin their research. Furthermore, there are many gaps in the research itself. Blockchain helps solve this problem (Jain, 2019). The Blockchain can give professors the ability to publish the content publicly while tracking their reuse without restrictions on content (see Figure 2). Such a system would

allow professors to be valued in the actual use and reuse of their content, as well as their remuneration, based on the number of maturity in their research report (Chen et al., 2018).

Storing a verified e-portfolio: Zimmerman (2012) described the e-portfolio as a group of digital proofs collected and controlled by a user. This digital proof may include typed textual content, digital files, pix, media files, blog entries, and hyperlinks. E-portfolios are both an illustration of the user's capabilities and private speech platforms. If they are online, users can keep them dynamically over the years. Blockchain technology can be used to launch a verified electronic portfolio (e-portfolio). Students can manage the property they have created, and provide access to specific universities to this e-portfolio through the university application process (Alexander & Anthony, 2017; Jirgensons & Kapenieks, 2018; Ravet, 2016).

3 RESEARCH METHODOLOGY

Primary and secondary data had been gathered for this study. Primary data was amassed by way of distributing questionnaires to academics from completely exceptional Arab international locations. The designation of these academics is different: lecturer, assistant professor, associate professor, and professor. A complete of a hundred and fifty questionnaires have been dispensed. An overview of the literature was applied to explore educational applications that have been developed with Blockchain technology, the benefits that Blockchain technology could awaken for education. A literature review is used to gather as many ideas and know-how as possible through the review of peer-reviewed journal articles, documents found in conference proceedings, as well as books, documents, and relevant journals. An online survey approach using Google Forms was used to capture survey responses, making data collection easier. This approach has been chosen because it generally generates a higher response rate and the time required to obtain the required data is faster because they are available online in real-time. Potential participants in the survey were contacted by e-mail and received the URL to access the online questionnaire. A total of 150 questionnaires were distributed. Sampling was based on convenience and 125 participants responded with a response rate of 83.3%. The analysis of the results of the survey is presented based on a valid response from 125 academics.

Data collection for this study was conducted in June 2020. The survey was used as the main data collection tool in this study. A survey was prepared, divided into three parts: The first part had no questions that could establish a personality. The demographic variables and factors used in this study include gender, status, age, purpose, and years of professional experience. Second part includes questions designed to explore educational applications that have been developed using Blockchain technology. Respondents were provided with a list of eight applications of Blockchain technology in IHL, these applications are the most common in IHL. The researcher had collected these activates from a review of the literature. Third part contains questions about the benefits that Blockchain technology can bring to education. Respondents were asked to indicate the important benefits that helped in the development of Blockchain technology applications in IHL. There were nine in total. All questions in this questionnaire used a five-point Likert-type scale. For sections 2,3,4 and 3, the scale was (NI = not important, QI = very important, I = important, VI = very important and MI = most important).

4 DATA ANALYSIS AND RESULTS

Respondent's Profile and Background Information: According to the demographic data and other personal information, 84% of the 125 respondents were males. Most of the respondents (71%) were o between 30-40 years old. The largest designation group was an assistant professor (52%). 44.8 of respondents felt that Blockchain offers one or more significant benefits, while 26% of respondents felt that Blockchain could be 'useful' or 'quite useful'. Figure 5 shows the respondent's profile and background information.

Educational applications of Blockchain technology in HLE: Even though an expanding number of Blockchain-based applications have been created for educational purposes, as it were many of them were propelled to the public. These applications, which have been examined within the past segment, can be classified into 8 fundamental classes. Table 1 and figure 6 show the educational applications of Blockchain technology in HLE ranked in ascending order of the mean value.

The applications had been ranked in ascending order of the mean value. It can be seen that the first class (M =

4.87) aimed at certain purposes related to certificate management. This class covers the processing of all types of diplomas, transcripts, and student certificates. In the field of education, many purposes use Blockchain to issue digital certificates. Most applications of these certificates have benefited from the high degree of trust and confidentiality provided by Blockchain technology. The second class (M = 4.83) is related to the transfer of fees and credits. It consists of some applications with similar functionality for the transfer of credential or fee records between institutions, organizations or even universities, due to Blockchain's high security and trust.
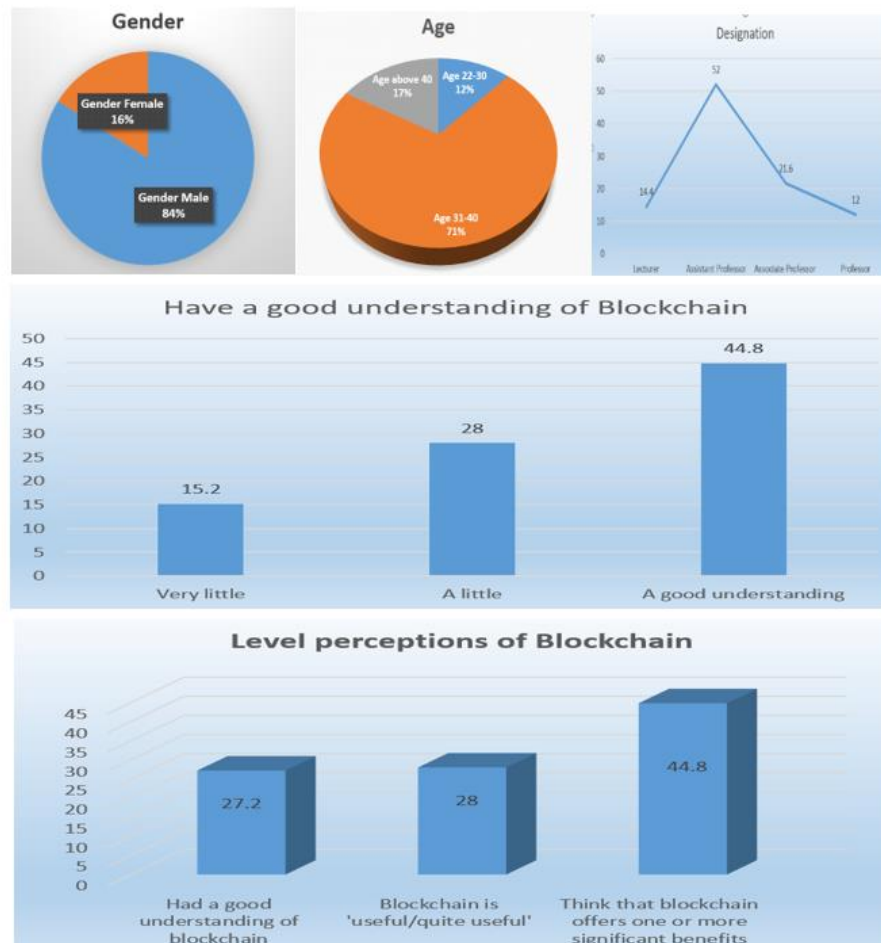

Figure 5: Respondent's profile and background information.

The third class (M = 4.65) was focused on the management of skills and learning outcomes. Greater attention has been given to build some Blockchain applications to improve learning goals and improve skills learned in education. The fourth class (M = 4.56) was centered on examination review. By applying an authorized Blockchain technique, the security of the audit of examination papers can be significantly improved by the use of ledgers. The fifth class (M = 4.34) focused on evaluating students' professional abilities. Blockchain's technological know-how should be a crossroads between academic institutions and employment companies to share all the basic information about recruitment and industry requirements. The sixth class (M = 3.78) focused on storing student's records. Using Blockchain technology, students can share a web link with their credentials with upcoming businesses, allowing them to check them without communicating with the university.

The seventh class (M = 3.32) focused on storing a verified e-portfolio. Blockchain technology can be used to launch a verified e-portfolio. Students can manage the property they have created, and provide access to specific universities to this e-portfolio through the university application process. The eighth class (M = 3.45) focused on intellectual property protection. The Blockchain can give professors the ability to publish the content publicly while tracking their reuse without restrictions on content

Table 1. Educational applications of Blockchain technology in HLE (Ranked by mean value)

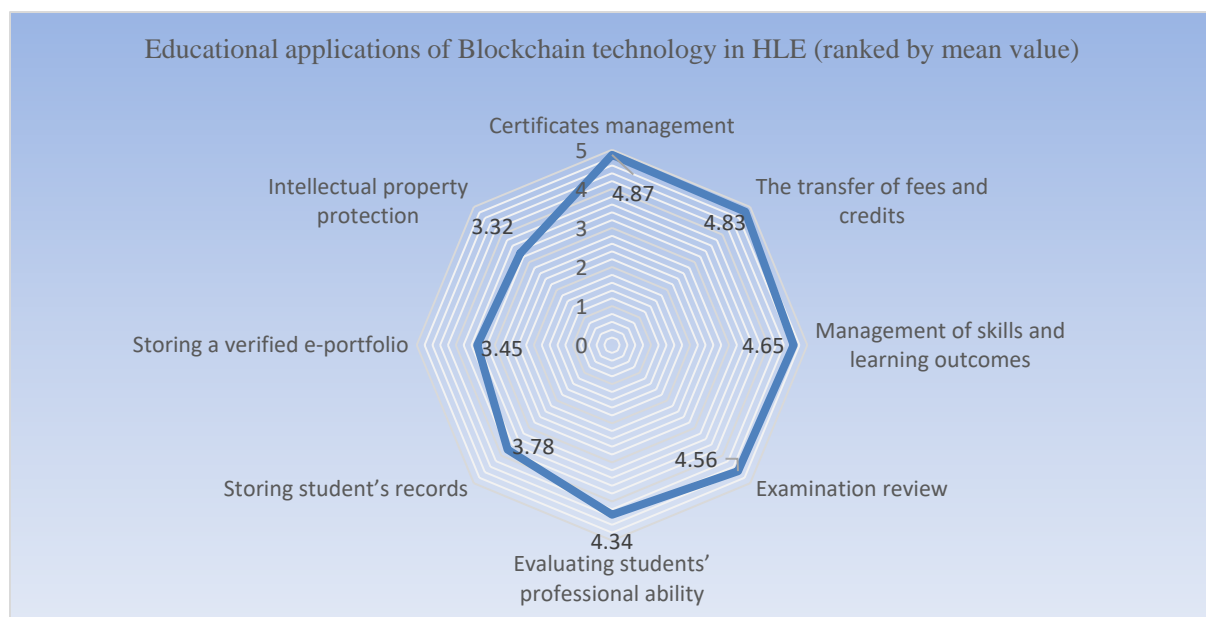| Blockchain Technology Applications	Mean
Certificates management	4.87
The transfer of fees and credits	4.83
Management of skills and learning outcomes	4.65
Examination review	4.56
Evaluating students' professional ability	4.34
Storing student's records	3.78
Storing a verified e-portfolio	3.45
Intellectual property protection	3.32

Figure 6: Benefits of adopting educational applications of Blockchain technology in HLE

Blockchain technology is expected to bring huge benefits to education, including security, managing manage on how students' records are accessed and by way of whom, improving accountability and transparency, building trust between all protected parties and simplifying the release between them, reducing the unnecessary costs of data transactions and storage, authenticating students' identities and digital certificates, helping academics publish their research on a flatbed an open platform, avoid the possibility of losing paper records, and launch a verified electronic portfolio. Table 2 and figure 7 show the benefits of adopting educational applications of Blockchain technology in HLE, which are ranked as mean values.

It can be seen that the first benefit of adopting educational applications of Blockchain technology in HLE was security and safety (M = 4.43). The use of Blockchain guarantees the security and confidentiality of the data/transactions exchanged between the parties concerned. The nature of the peer-to-peer topology in the Blockchain helps to reduce security risks in education. The second benefit was reducing the unnecessary costs of data transactions and storage (M = 4.21). The cost includes storage costs, related operation costs, and management and maintenance costs for educational records. Using Blockchain technology, accessible from anywhere, dramatically reduces the cost of standard cloud storage. The third benefit was assisting academics publish their research on an open platform (M = 4.11). The decentralized nature of the Blockchain paves the way for the creation of a data store in which the research activities of the entire research system can be stored collectively. Such a decentralized data store would mean that when a researcher, for example, downloads data, performs applied mathematical analysis, writes and submits an article or reviews a manuscript,

searches and recordings are systematically performed, making much more coherent research. The risk of fraud would even be reduced. The fourth benefit was keeping away from the possibility of losing paper records (M = 3.87). Blockchain technology incorporates components that ensure that storage records are accurate, visible, and come from an irrefutable source. Storing all educational records in a single location, where they are actually available, will expand the accountability and transparency of the use of these records. The fifth benefit was authenticating students' identities and digital certificates (M = 3.75). Blockchain technology is terribly helpful for authenticating student identity.

The sixth benefit was building trust between all protected parties and simplifying the release between them (M = 3.65). Trust is another benefit of utilizing Blockchain innovation. Just believed individuals can take an interest in adding blocks to the system and just believed gatherings can get to them. The trust might be a key problem when dealing with different authorities in multiple regions. HLIs can build a community of trust by putting in place reliable and secure systems based on the Blockchain. The seventh benefit was to launch a verified e-portfolio (M = 3.45). Students can manage the property they have created, and provide access to specific universities to this e-portfolio through the university application process. The eight benefit was managing on how students' records are accessed and by way of whom (M = 3.13). The use of Blockchain in HLEs can probably reduce the threat of transaction errors among supposed individuals. The ninth benefit was improving accountability and transparency (M = 3.05). Improving accountability and transparency are two of the benefits of blockchain technology. Keeping all educational information in one area can increase the accountability and transparency of the use of such information.

Table 2. Benefits of adopting educational applications of Blockchain technology in HLE (ranked by mean value)

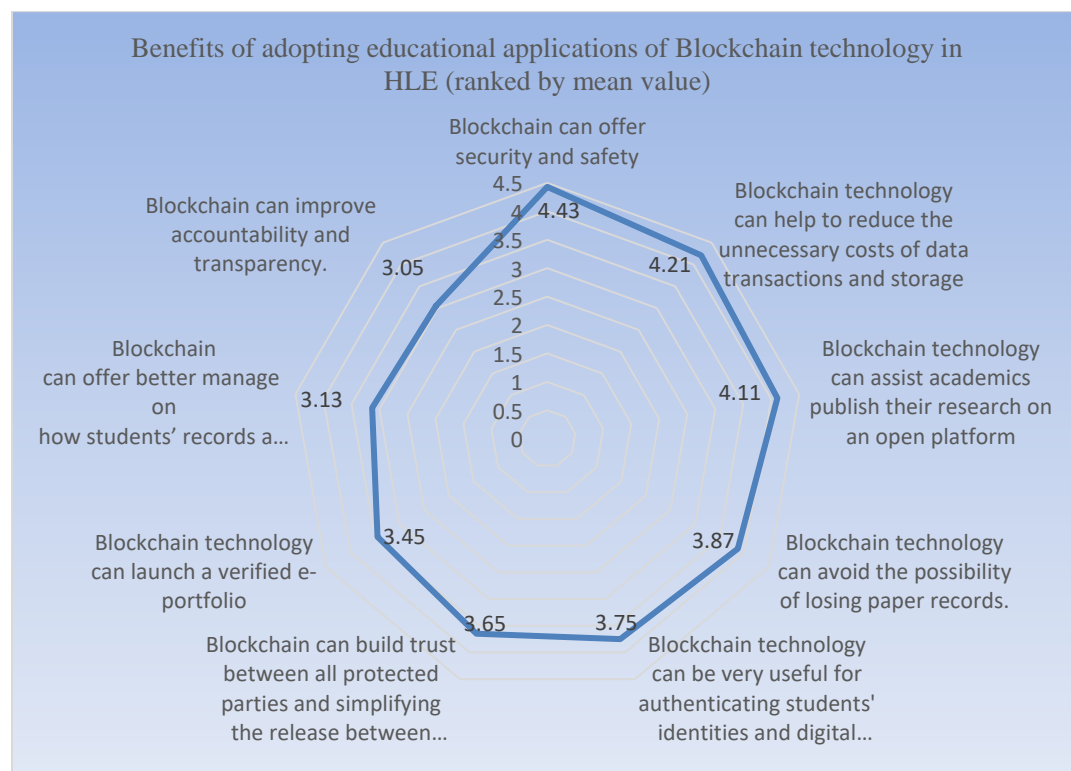| Blockchain Technology Benefits	Mean
Blockchain can offer security and safety	4.43
Blockchain technology can help to reduce the unnecessary costs of data transactions and storage	4.21
Blockchain technology can assist academics publish their research on an open platform	4.11
Blockchain technology can avoid the possibility of losing paper records.	3.87
Blockchain technology can be very useful for authenticating students' identities and digital certificates	3.75
Blockchain can build trust between all protected parties and simplifying the release between them	3.65
Blockchain technology can launch a verified e-portfolio	3.45
Blockchain can offer better manage on how students' records are accessed and by way of whom	3.13
Blockchain can improve accountability and transparency	3.05

Figure 7: Benefits of adopting educational applications of Blockchain technology in HLE (ranked by mean value)

5 CONCLUSIONS

Blockchain technology can enhance the educational system in some ways. This technology is perfect for secure storage, sharing, and networking of knowledge. With the assistance of this advanced system, several procedures will have made faster, simpler and more secure. It fills in the gaps in accreditation, copyright protection, and effective communication. The application of Blockchain technology in the field of education is in its infancy. As a result, the latest research on blockchain technology in the field of education has been examined. According to the authors' knowledge, this is the lack of investigation on this subject. This gives some results. To begin with, it has been shown that Blockchain technology is commonly used for: certificate management, expense and credit exchange, learning outcomes management, and evaluation in general. However, a wide range of different applications is developing rapidly. Secondly, it shows that blockchain could have major benefits for education, including offering security and safety, helping to reduce the unnecessary costs of data transactions and storage, assisting academics to publish their research on an open platform, and avoid the possibility of losing paper records. As a final point, this indicates that the educational domains in which blockchain technology is implemented are still limited. As a result, the potential of blockchain technology is still available

References

Acharya, R., & Binu, S. (2018). Blockchain based examination system for effective evaluation and maintenance of examination records. *International Journal Of Engineering and Technology*, 269-274.

Alammary, A., Alhazmi, S., Almasri, M., & Gillani, S. (2019). Blockchain-Based Applications in Education: A Systematic Review. *Applied Sciences, 9*(12), 1-18.

Alexander, G., & Anthony, F. C. (2017). *Blockchain in Education.* Seville, Spain: JRC Science Hub.

Andrew, Y., (2018). *CASE STUDY:Creating Immutable, Stackable Credentials Through Blockchain at MIT.* GOVLAB. Retrieved from https://blockchan.ge/blockchange-credentials.pdf

Business Sight Media. (2018, July 9). *Blockchain in Education; Adoption of Technology in Education.* Retrieved Nov 15, 2019, from businesssightmedia: https://businesssightmedia.com/2018/07/blockchain-in-education-adoption-of-technology-in-education/

Carmen, H. (2018). Understanding Blockchain Technology and How to Get Involved. In .. I. 14th (Ed.), *14th International Scientific Conference eLearning and Software for Education*, (pp. 1-9). Bucharest.

Chen, G., Xu, B., Lu, M., & Chen, N.-S. (2018). Exploring blockchain technology and its potential applications for education. *Smart Learning Environments, 5*(1), 1-10.

Dhillon, V., Metcalf, D., & Hooper, M. (2017). *Blockchain Enabled Applications: Understand the Blockchain Ecosystem and How to Make It Work for You.* New NewYork: Apress L. P Secaucus.

Farah, J., Vozniuk, A., Rodríguez-Triana, M., & Gillet, D. A. (2018). A Blueprint for a Blockchain-Based Architecture to Power a Distributed Network of Tamper-Evident Learning Trace Repositories. *IEEE 18th International Conference on Advanced Learning Technologies (ICALT)* (pp. 218–222). Mumbai, India: IEEE .

García-Bañuelos, L., Ponomarev, A., Dumas, M., & Weber, I. (2017). Optimized execution of businessprocesses on blockchain. *Springer, Cham*, 130–146.

Gartner 2019 CIO Survey. (2019). *CIO Agenda 2019: Exploit Transformational Technologies.* Gartner. Retrieved July 1, 2019, from https://www.gartner.com/smarterwithgartner/cio-agenda-2019-exploit-transformational-technologies/

Gartner. (2019). *IT Glossary: Blockchain.* Retrieved from https://www.gartner.com/itglossary/

Gatteschi, V., Lamberti, F., Demartini, C., Pranteda, C., & Santamaría, V. (2018). Blockchain and smart contracts for insurance: Is the technology mature enough? *Future Internet, 10*(20).

Gupta, M. (2018). *Blockchain for dummies.* John Wiley & Sons.

Hallie, B. (2018, Nov 13). More colleges are using the blockchain for student records. Retrieved April 20, 2019, from https://www.educationdive.com/news/more-colleges-are-using-the-blockchain-for-student-records/542093/

Han, M., Li, Z., He, J., Wu, D., Xie, Y., & Baba, A. (2018). A Novel Blockchain-based Education Records Verification Solution. *19th Annual SIG Conference on Information Technology Education*, (pp. 178–183). FL, USA.

Harsha, V., Kanchan, G. R., & Malati, V. (2018). A Study on Decentralized E-Voting System Using Blockchain Technology. *International Research Journal of Engineering and Technology (IRJET), 5*(11), 48-53.

Hölbl, M., Kamisali´c, A., Turkanovi´c, M., Kompara, M., Podgorelec, B., & Heri´cko, M. E. (2018). An Ecosystem for Managing Digital Micro-Credentials. In EAEEIE (Ed.), *2018 28th EAEEIE Annual Conference*, (pp. 1–9). Hafnarfjordur, Iceland.

Hoy, M. B. (2017). An introduction to the Blockchain and its implications for libra-ries and medicine. *Medical Reference Services Quarterly, 36*(3), 273–279.

Jabbari, A., & Kaminsky, P. (2018). *Blockchain and supply chain management.* CICMHE.

Jain, A. K. (2019). *Blockchain Goes to School.* Cognizant's Education Practice. Retrieved from https://www.cognizant.com/whitepapers/blockchain-goes-to-school-codex3775.pdf

Jirgensons, M., & Kapenieks, J. (2018). Blockchain and the Future of Digital Learning Credential Assessment and Management. *Journal of Teacher Education for Sustainability, 2*(1), 145-156.

Konstantinidis, L., G. S., & C. T. (2018). BC for Business Applications_ A Systematic Literature Review. *Springer International Publishing AG, part of Springer Nature*, 384-399.

Kukko, M. (2013). Knowledge sharing barriers in organic growth: a case study from a softwarecompany. *The Journal of High Technology Management Research, 24*(1), 18-29.

Kunal, S. (2017). A Revolutionary Approach to Academic Validation Using Ethereum. Retrieved Jan 10, 2019, from https://hackernoon.com/a-revolutionary-approach-to-academic-validation-using-ethereum-99a8818fc7cf

Linda, P., Rob, M., & Jonathan, H. (2019). *Deloitte's 2019 Global Blockchain Survey. Blockchain gets down to business.* Deloitte. Retrieved from https://www2.deloitte.com/content/dam/Deloitte/se/Documents/risk/DI_2019-global-blockchain-survey.pdf

Liu, Q., Guan, Q., Yang, X., Zhu, H., Green, G., & Yin, S. (2018). Education-Industry Cooperative System Based on Blockchain. *2018 1st IEEE International Conference on Hot Information-Centric Networking (HotICN)*, (pp. 207–211). Shenzhen, China.

Memon, M., Bajwa, U., Ikhlas, A., Memon, Y., Memon, S., & Malani, M. (2018). Blockchain Beyond Bitcoin: Block Maturity LevelConsensus Protocol. *2018 IEEE 5th InternationalConference on Engineering Technologies and Applied Sciences (ICETAS)*, (pp. 1–5). Bangkok, Thailand.

Mitchell, I., Hara, S., & Sheriff, M. (2019). Decentralised Application for Examination Review. *IEEE 12th International Conference on Global Security, Safety and Sustainability (ICGS3)*, (pp. 1–14). London.

NEC. (2019). *Blockchain for Digital Identity*. Retrieved from NEC: https://www.nec.com/en/global/solutions/blockchain/blockchain-for-digital-identity.html

Neethu, G., & Prakash, V. (2018). Survey on Blockchain Based Digital Certificate System. *International Research Journal of Engineering and Technology (IRJET), 5*(11), 1244-1248.

Nespor, J. (2018). Cyber schooling and the accumulation of school time. *Pedagogy, Culture & Society*, 325-341.

Ocheja, P., Flanagan, B., & Ogata, H. (2018). Connecting Decentralized Learning Records: A Blockchain Based Learning Analytics Platform. In ACM (Ed.). (pp. 265-269). USA: ACM.

Pamela, Y. K. (2019). Blockchain in Education Lifelong Learning. Retrieved from https://vottun.com/2019/02/28/blockchain-lifelong-learning-projects-3/

Pramod, K., K. Kiran, k., Sai Krishna, R., & Aruna Sri, P. (2019). Incorporation of Blockchain in Student Management System. *International Journal of Innovative Technology and Exploring Engineering (IJITEE), 8*(6), 664-668.

Ravet, S. (2016). *Reinventing ePortfolio technology and Practice.* Europortfolio project. Retrieved from http://www.eportfolio.eu/sites/default/files/ePortfolioWhitePaper.pdf

Svein, Ø. & Arild, J. (2017). Blockchain Technology as s Support Infrastructure in e-Government. *International Conference on Electronic Government.* St. Petersburg, Russia.

Sharples, M., & Domingue, J. (2016). The blockchain and kudos: A distributed system for educational record, reputation and reward. *European Conference on Technology Enhanced Learning*, (pp. 490–496). doi:https://doi.org/10.1007/978-3-319-45153-4_48

Shen, H., & Xiao, Y. (2018). Research on online scheme based on double-layer con-sortium blockchain. In IEEE (Ed.), *9th International Conference on Information Technology in Medicine and Education* (pp. 956-969). IEEE.

Skiba, D. (2017). The potential of Blockchain in education and health care. *Nurs. Educ. Perspect., 38*(4), 220–221.

Sony Global Education. (2017). Sony develops system for authentication, sharing, and rights management using blockchain technology. Retrieved Jan 10, 2019, from https://www.sonyged.com/2017/08/10/news/press-blockchain/

Tapscott, D., & Kaplan, A. (2019). *Blockchain revolution in education and lifelong learning.* Blockchain Research Institute. Retrieved from https://www.ibm.com/downloads/cas/93DDVAKE

Tapscott, D., & Tapscott, A. (2016). *Blockchain revolution: how the technology behind bitcoin is changing money, business, and the world.* New York: Portfolio / Penguin.

Tom, V. A. (2018). 20 Ways Blockchain Will Transform (OK, May Improve) Education. Retrieved Novernber 09, 2019, from https://www.gettingsmart.com/2018/08/20-ways-blockchain-will-transform-ok-may-improve-education/

Turkanović, M., M. Hölbl, K., Košič, Heričko, M., & A. Kamišalić. (2018). EduCTX: A Blockchain-Based Higher

Education Credit Platform. *IEEE*.

Williams, P. (2019). Does competency-based education with blockchain signal a new mission for universities? . *Journal of Higher Education Policy and Management, 41*(1), 104-117.

Yaga, D., Mell, P., Roby, N., & Karen, S. (2018). *Blockchain technology overview.* Bureau: National Institute of Standards and Technology . Retrieved from https://nvlpubs.nist.gov/nistpubs/ir/2018/NIST.IR.8202.pdf

Zhao, W., Liu, K., & Ma, K. (2018). Design of Student Capability Evaluation System Merging Blockchain Technology. *IOP Conf. Series: Journal of Physics: Conf. Series 1168 (2019) 032123.* IOP Publishing.

Zimmerman, E. (2012). Career couch: Showcasing Your Work, in an Online Portfolio. Retrieved from https://www.nytimes.com/2012/07/01/jobs/an-online-portfolio-can-showcase-your-work-career-couch.html