BLOCKCHAIN TECHNOLOGIES IN THE EDUCATIONAL SECTOR: A REFLECTION ON THE TOPIC IN THE MIDDLE OF THE COVID-19 SITUATION.

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This paper looks at current projects in the field of Blockchain in education, their specific areas of application, possible advantages and weaknesses. Three examples developed by the team of authors are introduced in detail. First: Gallery-Defender a Serious Game, which was adapted to serve as a demonstrator in a stand-alone version to show the possibility to carry out exams directly from within the game and store the grades and meta-data on Blockchain. Second: Art-Quiz, an e-learning tool, which can be integrated into existing LMS systems and map exam results and further data using Blockchain technologies. Both were developed following an iterative design process. And third: The results of a focus group, which simulated the assignment of grades after an oral online exam. The three examples presented here are based on the Blockchain system Ardor/Childchain Ignis, but each demonstrator has a different set of features and approaches. In addition, the integration of various Blockchain solutions was conceptually designed to make a Multi-Chain model possible.

1. Introduction

The rapid changes brought about by digital technologies in education offer rich, personalised and differentiated modes of e-learning. However, the anytime, anywhere access to teaching, learning and assessment material requires a paradigm shift in the conceptualisation and implementation of validation, verification, authentication and storing of students' data.

Blockchain technologies offer an interesting and innovative approach for securing sensitive information in online educational environments. One of its main impetus is the ability, or rather the non-ability of retrospectively altering data which is stored on the Blockchain. This indelible and unalterable nature of Blockchain technologies allow for greater safeguarding when compared to conventional password-protected directories, from both within and outside the organisational e-learning environment. Furthermore, the open nature of public Blockchains, supports decentralised data verification, hence independent of any central authority and consequently valid across different programmes, departments, institutions and countries. This also extends beyond traditional formal learning institutions, such as non-formal or informal education, but more importantly, it offers an easy and inexpensive way for businesses and job providers to safely and securely verify prospective employees' credentials. The current COVID-19 situation has shown that during times of massive travel restrictions, problems with mailings and even complete lockdown, we need to have digital capabilities where secure, non-manipulable storage of data and digital identities are combined. Even during this difficult period, school grades, certificates, employment certificates and similar documents must be issued on the one hand and checked for their validity on the other.

Furthermore, the period of lockdown, months of home schooling in the school system and online distance learning at universities has shown that e-assessment formats also require technological innovations, regardless of whether the examinations are conducted using modern approaches such as Game Based Learning & Assessment, classic e-learning tools or simple video chats. The aspects of identity verification, secure assignment and storage of grades, acceptance of the grading and digital transfer to the administrative departments are of utmost importance. And some of these were arguably not guaranteed over the past few months.

With regard to related research, the fundamental work "JR science for policy reports: Blockchain in Education" by Grech and Camillieri [1] should be highlighted. In 2017 they described that Blockchain in the educational sector is still in its beginning, but they see the following use cases in the 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.

They further describe various basic assumptions that need to be made in order for Blockchain to establish its place in the educational sector

- open implementations of the technology;
- use the open source software;
- use open standards for data;
- implement self-managed data management solution;
- further developments must be driven forward jointly by market participants and regulators / authorities.

Min et al. [2] discuss the Blockchain integration for games and then categorized existing Blockchain games from the aspects of their genres and technical platforms. Aini et al. [3] explore different approaches to Gamification that embed Blockchain technologies in the educational sector. In their work, Agustin et. al [4] describe the application of Blockchain technology in e-certificates in the open journal system. The study reports that issuance of e-certificates in an open journal system is a way to manage and verify, prevent duplications or even falsification of e-certificates and the reputation of the open journal system is already given. This project is based on Blockcerts by Learning Machine (originally developed at MIT). Merija and Kapenieks [5] compare Blockcerts with Ethereum Smart Contracts developed by Open University, UK, while Baldi et al [6] describe how to impersonate a legitimate issuer of Blockcerts certificates with the aim to produce certificates that cannot be distinguished from originals by the Blockcerts validation procedure.

Pfeiffer and König [7] discuss the use of blockchain technologies in educational games for assessment from a humanities perspective. The authors set up a category system for learning games and e-learning systems with the aim of also serving as examination tools. From this paper it is concluded that the game Gallery Defender and the Art Quiz fall into the category Game Based Learning & Assessment respectively E-Learning & Assessment. The learning environment corresponds to the exam setting. However, the exam takes place in a separate instance.

Serada et. al [8] analyze specific characteristics of value created through digital scarcity and Blockchain-proven ownership in cryptogames. Pfeiffer et. al [9] have identified 8 different types of Blockchain based tokens, based on their possible applications. In the further examples described in this article, the following token type is used to represent the grading or as a certificate:

> *"Non-freely tradeable utility tokens: These tokens store data, such as certificates, grades, ownership of a piece; fine art prints (e.g. limited edition prints, each with a unique number), or a last will; they can be a unique (singleton) token per record or a message attached to a specific token when sending. A separate series of tokens is generated for each different use case. Each series has its own asset ID on the respective Blockchain. (the name of the series does not have to be unique, only the asset ID). This means: The moment a message is added to one of the tokens (from a series) and this token is sent, the connection of the token with the message and the rule that the token cannot be forwarded without the knowledge of the original sender becomes a unique process, which is identified by the unique transaction ID. Messages can be attached unencrypted or encrypted. This data is usually linked to a person or a property and is not (or only under specific circumstances) tradable. It is also linked to a specific wallet (e.g. of the recipient). The Singleton/Unique Token form of this category is similar to the concept of non-fungible tokens (NFTs)."*

The 3 different approaches

- Game-based learning learning & assessment
- E-learning & assessment
- and online video education & assessment

All these approaches store the certificates on Blockchain.

2. Gallery Defender

To set up the demonstrator in an educational framework, the Serious Game is based on the requirements for art history in an introductory college level Art History Curriculum Framework:

The learning goal, which equals the game goal is defined as "All students, which means all players, will understand, analyze, and describe art styles in their historical, social, and cultural contexts."

The serious game introduces and later assess the art concepts to the player/learner. The game is inspired by the ARTé: Lumiere [10, 11] game. The player/learner slips into the role of a gallery owner. Using their profound knowledge of art history, the player must defend the artworks of the gallery from a master thief. The demonstrator utilizes Blockchain technologies in three different ways. It is important to note that 10 million of the respective tokens (for the teacher vedutt asset-ID 1653013092595194366 / for the students veduut asset-ID 1494447768104309209) were registered on the Ignis Childchain of the Ardor network.

A player/learner receives a digital token at the end of the assessment, which contains the grade, points, and time that the assessment was finished as a message. This token and the attached message are stored forever and unchangeably on the Blockchain in the player/learner's Ardor Blockchain Wallet. The certificate is encrypted and can only be decrypted by the sender and the original recipient. However, using a shared key enables the player/learner to share the results with third parties, such as their future boss, their family or another school/university. Teachers can receive a token with further information about the respective test result. After a definable time the message is deleted, and only the proof that the token

has been sent remains (and thus an assessment has been carried out).

A gamification system was also simulated on a conceptual level and in test runs using the API calls directly:

The idea is that a player/learner with particularly good results receives an additional token with which the authors of the article use to show gamification principles on Blockchain. This token can be exchanged for digital rewards, e.g. a game poster. This functionality shows off how an entire ecosystem for rewards can be built on Blockchain and included within the context of education. However, this is not yet implemented in the current version of the game. The tokens used in the token system of the demonstrator are defined as “non-freely tradeable utility tokens” (as discussed earlier), built on the Ignis child chain of the Ardor Network. It is of utmost importance that the tokens cannot be traded or sent outside of the learning/assessment environment. For this purpose we worked with approval models.

The communication between the ready-made game and the Blockchain works via API calls. These calls are set in the game engine unity during the development of the game. It was also important to us that the users do not need to have any knowledge of Blockchain and do not have to pay network fees with cryptocurrencies. Bundling accounts were used here, in case fees would be charged for the recipients.

Another essential point is to verify the identity and account of the game. In the third iteration, the game account from the Ardor main net was registered using Alexander Pfeiffer's digital citizen card. For this purpose, a document was placed in Alexander Pfeiffer's citizen e-vault and the transaction and the link to the document was stored in the wallet description of the game's Ardor account.

The game has been developed following an iterative game design process. The first two iterations took place on the testnet of the system, the third and last iteration was then implemented on the mainnet of the Ardor Blockchain.

All Blockchain transaction from the final iteration can be retrieved e.g. from https://ardor.tools/account/ARDOR-EEM6-N4UP-53XH-3LY9H

- ARDOR-EEM6-N4UP-53XH-3LY9H (Ardor Account of the Game)
- ARDOR-BN5K-N7EL-CQFD-EYD7W (Student Default)
- ARDOR-9UDW-4T5C-9D44-2Y5MX (Teacher Default)

Remark: Using the teacher account, all transaction data can be viewed as an unencrypted message.

The process is now shown in the form of a picture gallery:

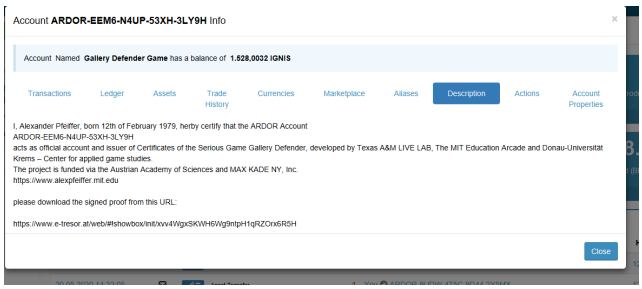

Fig. 1 - Proof of the account ownership, from the account properties of the Serious Game main Blockchain address • ARDOR-EEM6-N4UP-53XH-3LY9H

Fig. 2 - Proof of ownership retreived from the Austrian E-Government System RIS

Fig. 3 - Main screen of the game. The user can change between learning - simulation or assessment. If assessment is selected, a warning screen that the results are recorded on Blockchain pops up

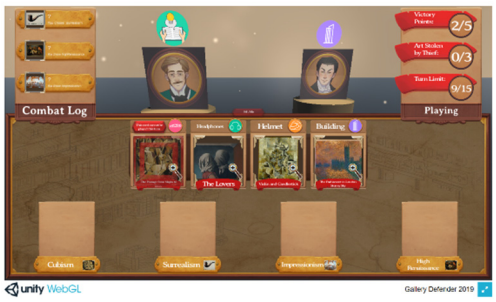

Fig. 4 - Screenshot of the actual game play

Fig. 5 - The game has been completed in 300 seconds, with an A grade and 100 points

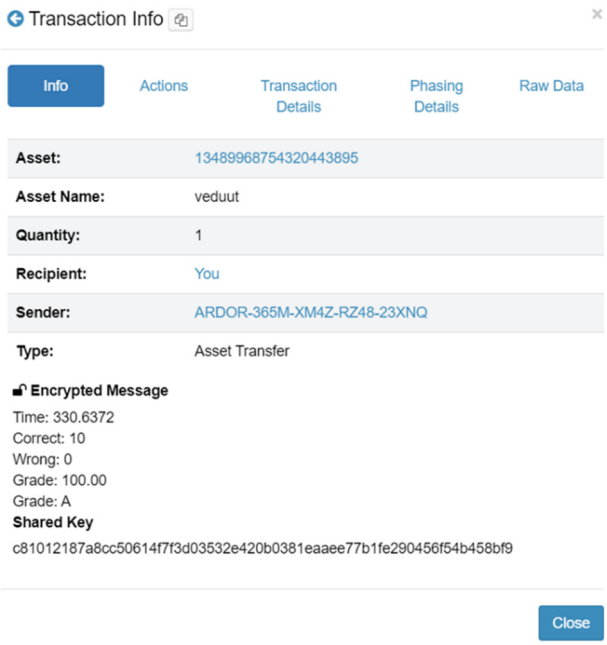

Fig. 6 - Exactly this result is sent as token (one piece of the veduut token with the message attachted) to the Blockchain address of the learner. After the learner has accessed the information with his private key, a shared key is generated to share the information with others. For example during an application. The teacher received at the same time one piece of the vedutt token, in our example with the same content, but as unencrypted message. Of course the teacher could receive additional information from the game-engine, that helps to guide the learner through his/her further learning experience

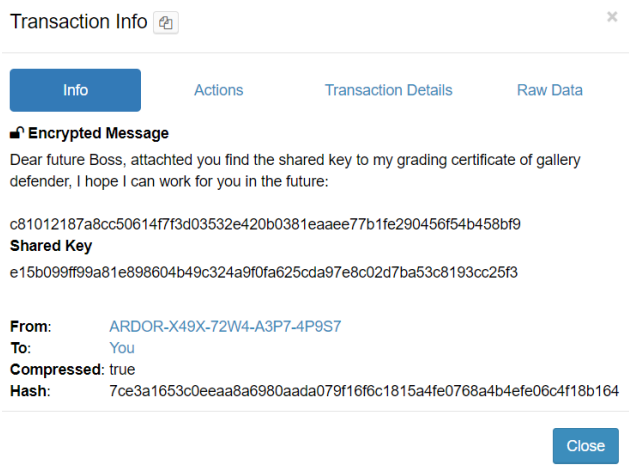

Fig. 7 - In this example the token information is shared during such application process with "the future boss"

3. Art-Quiz

The Picapipe GmbH Quizengine was enhanced for this project with a Blockchain module. In this special iteration, learning content and exam questions were developed to be an optimal addition to the Serious Game Gallery Defender by providing learners with additional information about the artworks and artists in the form of a quiz.

With the Blockchain approach chosen in this example a Singleton Token (NFT) is registered on the Blockchain after each completed test. Each exam is therefore registered on its own Asset-ID on the Ignis Childchain. Personalized information can now be provided not only as in an (encrypted) message but also in the asset properties However, the information in the Asset Properties is publicly accessible if you know the asset ID of the token. However, this is not public information per se. Lightweight Smart Contracts connect the Blockchain operations with the Learning Management System. Shared keys can be used to share exam results with others.

With the Art Quiz not only a different approach to the token structure was chosen, it was demonstrated that a web app, which can also be easily integrated into a Learning Management System (LMS), can store grades and certificates on Blockchain. Not only in the form of a 1-way-hash but, as already achieved with the Gallery-Defender game, also including meta data from the exam.

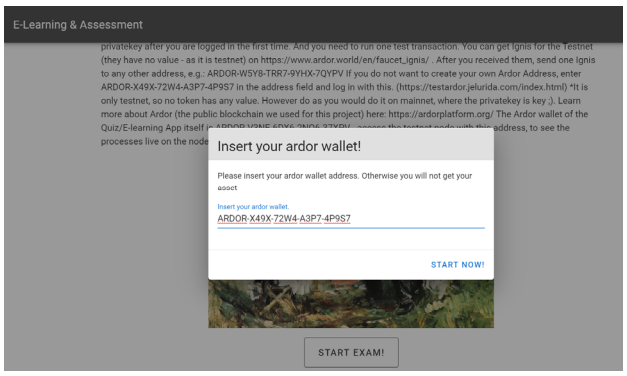

Fig. 8 - The examinee has to enter his/her ardor account address before the test starts

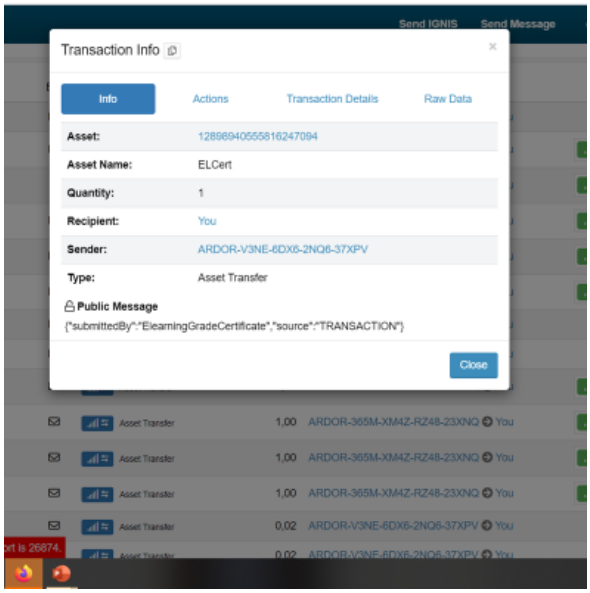

Fig. 9 - a singleton asset called "ElCert" is being created each time an exam has been finished. Each asset has its own ID on the Blockchain. A Smart Contract process the data and sends the results to the examinee

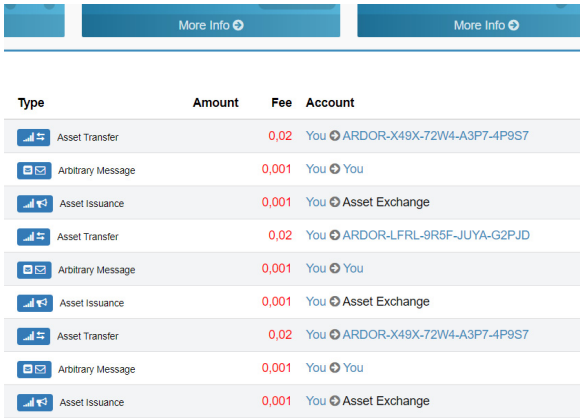

Fig. 10 - (1): Asset Creation - (2): Attachment of the meta data (grades) - 3: Transfer to the student's account

4. Online Video Education & Assessment

The goal of the third demonstrator was to conduct a role of an verbal exam, creating the tokens and transactions directly on the Ignis Childchain‘s Backend. Therefore this setting intended to imitate a online verbal exam situation using Zoom and the certificate transfer process via Blockchain following the successful completion.

The first step was the confirmation of the Ardor Blockchain account. To demonstrate this the account address was published via the twitter account of the applied game studies center of Donau-University Krems. The next step was to demonstrate the registration of students' Ardor addresses. This was done via a permanent text message from the university account to the same account.

The process for the verbal exam is as follows: For each exam a singleton (NFT) token is created. In the token properties the subject / university is described. When the token is sent, the exam performance is recorded as an encrypted message.

In the approval model, both the student's account and the sender's account must agree. This guarantees the acceptance of the exam grade by the student and the exam token cannot later leave the student's account. Again, shared keys can be used to share exam results with others. Smart Contracts can of course extend the functions significantly.

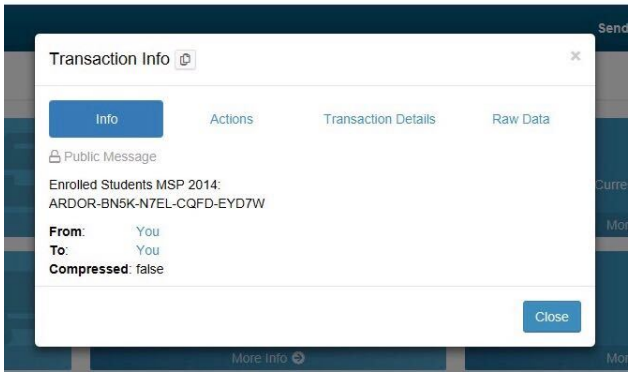

Fig. 11 - Registration of the studentes ardor accounts on Blockchain

Fig. 12 – Actual online exam situation. Screenshot was taken during the Covid-19 lockdown

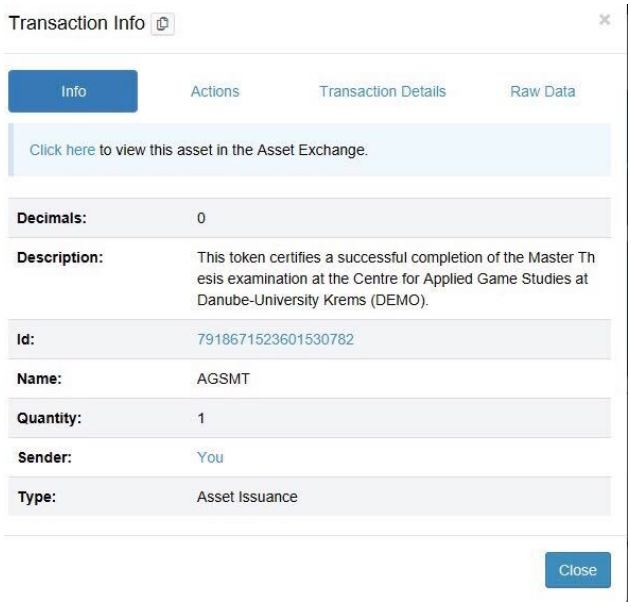

Fig. 13 - (Singleton) Token representing the successful completion of a Master Thesis Defensio (Demo)

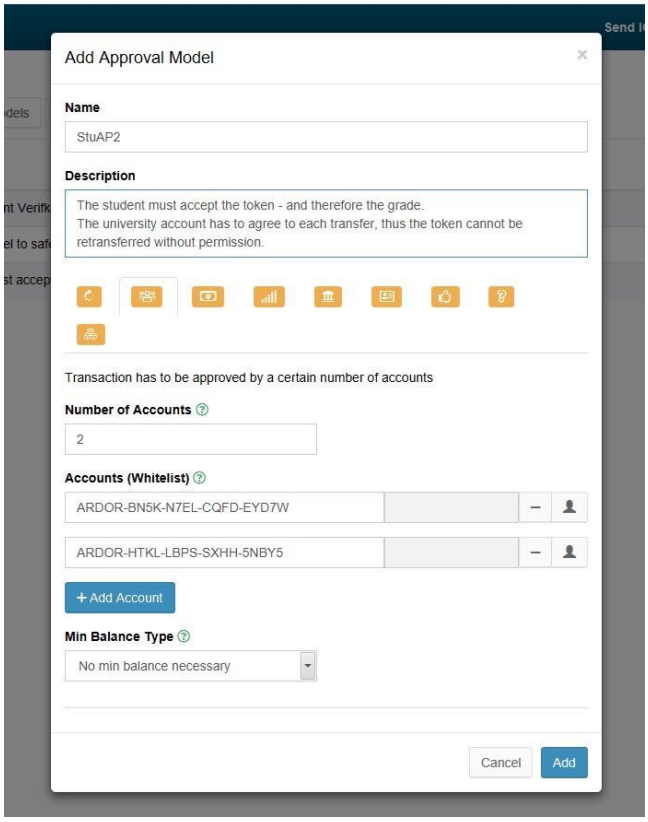

Fig. 14 - Approval model setting the rules for transfering the token. In this case both the student and the university have to agree on the transaction

5. Conclusion and further research

With these three examples the authors had the goal to show different use cases how Blockchain can be used in the educational sector. In all three cases the result should go beyond the mere proof of an original certificate. In any case, the initial findings are promising and have led to the list of the following questions, which further projects in this sector should address.

- Is a private or public Blockchain to be used?
- Which Blockchain or combination of Blockchains systems is to be used?
- Can the information-carrying tokens be sent from one account to another without this being originally intended?
- Is the private information of the token sufficiently encrypted? And if so, who has the keys to access the data?
- Can (temporary) shared-keys be created and in turn give access to (specific) information for third parties?
- Is it possible for companies / universities / government institutions to operate their own nodes in the network and thus have data sovereignty? If so, how much effort and costs are involved?
- Is it even possible for users to run their own node? And if so, with what effort and costs?
- Do the partners involved have to purchase Cryptocurrencies? If so, for what purposes? And subsequently, do the users have to purchase cryptocurrencies?
- Further: Who pays the transaction fees to the network? Can solutions be used that do not charge transaction fees? If this is the case – which network was used and what are the effects of using a transaction fee-free solution?
- Do the partners of the respective project or the users create their own Blockchain Wallets? Or is this done for them "through the app". In the case of the latter, who and in what form has control over the private keys?

The team of authors would like to pay special attention to two aspects in the next research. The development/implementation of an internationally recognized solution in the field of identity management and the expansion of the system to include various public or private (e.g. for GDPR sensitive information) Blockchain systems. This would only be possible in practice if it involves multi-chain systems.

Acknowledgements

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References

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

[2] T. Min, H. Wang, Y. Guo, and W. Cai, Blockchain Games: A Survey. In Proceedings of the IEEE Conference on Games (CoG). IEEE (2019)

[3] Q. Aini, U. Rahardja, and A. Khoirunisa. Blockchain Technology into Gamification on Education. IJCCS (Indonesian Journal of Computing and Cybernetics Systems) [n.d.]. 14

[4] F. Agustin, Q. Aini, A. Khoirunisa, E. A. Nabila, Utilization of Blockchain Technology for Management E-Certificate Open Journal System. Aptisi Transactions on Management (ATM). 4, 2(Apr2020), (2020)134-139.

[5] J. Merija, J. Kapenieks, Blockchain and the Future of Digital Learning Credential Assessment and Management. Journal of Teacher Education for Sustainability. 20.(2020) 145-156. 10.2478/jtes-2018-0009.

[6] M. Baldi, et al., Security analysis of a Blockchain-based protocol for the certification of academic credentials. arXiv preprint arXiv:1910.04622 (2019)

[7] A. Pfeiffer, N. König, Blockchain Technologies and Their Impact on Game-Based Education and Learning Assessment. In: Elmenreich W.,

Schallegger R., Schniz F., Gabriel S., Pölsterl G., Ruge W. (eds) Savegame. Perspektiven der Game Studies. Springer VS, Wiesbaden (2019)

[8] A. Serada, T. Sihvonen, J. Harviainen, CryptoKitties and the New Ludic Economy: How Blockchain Introduces Value, Ownership, and Scarcity in Digital Gaming. Games and Culture. https://doi.org/10.1177/1555412019898305. (2020)

[9] A. Pfeiffer, S. Bezzina, S, T. Wernbacher, , S. Kriglstein, Blockchain Technologies for the Validation, Verification, Authentication and Storing of Students' Data., in ECEL 20 Proceedings (2020) retrieved from: https://www.researchgate.net/publication/339254736_BlockchainTechnologies_and_Social_Media_A_Snapshot (last visitied 31.08.2020)

[10] A. Thomas, H. Ramadan, L. Campana, D. Leiderman, Sutherland,. M. Zawadzki, ARTé: Lumiere. Available electronically from https://hdl.handle.net/1969.1/188003 (2018)

[11] W. Weng, H. Ramadan, A. Thomas, Understanding Enjoyment in ARTé: Mecenas with EGameFlow. The IEEE Conference on Games (CoG) 2020 Proceedings (2020)