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Blockchain and the Future of Digital Learning Credential Assessment and Management

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Abstract

Blockchain educational technology has created assessment and management tools for learner credentials that are permanent, transparent and sustainable while giving users direct access. Personal encrypted credentials enable users to shape lifelong learning pathways and personalizes education according to individual values and needs. They allow for the permanent documentation of both formal and informal learning based on transversal competencies, adjustable across the economic sector and responsive to situational needs. Badging was the initial response to online credentialing. Mozilla's open digital badges have become the unofficial global standard and the specifications remain free. They may be viewed in e-portfolios and social networks. Yet, if issuers cease hosting badges, they become invalid even when authentic. Some experiments with blockchain technology remedy this situation by creating a permanent, secure and sustainable infrastructure for learning records. The MIT Media Lab has produced the bitcoin based Blockcerts; whereas the Knowledge Institute, Open University, UK has developed Ethereum's Smart Contracts to document Microcredentials (Badges). Both are Open Source products. Most EU nations are experimenting with educational blockchain. The technology creates an infrastructure to document, store and manage credentials and provides learners with a sustainable record of achievements they can control. It also benefits universities by reducing administrative costs and bureaucracy.

Keywords: Open digital badges, Microcredentials, blockchain, Blockcerts, smart contracts

Introduction

The traditional transcript is being challenged. It has been found as too limited, i.e., a paper record of courses taken affixed with a letter or number grade. The missing elements include a description of the skills achieved, mastery level, and extra-curricular activities contributing to the student's development, such as voluntary service, internships and study-abroad. Personal factors such as creativity, motivation or leadership potential are also missing – factors that may give a fuller picture of students' achievements and potential. Most significantly, learners cannot directly access their credentials but must depend upon third parties, often a university or former employers. If these organisations or individuals cease hosting the credentials; they become invalid or orphaned even when the credentials are still authentic. Added to the problems is slow turn-about time. The verification process for traditional paper transcripts is slow and may take weeks from the time of the original request is made to the time the requesting agent receives them. It seems counterproductive that in our information age where there appear a continuous stream of innovations every day that require continuous skills update and learning has indeed become lifelong, transcript validations should be such a slow and cumbersome process. A transcript therefore cannot be a closed archive, as now is the case, but a continuous record of achievements to which teachers, tutors or other experts may add throughout a learner's lifetime. In an effort to speed-up credential validation, some universities are relying on pdf format transcripts appended with electronic signatures. But the method is vulnerable to forgery, and therefore not fully trustworthy as authentic (AACRAO 2016, May 31). In our digital age, it would make sense to have immediate access to credentials, and that they be encrypted similar to online banking with potential for records update according to need. Online banking has been around for decades, why not encrypted learner credentials? Many top ranking universities have responded to this need by recognising that new metrics are required to evaluate student ongoing learning. Recognising the limits of the traditional transcript in December 2016, fifteen registrars met at the University of Michigan to discuss ways to modernise the traditional transcript (Gnagey, 2017). At the conference, the consensus was that the learning record needed to be digitalised and designed to integrate and update continuous learning and skills. One of the presenters recommended an application of blockchain technology that could host badges, certificates, transcripts and diplomas. It would work by stringing together these diverse credential records (blocks) into a chronological order (chain). The presenter claimed that the validated records would be secure. It was adapted from the bitcoin blockchain although in order to control the documentation the university created its own cryptography (Gnagey, 2017); (AACRAO 2016, May 31). Moreover, the universities would benefit: it is a way of cutting administrative costs and bureaucratic procedures while adding security to the maintenance of student records (Matthews, 2017).

These educational trends express the holistic aims of Education for Sustainable Development (ESD). Today in the EU nations, educational reform addresses those skills and competencies that match the needs of the modern economy which are fully in line with the mandates of the European Qualifications Framework (EQF) (Recommendations of the European Parliament, 2008). These skills and competencies are also transversal; they are suited to a particular sector or situation; yet can be transferred and adjusted across the economic sector. Transversal skills may be university based or follow alternative pathways, but the process is lifelong. The personal element is important and involves personal wellbeing, autonomy, effective communication and constructive interpersonal relations. These skills and competencies are a high priority for ESD and are the cornerstone of educational reform in Latvia in accordance with EQF mandates. Initiating blockchain in Latvia – a developing well underway in Estonia – would allow learners to collect competencies and achievements garnered lifelong in an environment that is secure, transparent, and permanent with direct user access.

European Educational Experiments with Blockchain Technology

Blockchain is the dynamic new technology that was introduced with bitcoin in 2009 and since that time, it has received wider application. Banks, who first felt the competition, adapted it to finance. In reality blockchain is not a new technology, but a rearrangement of existing technologies deployed in a new way. Bitcoin was adapted to educational requirements at MIT's Media Lab that created Blockcerts – a mobile app for educational credentialing. Another important blockchain is Ethereum that was developed from another cryptocurrency Ether launched in 2014 (Halpern, 2018). It is really a simplification of bitcoin and represents the second generation blockchain technologies (Gupta, 2017, February 28). It is a simpler system and was intended to allow business transactions with "smart contracts" – although critics claim that "smart contracts" can lack smarts (Derousseau, 2017). No doubt, the system needs improvement. Ethereum has been used in various fields, including finance, law, government and more recently education. It may be used together with other technologies. The Europeans, especially in the UK, have preferred Ethereum; while the Americans have opted for the bitcoin blockchain. Americans have generally viewed blockchain technology with greater scepticism than the Europeans, except in the field of finance. Other blockchains have appeared, but they are adaptions of one or the other of these technologies designed to match organisational needs. Many of the big name IT corporations are actively developing blockchain technologies: Microsoft (Azure), Intel, IBM, and many start-ups that are growing apace. Yet the biggest technology monopolies in the United States Apple, Amazon, Facebook and Google have been critical of blockchain (Maney, 2017). Yet they are potentially the most vulnerable to disruption by the technology. Google, however, with Deep Mind (its artificial intelligence lab) has viewed blockchain with ambivalence.

Blockchain is a decentralised ledger, like an old fashion account book only adjusted to computer specifications that can send files or "blocks of information" to all participating computer "nodes" in a common activity, bitcoin, banking or e-government. Because blockchain is a decentralized system where information is distributed over a number of computers (nodes), it is harder to hack than centralized networks because each node receives the same information and any tampering is transparent to all nodes. Moreover, information once entered is permanent. Each block is identified with a hashtag that is signed and dated. Once information is entered into the blockchain, it cannot be changed or removed. If a correction is entered, it appears next to the original entry. Therefore, the issues of correction and update still need to be addressed. To facilitate retrieval, the blockchain system employs the Merkle Tree that is the root hash of a tree structure and serves as an indexing tool to verify specific transactions without need to retrieve the entire blockchain. Most simply put, the Merkle tree is a "hash of other hashes" (Grech & Camilleri, 2017, p. 94). While it is possible to develop blockchains without Merkle trees, a blockchain without these "binary hash trees" would make verification a cumbersome process and lead to many "orphaned blocks." Most blockchain developers today include the Merkle Tree (Merkle Tree, n.d.). Merkle trees are not easy to navigate and the technology will need to be revised for improved usability.

More recently blockchain has been adopted by educational institutions. A few adventurous universities are experimenting with the technology. There are advantages for universities: besides the cost cutting and increased security issues already noted, universities would not need to act as credential gatekeepers for student populations that are becoming increasingly peripatetic (Matthews, 2017). Moreover, there is a growing demand for skills update that is really making learning lifelong that requires permanent, verified documentation.

In Europe, UK's Open University Knowledge Media Institute (KMI) is one of the pioneering universities to employ blockchain. KMI has created an Ethereum based blockchain platform: OpenBlockChain for academic applications partnered with British Telecommunications (BT). KMI's priority is the students of the UK. The institute is conducting experiments with Microcredentials (badges) for courses available on the Open Learn website and MOOCs (UK platform FutureLearn). The Microcredentials are documented by smart contracts that are signed and give details of how and when the badge was earned, such as Security Assertion, Recipient, Issuer, criteria applied and evidence of accomplishment. Samples of the students work may be added. The contract then is embedded and becomes part of the blockchain (Domingue n.d., Video) (Appendix A). Additionally, there is an international strategy employed by KMI. The Media Institute is developing collaborative networks that include KMI, JISC (the UK based non-profit educational digital organisation), the University of Southampton, BT, and the University of Texas, Austin creating a core global outreach community (Grech & Camilleri, 2017, p. 64). Moreover, KMI Director John Domingue argues that blockchained Microcredentials have a special role to play in Africa and other developing nations where students have limited opportunities to study abroad and with available online courses are able to collect academic credentials. Blockcerts, the mobile app for credentials storage developed by MIT is currently unavailable for Ethereum. It is, however, under development (Blockcerts, 2017) and will be further discussed in the section analysing MIT's experience with blockchain.

Most states in the EU are planning blockchain strategies to fit national agendas, and most employ the Ethereum blockchain. Education is a priority in all EU countries, and some interesting experiments are being developed (Inamorato dos Santos, 2017). Some examples are discussed below. Estonia is touted as "the blockchain" nation and recently *Fortune* magazine gushed "if you want to see the future, go to Estonia (Walt, 2017). In reaction to the 2007 cyber-attack, nearly all public services are blockchained; these included: e-Voting, e-Tax Board, e-Business, e-Banking, e-School, and e-health. An innovation is e-residency, where a company may register its business in Estonia by paying a 145 Euro fee to gain access to the EU market (Korjus, 2017). But Estonia is no tax haven; its e-citizens are expected to pay taxes in their country of citizenship. Estonians access their e-services by digital identifiers, a string of eleven numbers to which they are assigned at birth. The security technology is the Keyless Signature Infrastructure (KSI) that safeguards all public data. There are no paper originals and signatures are almost exclusively electronic. In 2018 Estonia planned to open a "data embassy" in Luxembourg that will hold backups for all of Estonian data. It has the only NATO accredited cyber-defense centre in Europe (Walt, 2017). And yet, it seems odd that in this thoroughly digitalised nation, credentials and university certificates are not digitalised. However, a national qualifications database is currently being planned in which all Estonian universities will participate. The system will be interactive with all job applications; university graduates' CVs will be matched to potential employers (Grech & Camilleri, 2017, p. 85).

The Netherlands is in the planning stage about blockchain implementation. It has created the Dutch Blockchain Commission that involves 20 organisations drawn from the logistics, energy and financial sectors, as well as government and research institutes. They hope that from this seedbed a blockchain infrastructure can develop that is secure, trustworthy, and reliable. Eventually, the Dutch hope to become leaders in the development and application of blockchain technology, but their approach is gradual; they want to test and evaluate blockchain development at each step, making modifications as needed. The Dutch gradualist approach contrasts to Estonia's radical model (Grech & Camilleri, 2017, p. 88). But rapid change in Estonia was galvanised by the country's lack of infrastructure in 1991 when the Soviet Union collapsed and further accelerated by the 2007 cyber-attack.

On the periphery of the EU on the island nations of Cyprus and Malta some innovative blockchain strategies are being introduced. The University of Nicosia (UNIC) in Cyprus is the only university to date that provides full blockchain credentials, including all certificates and diplomas. The university boasts of being #1 in the world for blockchain education (UNIC, 2017). Moreover, it is accepting bitcoin (bitpay) for application fees and tuition payments (UNIC, n.d.). It seems only natural that the university offers courses in cryptocurrencies. UNIC is part of the Blockcerts consortium initiated by the MIT Media Lab – its relationship to MIT dates back to 2015 (Grech & Camilleri, 2017, p. 71). But UNIC uses a variety of tools to improve its system and has designed a strategy to foster its own unique brand.

On the archipelago of Malta another EU nation is employing the MIT developed technology Blockcerts. In January 2017 the Maltese Ministry for Education and Employment (MEDE) signed a contract with Learning Machine (LM), MIT Media Lab's partner, to implement a pilot project for learner and worker owned records (Learning Machine Blog, 2017). Learning Machine's vision matches the Groningen Declaration of 2017 whose mission is to promote the portability of global citizens' skills across borders by sharing authentic educational credentials with whomever they want, whenever they want, wherever they are (Groningen Declaration, n.d.). Something of this vision seems reflected in the Malta project. LM together with the Malta College for Arts Science and Technology (MCAST) plans to design digital diploma templates that can be independently verified as authentic. They will also develop training certificate templates with the local Institute for Tourism. Another innovation at Malta is the workplace equivalency certificate that would give workers official recognition for demonstrated skills even if they do not possess university credentials. The pilot will be studied for its potential for deployment in e-government services such as health care, land registry, vital records, notary and law, drivers' licenses and e-Democracy (Grech & Camilleri, 2017, pp. 76–78). It is an ambitious program and covers most of Malta's infrastructure.

Blockcerts at MIT

In the United States, only the MIT Media Lab has developed a full-scale blockchain education credentialing system. It is using the bitcoin software platform rather than Ethereum because the team at the Media Lab regards it as the more powerful technology and views Ethereum rather condescendingly. The Media Lab's team also feels that because bitcoin is associated with robust financial investment, it has a better chance of survival (Nazaré, Duffy, & Schmidt, 2016). In 2015 an incubator project at MIT Media Lab produced Blockcerts, a digital mobile app for delivering electronic certificates of achievement (Appendix B). The Media Lab collaborated with Learning Machine (LM), a Cambridge, MA based Software Company. In 2015, the Media Lab produced its first blockchain certificates issued to the Director's Fellows, an international group of IT innovators (Schmidt, 2015). Over the years, the MIT partnership with LM has grown. In June 2017, MIT issued diplomas secured by blockchain technology to two groups of students in MIT's Media Arts and Sciences and the Sloan School of Business (Grech & Camilleri, 2017, p. 73). The graduating students had the option to receive their diplomas with the mobile app Blockcerts in addition to the traditional hard diploma (Wilmoth, 2017).

MIT uses the blockchain wallet for storing Blockcerts. Arguably, it solves the problem of the public / private keys that are needed for secure bitcoin blockchain transactions and can be confusing to users. After the wallet has been downloaded, algorithms automatically generate the public / private key combinations which are a series of digital codes. The private key is used to generate the user's cryptographic signature (really a digital ID) needed to verify each transaction. Now the Blockcerts wallet is available on Apple's iTunes and Google Play, but not the Blockcert itself that is issued by the university. Next, the student sends the public key to MIT that makes a digital record of it and returns a hash string of numbers to the student as verification of the authenticity of the diploma. The diploma itself is sent later by e-mail as a JSON file (JavaScript Object Notation file) on which the student's public key information is inscribed. The private key in the student's possession verifies the authenticity of the diploma. However, an employer or another university may seek to further verify the authenticity of the diploma by checking the MIT verification portal by entering the certificate's URL (Durant & Trachy 2017). Verification is sent almost immediately. The portal also lists contact information, giving a phone number and e-mail address for further information (Massachusetts Institute of Technology, n.d.). These measures double the authenticity assurance of the diploma. MIT plans to study and learn from its pilot blockchain projects and from the feedback it receives from the graduating students of 2018 to further develop and deploy the technology (Grech & Camilleri, 2017, p. 74). MIT already has available eTranscripts, but there are forgery and hosting issues that have already been noted.

Philipp Schmidt, director of MIT Media Lab, has been an active promoter of blockchain technology for education. As Schmidt claims, Blockchain and cryptography can now provide the technical infrastructure that would allow for the storage and secure management and distribution of digital credentials (Schmidt, 2015). It puts users in control of their achievements without needing to resort to third parties, most often universities and sometimes former employers, for hosting, validation and reputation. And faking of the blockchained records is more difficult than with the existing paper system. Moreover, the system can accommodate all kinds of document formats (PDF, XML, DOC, etc.) (AACRAO, 2016, May 31). Any tampering can be easily identified. The certifier appends a hashtag that is signed and dated and submits the record. Any tampering is detected by alterations in the hashtag (Schmidt, 2015). The Media Lab has tried to keep the programming specifications as close to Mozilla Open Badges as possible because Schmidt was also one of the authors for the White Paper for the project in 2011 and effort was made to bring uniformity to digital credentialing. All of the Media Lab's codes are in GitHub repository. The lab invites feedback on users' experiences (Nazaré, Hamilton, & Schmidt, (n.d.). At present, a technology that combines Ethereum's smart contract with MIT's Blockcerts does not exist. While the team at MIT's Media Lab is open to Ethereum's smart contracts, it is in no hurry to develop the protocol. The consensus there is that the Blockcert wallet is more accessible option for students to store and manage their digital credentials (Nazaré, Duffy, & Schmidt, 2016).

A Blockchained Future for Open Digital Badges?

Currently there is much discussion and experimentation about storage, access and verification of Open Digital Badges. Badging was the initial response to online credentialing. By the 2010s there was such a proliferation of digital badges that a virtual "wild west" was created in the online learning environment. This effusion was a response to a felt need. It addressed the "skills gap" of youth and adults who did not possess university degrees and others who needed skills upgrades, the lifelong learners. Online learning gave them an opportunity to acquire credentials by "alternative learning pathways." But soon universities recognised an opportunity in the digital credential market. In part to co-opt the competition from private online providers, but also it made sense in a digitally driven world to match credentialing to the needs of the times. Some order was brought to the messy digital badges online environment by Mozilla when in 2011, sponsored by a grant from the MacArthur Foundation, it designed and made available free open digital badges, complete with a short instructional program and free backpacks where users could stack their earned badges (Surman, 2016). Mozilla aspired to create an open digital framework that was transparent and that could be shared in social networks across the web and shown in social networks and e-portfolios. By definition a digital open badge is a shared digital artefact (Willis et al., 2016, p. 24). Mozilla designed Open Digital Badges to be portable and stackable (earned competencies could be stored and arranged and re-arranged as needed). The badges had an image that answered to the designer's taste and needs of the occasion but standardised metadata was "baked into the badge" (information was encrypted within the badge that gave details of issuance complete with electronic signature). Mozilla's encrypted metadata (the specifications) became the unofficial world standard – as they continue to be today. Periodically, the specifications for the badges are updated. With the termination of the MacArthur grant, Mozilla stopped issuing free open badges, but it is still possible to acquire specifications. In 2014 Mozilla launched the IMS Global Learning Consortium, a non-profit educational technology organisations that include many technology providers world-wide. IMS gives access to the specifications (IMS webpage) for the digital open badges which may be downloaded for free; but interested parties must develop their own badges or else pay a provider.

The original badges provided a backpack for storage in the web 1.0 standard and later 1.1. (Casilli, 2016). After long deliberation – and even discussion about phasing out the backpacks (Surman, 2016) – the backpack was updated to support the Open Badges standard 2.0. Yet expect this measure to be temporary. There is currently a Badgechain project underway for user direct access, retrieval and verification (Lemoie, 2017). It draws on both the MIT Blockcerts technology and Smart contract of Ethereum (Otter, n.d.). It is a necessary step because without independent verification, the badges can become worthless. Badges could be "orphaned" or worse turn into "zombie" badges when issuers no longer want or are unable to host them or when a software program falls into disuse even when the credentials earned are still valid. Badges could also be "siloed" and remain unused when verification is problematic. When badges are not supported by networks of trust that a sustainable credentialing system requires, both learners and employers lack confidence in them.

Digital credentialing also presents commercial opportunities. Purdue University in Indiana, a highly ranked in engineering, was a pioneer in designing and applying digital Mozilla apps. In 2012 it designed the Purdue Passport (Passport, 2012). Now the app may be downloaded from Apple's iTunes and Google Play (Passport, 2018). There is a considerable fee, but for students and faculty of Purdue it remains free. It is stated on the app that badges may be stored in the backpack – a stop gap measure at best. No doubt, many users are awaiting Blockcerts to become available for Mozilla Open Badges.

Conclusion

Blockchain promises permanent authentication and storage for the growing alternative credentials market that is made up of various kinds of Microcredentials, nanodegrees, MOOCs, and certificates / badges from various types of training programmes while giving users direct control and management over their credentials. Most of these alternative credentials supplement the education of older learners who received little or no IT training as part of their formal education. Yet today we are all lifelong learners. It is also encouraging that there is growing indication that employers are reviewing the actual competencies of applicants, not just dates of graduation and universities attended (Horn, 2017). In this respect, Blockchained credentials may help to reduce the skills gap. Moreover, Blockchain offers a high degree of security because a distributed ledger is hard to hack.

The most serious problems with blockchain technology are the issues of scalability, privacy and increasing storage capacity. Scalability refers to increasing the speed of blockchain deliveries. The blockchain today is slow and uses a lot of energy. Yet fusing blockchain with AL technologies will increase efficiency and delivery, and blockchain is one of the drivers of Web 3 development. Privacy is another issue since all participating nodes share the information even forever. For now the public /private keys have dealt quite successfully with the problem although the issue will need to be further addressed as well as the related topic of information editing. A further issue is storage. Yet experiments are underway with cloud computing especially the decentralised cloud. And, no doubt, other options will appear. It is also likely that in some areas centralised web options will remain even as the decentralised web develops.

Blockchain at this point is an experimental technology, except in the case of Estonia where it has a longer track record dating back to the cyberattack of 2007. Yet even though the technology is in its infancy, its power, relative security from hacking, and durability make it an attractive option to many respected institutions such as MIT and Open University, UK. At this point, there are many pilots concerning the application of this technology to higher education in Europe, EU and the USA. The field is wide open for future work. More information is needed about the operations of blockchain in a higher education setting. Case studies that would engage the technology in various courses and programmes would be most enlightening about its potential and relevant applications. The most credible models are Open University's smart contracts with Ethereum for storing Microcredentials and MIT's / Learning Machine's Blockcerts. It is not possible to combine the functions at this point because the technology is still under development but advancing rapidly. The dynamic innovations that are occurring in technology almost on a daily basis will sharply increase the demand for lifelong learning in the future. Blockchain promises an infrastructure for learner records that is permanent, secure, and offers reliable management for lifelong learning development, giving learners direct access and control over their achievements. Moreover, the technology supports a constructive learning approach that is student-centred and recognises flexible pathways in education. These developments are fully in line with Standards and Guidelines for Quality Assurance in the European Higher Education Area that requires a more student-centred approach to education and recognition of more flexible learning pathways, including competencies gained outside the formal curricula (Standards and Guideline, 2008). The notion of alternative credentials and the promise of blockchain record management is also supported by the goals of the United Nations Development Programme (UNDP) that recommends accessibility to educational opportunities for all children that will teach them the knowledge and skills necessary to promote sustainable development – goals that are fully endorsed by the EU (UNDP, 2030).

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References

AACRAO (American Association of Collegiate Registrars and Admissions Officers) (2016, May 31). Blog: How blockchain (the foundation for Bitcoin) may revolutionize student data verification. Retrieved 10 October 2017, from http://www.aacrao.org/resources/resources-detail-view/how-blockchain–the-foundation-for-bitcoin–may-revolutionize-student-data-verification

Blockcerts (2017, September). Issue of Blockcerts on Ethereum [under development] [Blog]. Retrieved 20 March 2018, from http://community.blockcerts.org/t/issue-blockcerts-on-ethereum-under-development/348

Casilli, C. (2016, April 7). From Badges to BadgeChain: Part 1 (blog) Medium. Retrieved 11 November 2017, from https://medium.com/@carlacasilli/from-badges-to-badgechain-part-1-d90feaff9514

Derousseau, R. (2017, Dec. 22). Everything you need to know about Ethereum, Bitcoin's biggest rival cryptocurrency, Money. Retrieved 26 March 2018, from http://time.com/money/5073131/what-is-ethereum-everything-know-cryptocurrency/

Domingue, J. (n.d.). OpenBlockchain [video file]. Retrieved 16 November 2017, from http://blockchain.open.ac.uk

Durant, E. & Trachy, A. (2017, October 17). Digital Diploma debuts at MIT. *MIT News*. Retrieved 20 November 2017, from http://news.mit.edu/2017/mit-debuts-secure-digital-diploma-using-bitcoin-blockchain-technology-1017

Gnagey, L. T. (2016, December 16). Registrars from Top Universities Discuss the Transcript of the Future, *Michigan News* Ann Arbor: University of Michigan. Retrieved 23 September 2017, from https://worldclass.umich.edu/registrars-from-top-universities-discuss-the-transcript-of-the-future/ (article has been archived)

Groningen Declaration (n.d.). Groningen Declaration Network, Paris 2018, 18–20 April. Retrieved 20 March 2018, from http://www.groningendeclaration.org/who-we-are/

Grech, A. & Camilleri, A. (2017). *Blockchain in Education*. Inamorato dos Santos, A. (Ed.) EUR 28778 EN. Retrieved from doi: 10.2760/60649.

Gupta, V. (2017, February 28) A Brief History of Blockchain *Harvard Business Review*. Retrieved 11 December 2017, from https://hbr.org/2017/02/a-brief-history-of-blockchain

Gupta, V. (2017, March 6). The Promise of Blockchain is a World without Middlemen, *Harvard Business Review*. Retrieved 22 March 2018, from https://hbr.org/2017/03/the-promise-of-blockchain-is-a-world-without-middlemen

Halpern, S. (2018, January 18). Bitcoin Mania, *New York Review* 65 (1), pp. 52–56. Retrieved 30 January 2018, from http://www.nybooks.com/contributors/sue-m-halpern/

Horn, M. (2017, Jan. 20). Will Alternative Credentials Replace College Degrees? *Forbes* Retrieved 22 March 2018, from https://www.forbes.com/sites/michaelhorn/2017/01/20/will-alternative-credentials-replace-college-degrees/#74743eb61b0e

How Smart Contracts Work (28 Sep. 2017). IEEE Spectrum. Retrieved 15 December 2017, from https://spectrum.ieee.org/computing/networks/how-smart-contracts-work

IMS Global Learning Consortium (Web page). Open Badges (©2001–2018). Retrieved 21 March 2018, from http://www.imsglobal.org/tags/open-badges

Inamorato dos Santos, A. (2017, September 5). Blockchain in Education [video file] Conference presenter at Academiegebouw Rijkuniversiteit, Groningen: European Commission JRC. Retrieved 21 March 2018, from https://www.youtube.com/watch?v=8VY0gv9Sseo

Korjus, K. (2017, Aug. 21). Estonia could offer 'est-coins' to e-Residents, Medium. Retrieved 20 March 2018, from https://medium.com/e-residency-blog/estonia-could-offer-estcoins-to-e-residents-a3a5a5d3c894

Learning Machine (LM) blog (2017, Jan 16). Blockcerts and learner owned official records: an interview with Learning Machine. Retrieved 20 March 2018, from https://medium.com/learning-machine-blog/blockcerts-and-learner-owned-official-records-f02ecfb785a9

Lemoie, K. (2017, October 26). Innovations in Open Badges & Blockchain, *BadgeChain* Retrieved 26 October, from http://badgechain.com/innovations-in-open-badges-blockchain/

Maney, K. (2017, September 17). How Amazon, Apple, Facebook and Google could be toppled by blockchain, *Newsweek*. Retrieved 26 March 2018, from http://www.newsweek.com/2017/10/20/amazon-apple-facebook-google-toppled-blockchain-680513.html

Matthews, D. (2017, August 31). What Blockchain Technology could mean for Universities, Times Higher Education World Rankings. Retrieved 20 March 2018, from https://www.timeshighereducation.com/news/what-blockchain-technology-could-mean-for-universities

Massachusetts Institute of Technology (n.d.). MIT Degree Verification. Retrieved 21 March 2018, from https://credentials.mit.edu/

Nazaré, J., Duffy, K. H. & Schmidt, P. (2016, June 2). What we learned from designing an academic certificates system on the blockchain, MIT Media Lab (blog). Retrieved

12 November, from https://medium.com/mit-media-lab/what-we-learned-from-designing-an-academic-certificates-system-on-the-blockchain-34ba5874f196

Nazaré, J., Hamilton, K., & Schmidt, P. (n.d.). MIT Media Lab, Digital Certificates Project. Retrieved 22 September 2017, from http://certificates.media.mit.edu/#home

Otter, M. (n.d.). Everything You need to know about Digital Badging 2.0. [Blog] Retrieved 11 January 2018, from https://www.participate.com/blog/everything-you-need-to-know-about-digital-badging-2-0

Passport (2018). Purdue University. Retrieved 21 March 2018, from https://www.openpassport.org/Account/Login?ReturnUrl=%2f#WhatIsPassport

Passport (2012, September 12). Purdue.edu/studio, Purdue News. Retrieved 21 March 2018, from http://www.purdue.edu/newsroom/releases/2012/Q3/digital-badges-show-students-skills-along-with-degree.html)

Recommendation of the European Parliament and the Council (2008, April 23). On the establishment of the European Qualifications Framework for lifelong learning.

Schmidt, P. (2015, Oct. 27). Certificates, Reputation, and the Blockchain, MIT Media Lab. Retrieved 25 March 2018, from https://medium.com/mit-media-lab/certificates-reputation-and-the-blockchain-aee03622426f

Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG). (2015). Brussels, Belgium.

Surman, Mark (2016, Jan. 29). Mozilla Learning. Retrieved 27 March 2018, from https://learning.mozilla.org/blog/mozillas-continued-commitment-to-open-badges

UNDP (United Nations Development Programme) 2030. Support to the implementation of 2030 Agenda for Sustainable Development .

UNIC (University of Nicosia) (2017). Academic Certificates on the Blockchain up to Mar 2017. Retrieved 3 December 2017, from https://digitalcurrency.unic.ac.cy/free-introductory-mooc/self-verifiable-certificates-on-the-bitcoin-blockchain/academic-certificates-on-the-blockchain/

UNIC (University of Nicosia) (n.d.). Payment Options. Retrieved 26 March 2018, from https://www.unic.ac.cy/study/admissions/financial-information/payment-options#

Walt, V. (2017, April 27). Is this tiny European country a preview of our tech future? *Fortune* Retrieved 25 March 2018, from http://fortune.com/2017/04/27/estonia-digital-life-tech-startups/

Web 3 – the Decentralized Web (n.d.). Blockchain Hub. Retrieved 26 March 2018, from https://blockchainhub.net/web3-decentralized-web/

Willis, J. E., Flintoff, K. & McGraw, B. (2016). A Philosophy of Digital Open Badges. Editors Dirk Ifenthaler, Nicole Bellin-Mularski & Dana-Kristin Mah. *Foundation of Digital Badges and Micro-Credentials,* Switzerland: Springer, pp. 23–40.

Wilmoth, Josiah (2017, October 23). MIT issues diplomas using the Bitcoin Blockchain, *Cryptocoins News*. Retrieved 6 December 2017, from https://www.cryptocoinsnews.com/mit-issues-diplomas-using-bitcoin-blockchain/

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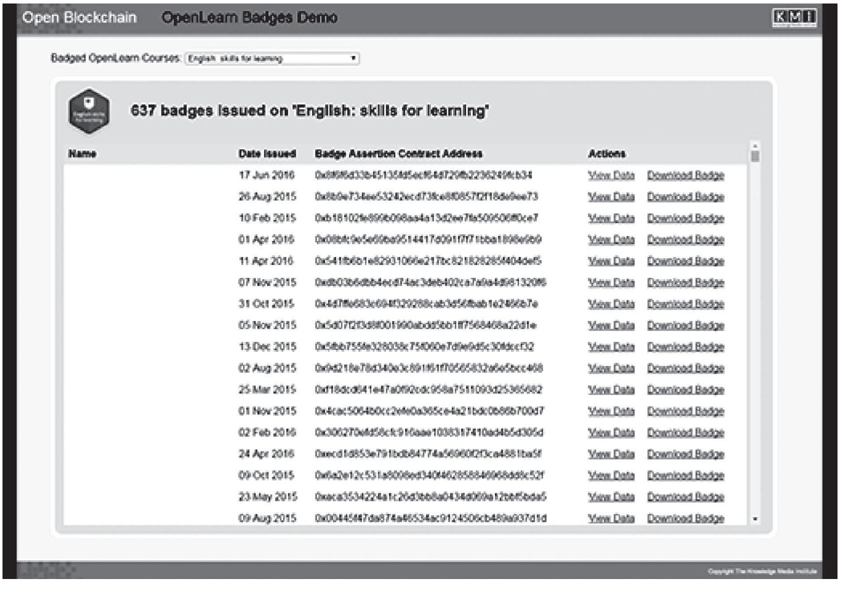
Appendix A

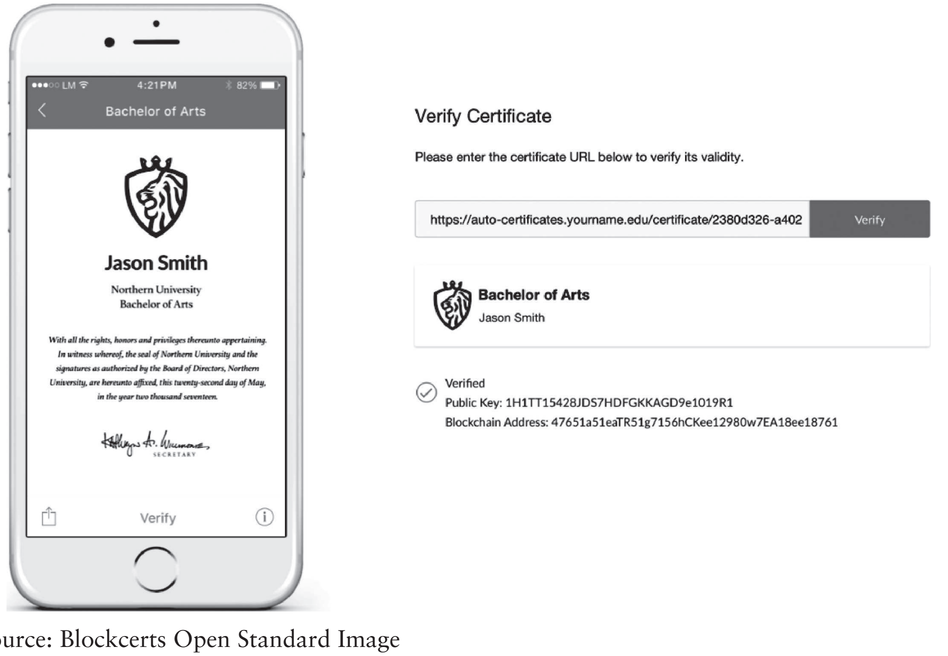
KMI Open Learn: Image of Smart Contracts as a Record for Microcredentials (Badges)



Source: Knowledge Media Institute (KMI), Open University, UK, OpenLearn

Appendix B

Blockcerts Model Image of Blockcert and verification similar to the MIT model



Source: Blockcerts Open Standard Image