THE ROLE OF BLOCKCHAIN TECHNOLOGIES IN DIGITAL ASSESSMENT

A. Pfeiffer[1,3,6], S. Bezzina[2], T. Wernbacher[3], S. Kriglstein[4,5]

[1]Massachusetts Institute of Technology (UNITED STATES)
[2]Ministry for Education and Employment (MALTA)
[3]Donau Universität Krems (AUSTRIA)
[4]Austrian Institute of Technology (AUSTRIA)
[5]University of Vienna (AUSTRIA)
[6]University of Malta (MALTA)

Abstract

Once information is stored on the Blockchain, it cannot be altered retroactively. This immutability makes Blockchain technology an ideal candidate to secure learning achievements and educational credentials. Keeping data trustworthy, secure and manipulation-proof has become an increasing issue in education due to the rise of digital learning environments, which often combine learning experiences, testing procedures and educational credential management. Currently, most digital learning environments safeguard their data using traditional safety systems (e.g. password protection), which in turn are not Blockchain-based, but controlled by a centralized authority. While these centralized systems provide a certain level of security against unauthorized access from outside the system, manipulation from within the system cannot be excluded. Users with high enough access rights (teachers, administrators, system managers) can still add, change or delete entries. This becomes an even greater problem when learning achievements are to be reflected in fair and transparent credit systems, and especially when these educational credits are to be valid across different institutions or even countries. Due to their ability to store data in a decentralized, transparent and manipulation-proof way, Blockchain-based technologies can provide solutions to this problem. The aim of this paper is to describe the status quo of Blockchain technologies in the educational sector, including the expected merits and drawbacks.

Keywords: Blockchain, DLT, Assessment.

1 INTRODUCTION

Once information is stored on the Blockchain, it cannot be altered retroactively [1]. This immutability makes Blockchain systems the perfect technology to secure learning achievements and educational credentials [2]. Keeping data trustworthy, secure and manipulation-proof has become an increasing issue in education due to the rise of digital learning environments, which often combine learning experiences, testing procedures and educational credential management. Currently, most digital learning environments safeguard their data using traditional safety systems (e.g. password protection), which in turn are not Blockchain-based, but controlled by a centralized authority. While these centralized systems provide a certain level of security against unauthorized access from outside the system, manipulation from within the system cannot be excluded. Users with high enough access rights (teachers, administrators, system managers) can still add, change or delete entries. This becomes an even greater problem when learning achievements are to be reflected in fair and transparent credit systems, and especially when these educational credits are to be valid across different institutions or even countries. Due to their ability to store data in a decentralized, transparent and manipulation-proof way, Blockchain-based technologies can provide solutions to this problem. The aim of this paper is to describe the status quo of Blockchain technologies in the educational sector, including the expected merits and drawbacks.

Blockchain Systems as we know them today are based on the white paper “Bitcoin: A Peer-to-Peer Electronic Cash System” [3], by the anonymous author Satoshi Nakamoto. Blockchain technologies belong to the Distributed Ledger Systems, or DLTs in short. This means that information of the same type is stored on different computers. The ledger is therefore divided into different locations, operated by different persons or companies, none of these people or companies have to know or personally agree with each other when using a public Blockchain. The special thing about Blockchains is that, according to a set of rules that varies slightly depending on the Blockchain system, transactions (in the

sense of data records, for example, after a certain period of time or when a certain size of the total data volume has been reached) are combined in a block and stored in encrypted form (as a block). This process is intended to ensure that the exact same information is actually stored on the distributed systems and that there is no file or text information among them that may have the same file name and size as all the others, but does not contain the correct information. The storage process of a Blockchain is therefore based on the fact that new data blocks are continuously generated. Each of these new entries (blocks) increases the size of the Blockchain.

This results in the so-called "block height". The block height is the counting mechanism of a Blockchain. It counts up, starting with block #1, the "Genesis block" without any basic limitation. Each block is encrypted and has a unique hash value. A hash value results from the data stored in a block plus additional information such as the time, or for example random numbers that are added by the respective Blockchain according to a certain algorithm. This has the goal of ensuring the uniqueness of the hash value. Each block now starts with the hash value of the previous block and passes on its own hash value to the next block. A good metaphor would be that the blocks are stuck together with a labeled super glue. On the one hand, the connection can be seen in the chronological order to the previous and next block and on the other hand, in terms of the hash value per block. It is therefore verifiable that all blocks of the same block height verified as correct are absolutely identical on all "nodes" that store a copy of the blocks. Nodes is the name for computer systems that store a copy of the Blockchain. But why is it a decentralized system? It is a decentralized system, because the blocks, which as already mentioned, must all have the same hash value, are stored on many different computers (nodes). The way nodes agree on the correctness of the information is determined by the so-called "consensus algorithm". There are different approaches to this, which were consciously chosen depending on the purpose of the Blockchain being used. The best known are the "Proof of Work, PoW" and the "Proof of Stake, PoS" algorithm. PoW is about being the first computer to find a random number, PoS is about the percentage of network tokens you hold and a random factor that determines whether you are the first to validate a new block. This process is called "Mining" (with PoW), or "Forging" (with PoS). A node can now simply always save the valid copy of the Blockchain, or one can decide to additionally secure the Blockchain and perform further validation processes. As a reward, the "miners" or "forwarders" receive, for example, shares of the transaction fees paid. This is because every transaction made on a public Blockchain has to be paid by the sender or by a sponsor (in technical jargon sponsoring is called "bundlng").

Blockchain systems can basically be operated in three different ways:

- Private Blockchain: is basically a closed system and is operated exclusively within organisations, companies or government structures. No information is passed on to the outside world unless there is evidence that a transaction has taken place.
- Blockchain operated by a consortium: serves connected parties who have a common goal. Consortium partners may join the Blockchain on the basis of joint agreements.
- Public Blockchain: has no restrictions on joining and/or leaving the Blockchain. All information is public, although it is possible to store some information in encrypted form.

Private and consortium Blockchains can also store information on a public Blockchain, for example the hash value of all transactions within 24 hours. This keeps the data content itself private but ensures that no data manipulation takes place retroactively. Not block by block, but still, as in the example above, for all data older than 24 hours.

The aim of this paper is to describe the status quo of Blockchain technologies in the educational sector, including the expected merits and drawbacks.

2 RELATED STUDY

For Grech and Camilleri, the authors of the "JR science for policy reports: Blockchain in Education" [4] report, Blockchain offers significant opportunities, especially from a societal perspective, that go beyond the current ways we deal with data storage. In particular, the transfer of data sets into the Blockchain and the rapid verification of their validity opens up new options for action. According to Grech and Camilleri, Blockchain offers technologies:

- self-determination, which means that users can identify themselves while retaining control over the storage and management of their personal data;

- trust, i.e. for a technical infrastructure that gives people enough confidence in how it works to be able to carry out transactions such as payments or the issuing of certificates;
- transparency & origin, i.e. for users to carry out transactions in the knowledge that each party has the ability to make that transaction;
- immutability, i.e. that the records can be written and permanently stored without the possibility of modification;
- impartiality, i.e. the elimination of the need for a central controller to manage transactions or keep records;
- collaboration, i.e. the ability of the parties to negotiate directly with each other without the need to mediate third parties.

The report (from 2017) concludes that the use of Blockchain applications in education is still in its infancy, although it is gaining momentum rapidly. It describes case studies of implementations at the Open University UK, the University of Nicosia, MIT and various educational institutions in Malta: each of these implementations was in a pilot phase at the time of the report. Grech and Camilleri assume, however, that the results of the pilot phase already show that Blockchain technologies will have a disruptive effect on current providers in the market for educational software.

Grech and Camilleri see the following use cases in the near future:

- creation of digital certificates/certificates or creation of digital proof of authenticity of printed certificates;
- storage of proofs of performance after examinations including meta data;
- recognition of examination results between and within educational institutions;
- use of a personal "lifelong learning" directory (virtual CV);
- verification of the authenticity of the certificates by third parties (e.g. personnel managers authorised by applicants);
- management of intellectual property, e.g. in the context of project implementation;
- processing of payments.

Grech and Camilleri also conclude that the above benefits can only be achieved through

- open implementations of the technology;
- use the open source software;
- use open standards for data;
- implement self-managed data management solutions.

Grech and Camilleri also note that it is often easier to create centralized solutions that have a commercial background. Their recommendation for action is that further developments must be driven forward jointly by market participants and regulators / authorities.

Based on the results of Grech and Camilleri, the aim of this work is to assess the status quo of Blockchain in education in the period 2019-2020. For this purpose, an online survey and a focus group analysis were created and evaluated.

3 METHODOLOGY & LIMITATIONS

A hybrid approach consisting of a qualitative and a quantitative method has been used. In moderated focus group discussion was chosen as the qualitative method. This was evaluated on the basis of Mayring's model of qualitative content analysis [5, 6]. The group consisted of 10 people (five teachers, three of them also with administrative roles within their institution (High-School, College, University), three researchers (in the fields of Blockchain, Education, Sociology) and two full-stack developers. The participants have been from different European countries (Luxembourg, Austria, Italy and the USA) The focus group discussion took place at the Massachusetts Institute of Technology / Comparative Media Studies / Writing Department in July 2019. Descriptive statistics were conducted as a quantitative method. The data material was taken from an online survey (n=150) conducted between August and October 2019. As an initial question the participants could choose from which

perspective the questions were answered. The choices were as follows: teacher, IT professional, researcher in a related field or someone who feels being part of the Blockchain community. There was no reward for filling out the questionnaire in order to reduce incorrectly filled out questionnaires as best as possible. It was possible to skip any question.

A methodological limitation is due to the fact that the participant selection for the focus group was conducted by the authors of the study, rather than by an agency or external entity. On the other hand, the personal selection of the participants by the authors of the study, implies that the interviewees are of high caliber. The limitation of the quantitative study is, on the one hand, that the assignment of professions was only made on the basis of self-selection. Furthermore, no personal data (age, gender, origin) was collected. From the point of view of the authors of the study, however, this is not necessary for an initial survey and it does not lead to any data protection concerns. Possibly this might even lead to more honest answers.

Table 1 – Participants of the online questionnaire

A Person…	*Number of participants in the online survey*
working as an educator	45
working as an IT-professional	30
working as a researcher in a related field	19
Blockchain Community	48
n=146 / skipped 4	

4 RESEARCH QUESTIONS

- At what point in time and why did the interviewees learn about Blockchain as technology?
- How do the interviewees assess their knowledge of the Blockchain? And have they already made a transaction on Blockchain basis or at least observed it?
- From which sources do the interviewees obtain information about Blockchain?
- Which Blockchain systems are known to the interviewees?
- Which steps are necessary before considering using Blockchain in education?
- Where, in the education system, is Blockchain to be used? Or where is this particularly useful?

As a final question, the participants of the online questionnaire as well as the focus group were able to bring further points into the discussion that had not yet been mentioned.

5 RESULTS

The above questions are now analysed from the point of view of all professional groups involved, although with a special perspective from the perspective of educators. Additionally, the analysis of each question is combined with the results of the content analysis of the focus group.

5.1 At what point in time and why did the interviewees learn about Blockchain as technology?

Table 2 - The year of hearing about blockchain as a technology.

IT Professionals / Researchers / BC Community		*Educators*	
Year	*Percentage*	*Year*	*Percentage*
2017	27,00%	2018	22,22 %
2013	16,00%	2017	15,56 %
2016	13,00%	2013	11,11 %
2011	9,00%	2016	11,11 %
2014	8,00%	2015	8,89 %
2019	0 %	2019	4,44 %
IT Professionals / Researchers / BC Community n=101 / skipped 1 | teachers: n=45 / skipped 0			

In late December 2017, Bitcoin reached its previous record high of just over US$ 20,000, the total market capitalization of traded blockchain based tokens was several hundred trillion. As a result, the broad media landscape has reported extensively on the topic of blockchain and especially bitcoin and the speculative hype, and many people have heard about it for the first time. This continued into the beginning of 2018, until the bear market started in February 2018, which has not yet completely ended [7]. In October 2013, the money laundering scandal surrounding Silk-Road, a trading exchange in the dark web [8], became known. This led to the first major coverage of Bitcoin and Although it was not a positive matter it fueled the first major wave of speculation. At the end of 2013 Bitcoin was traded for the first time around US$ 1.000, and similar to 2018, a long bear marked started in the first quarter of 2014.

In 2019, 0% of the group of responders including IT Professionals / Researchers / Blockchain Community heard about Bitcoin and Blockchain for the first time, on the other hand still 4,44% of the teachers learned about Blockchain the first time in 2019. However, this shows that the term per se (without judging whether one can explain exactly what it is) has thus become a term that is already widely known.

5.2 How do the interviewees assess their knowledge of the Blockchain? And have they already made a transaction on blockchain basis or at least observed it?

Table 3 - Knowledge about Blockchain, self-estimation.

IT Professionals / Researchers / BC Community		***Educators***	
Number of interviewees	***Weighted Average***	***Number of interviewees***	***Weighted Average***
100	4,19	43	2,67
Scale: 1: no knowledge to 7: very high knowledge			
IT Professionals / Researchers / BC Community n=101 / skipped 1| teachers: n=43 / skipped 2			

The group of 'IT Professionals / Researchers / BC Community' estimates their knowledge of blockchain technologies to be slightly above average with a mean value of 4.19, the 'Educators' consider their level of knowledge to be below average with a mean value of 2.69. The results can be interpreted with the answers from the open answer field to this question and the summary of the focus group as follows: For the group of 'IT Professionals / Researchers / BC Community' it is difficult to keep up with the rapid technical development, especially in the last three years. In particular, it is difficult to distinguish marketing talk from actual innovations. And innovations have to undergo a stress test or code review. There are also still few offers in the university sector, especially interdepartmental activities are still not promoted enough and there are hardly any interactions with corresponding labs at the universities. In the area of teacher training, there are still hardly any offers, or, if they exist, they are still being actively used by too few people, since there is currently no basic understanding of blockchain in the education system.

75% from the ‘IT Professionals / Researchers / BC Community‘ group of people have already carried out a transaction on a blockchain basis, 9% have observed this with someone else. Among the target group ‘Educators‘ this is much lower. 31.11% have already interacted with blockchain technologies themselves and 6.67% have witnessed how a transaction works. This shows that conducting blockchain transactions is not yet ‘mainstream‘ and underlines the thesis from above that there are still too few continuing education offerings for educators.

5.3 From which sources do the interviewees obtain information about blockchain?

Table 4 - Source of information

All Interviewees together (multiple responses possible)					
#	*Source*	*Percentage*	*#*	*Source*	*Percentage*
1	Reddit	48,61%	9	Participating at Lectures	27,08%
2	YouTube (Online Video)	47,92%	10	Friends & family	27,08%
3	Blogs	43,75%	11	Git-Hub and/or similar ressources	25,00%
4	Colleagues / at work	41,67%	12	Academic Journals	22,22%
5	Twitter	38,89%	13	Magazines	20,14%
6	Medium.com	36,81%	14	Books	18,75%
7	Reading Whitepapers	36,11%	15	Other Sources	13,89%
8	Newspapers	30,56%	16	TV & Radio	11,81%
All interviewees n=144 / skipped 6					

When asked where the information about blockchain is obtained, sources available on the Internet are at the forefront. Reddit, online video portals such as YouTube, blogs (especially Medium.com) and Twitter are the main sources, with responses ranging from 38% to just under 50%. Colleagues at work also play a major role with 41.67%, while family and friends account for 27.08%. Classical TV or radio, as well as books are under 20%. Daily newspapers also do not play a very big role with 30%. The interpretation of the results by the focus group shows that the Blockchain community usually has a high affinity for IT and also contributes a lot to the discussion in the form of contributions on Reddit. In addition, there are people from the financial sector who use YouTube in particular for their analyses. Both groups like to blog, in their own blogs, on Wordpress or Medium.com. In the classic media sector there is a lack of well-trained journalists and the articles are often only superficial. According to the IT experts and scientists from the focus group, these articles often contain false information.

5.4 Which blockchain systems are known to the interviewees?

Table 5 - Which Blockchain networks are known to the interviewees?

All Interviewees together (multiple responses possible)					
#	*Name of the Network*	*Percentage*	*#*	*Name of the Network*	*Percentage*
1	Bitcoin	93,10%	12	Binance Coin	51,03%
2	Ethereum	80,69%	13	Stellar	51,03%
3	Bitcoin Cash	69,66%	14	EOS	50,34%
4	Litecoin	68,97%	15	Bitcoin SV	49,66%
5	Ethereum Classic	59,31%	16	Tron	47,59%
6	Ripple	58,62%	17	Cardano	44,83%
7	Monero	54,48%	18	Neo	44,14%
8	IOTA	53,79%	19	NXT	40,00%
9	Dogecoin	53,79%	20	NEM	36,55%
10	Tether	53,10%	21	Ardor	35,86%
11	Dash	53,10%	22	Others	26,21%
All interviewees n=145 / skipped 5					

Bitcoin with 93.10% is clearly the best known blockchain network and a synonym for blockchain technology itself. 80.69% know Ethereum, a network which allows smart-contracts and the creation of sub-/metatokens. The original Ethereum network is still known by just under 60%. With just under 70% still very well-known is Bitcoin Cash (the first big fork [9] of the Bitcoin network) and Litecoin, the first network which builds on the Bitcoin source code to create a new network with some changes (total number of coins, speed of block generation). Networks like NXT, Ardor or NEM, although quite popular with the developer community and technically mature, can be found at the lower end of the scale in the survey. According to the focus group, this is often due to the fact that there is little or no advertising budget available to promote the system tokens, or that this is deliberately not wanted in order to avoid being placed in the speculation corner.

5.5 Which steps are necessary before considering using Blockchain in education?

Table 6 - Necessary steps, before considering using Blockchain in education

All Interviewees together (multiple responses possible)	*Weighted Average*
Basic information/education about blockchain-technologies for all people involved in the educational sector	4,17
Sophisticated privacy-settings	4,17
Clear and transparent rules about who is responsible for payment of fees	4,17
In-depth education about blockchain-technologies for IT-professionals and administrative-officers in the educational-sector	4,15
The ability to get a copy of my own data that can be stored on my own node, regardless of which blockchain system was originally used.	3,82
The possibility to process information from various blockchain-systems	3,78
Everything has to be set up with open-source technologies	3,74
The ability to operate a full node and store an encrypted copy of the blockchain used to store credentials	3,48
Having a close look if and which patents are involved within the used technology	3,39
Involvement of Government, strict worldwide regulation	3,01
Involvement of Government, strict local regulation	2,86
Involving corporations in the process of setting up Blockchain-technologies in the educational sector	2,86
All interviewees n=144 / skipped 6	

When asked which steps are necessary, it was possible to choose from various given answers, which were mentioned within the focus group. The scale was divided from 7=very important to 1=not important. With 4.17 clearly above the average, a basic training for all persons from the education sector, a clear solution as to how and who pays the transaction fees (should a public blockchain be used) and a modern solution in the area of privacy settings were ranked. Further relevant points are an in-depth training for the IT staff in the education sector, a solution that includes different blockchain systems, the open-source idea and the possibility to have your own data, or even to operate your own node. The interviewees are undecided in the area of regulation and whether large companies should push the developments. Here the score is even below average (2.86).

5.6 Where, in the education system, is Blockchain to be used? Or where is this particularly useful?

Table 7 - Usecases for Blockchain in the educational sector

All Interviewees together (multiple responses possible)	*Weighted Average*
Handle payment transactions, for example for course fees	4,25
Taking exams "off-school/university/education center", assuming a suitable ID-checking solution is in place	4,11
Storing the successful completion of a course or class, without any specific grades	4,09
Storing grades at the end of the term	4,03
Handling of votings (e.g. vote for school representatives)	4,01
Scholarship processing and funding management	3,79
Storing competence profiles at the end of the term	3,73
Storing each test completed that has been completed during a term	3,62
Adapting digital serious games for use as assessment tools	3,61
Storing each step/chapter of an exam through e-learning tools while being examined	3,44
Class book and validated communication with parents/relatives	3,27
Storing a behavioral grade at the end of the term	3,2
All interviewees n=144 / skipped 6	

For this final question, a rating between 1 (not suitable) and 7 (very suitable) was used. The possible applications are based on the suggestions from the focus group discussion. With a score above 4, two classic applications of blockchain are mentioned: Payment (e.g. of tuition fees) and voting (e.g. of the school or university student representative). Also mentioned, with a score just over 4, are the storage of diplomas, year-end transcripts and exams taken from outside school or university (if there is a target-oriented solution for digital identity). Only minimally above the average, are areas such as the behavioral grade, the recording of every (even the smallest) test achievement or the class register.

6 CONCLUSIONS

In comparison with the study for the European Union by Grech and Camilleri from 2017, several points are confirmed. The knowledge about blockchain is still in its infancy, open source solutions are essential for a broad and real use of blockchain technology, privacy settings are important, digital identity such as SSI (Self Sovereign Identity) or qualified signatures have to be considered, different blockchain solutions have to be processed by comprehensive educational software solutions and last but not least the possession of one's own data is essential.

The data presented here is part of a larger study "Blockchain Technologies and their impact on game-based Education and Learning Assessment" led by Alexander Pfeiffer and funded through a Max Kade Scholarship. In this project different prototypes are being developed, such as e-learning systems and learning/test games, together with the identification of reliable solutions in connection with blockchain wallets.

ACKNOWLEDGEMENTS

Alexander Pfeiffer likes to thank the Austrian Academy of Sciences and the Max Kade NY Foundation Inc.

REFERENCES

[1] Schmidt, N., Kryptowährungen und Blockchains, in Technologie, Praxis, Recht, Steuern, Linde Verlag, Wien, 2019

[2] Atzei N., Bartoletti M., Lande S., Zunino R., ‘A Formal Model of Bitcoin Transactions’, in S. Meiklejohn, K. Sako (eds.). ‘Financial Cryptography and Data Security. FC 2018’, Lecture Notes in Computer Science, vol. 10957, pp. 551–60, Berlin, Heidelberg., 2018

[3] Satoshi Nakamoto, Bitcoin: A Peer-to-Peer Electronic Cash System, in Whitepaper; online available under: https://bitcoin.org/bitcoin.pdf (05.05.2020), 2008

[4] Grech, A.; Camilleri, A. F., lockchain in Education. Luxembourg, in Publications Office of the European Union 2017, 132 S. - (JRC Science for Policy Report) - URN: urn:nbn:de:0111-pedocs-150132, 2017

[5] Mayring, P., Die Praxis der Qualitativen Inhaltsanalyse, Beltz Verlag, Weinheim, Basel, 2008

[6] Mayring,P., Qualitative Inhaltsanalyse; Grundlagen und Techniken, Beltz Verlag, Weinheim, Basel, 2010

[7] Statistics about digital Blockchain-based Tokens: https://www.coinmarketcap.com

[8] Article about Silk Road on Coindesk: https://www.coindesk.com/silk-road-seller-pleads-guilty-to-money-laundering-19-million-with-bitcoin

[9] What is a Bitcoin fork?: https://blockgeeks.com/guides/bitcoin-forks-guide/