Blockchains and Education

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1 Introduction and scope

The theme of this paper is the use of blockchain and distributed ledger technology for education. The scope for the state-of-the-art is global, but conclusions and recommendations focus on the significance and barriers in the European context.

We assume general familiarity with blockchain and smart contract technology. For the purposes of this document, the essential features are that a blockchain has no central data controller or storage, and that it is an append-only immutable record store with reliable timestamping. More specific details, such as consensus mechanism, which vary from one blockchain network to another, are omitted.

2 Stakes

The technological and social ecosystem around education is extremely broad and diverse, with multiple stakeholders – learners, educators, employers, governments, and so on – each of whom interact in multiple ways and with great significance in the outcomes. For example, individuals' educational interactions may have significant effects on their careers and earning, much as recruitment based on educational information may represent significant and risky investment on behalf of an employer. Decentralised and "trustless" blockchain technology, in the sense of an immutable reference ledger of historical activity, to which multiple parties can refer without any one party being required to trust any other, can play a useful role in high-stakes spaces such as education.

This paper surveys the activities ongoing in the use of blockchains for education globally, with a particular focus on European applications, and taking into account the risks, particularly those associated with data protection and privacy.

3 Themes

The uses of blockchain for education can be divided broadly into two themes, which are a) **certification and the recognition of learning**, and b) **disintermediation and collaboration**. We group the ongoing initiatives in this area under these themes.

In applying blockchains to education, the primary driving factors seem to be a) verifiability & trust, and b) decentralisation, in the form of decentralised control, storage, or both. The proposed benefits deriving from blockchains in education ultimately rely on these factors. While cryptocurrencies do feature as well, the focus is, on the whole, on immutability and decentralisation. There has also been, unfortunately, the tendency at the height of the blockchain hype for initiatives of the form "do X, but on the blockchain", with little description or reasoning as to the relevance of blockchains to the performance of X. In compiling this report, we have attempted to filter these out while also trying to retain interesting radical ideas.

3.1 Certification, accreditation and the recognition of learning

Verifiable qualifications The primary focus of effort in the area has been for the provision of verifiable digital qualifications. Educational recognition has all the key properties of a blockchain use case: there are multiple parties (educational institutions, learners, employers, recruiters, governments, and so on), who each may need to interact with the data, the items to be recorded in the ledger have real value to the parties (in terms of career, income, and productivity, among others) and, therefore, there are reasons for a lack of trust in, or a desire not to have to depend on, others. Learners have an incentive for their qualifications to appear as high quality as possible, employers need to be sure they are hiring the right people, institutions want to be able to market their courses as leading to good careers, etc. There are reports claiming frequencies such as 200 000 fake diplomas in the US per year, sold to fraudulent jobseekers for prices between $100 to $50000[1].

[1] `https://nooor.io/blockchain-in-education`

The notion, then, is that distributed ledgers can serve as the guarantors of the authenticity of educational credentials. An immutable record of, say, a degree, stored on a blockchain and signed by the (known) public key of the issuing university can be a decentralised trusted source of information, and can be used to verify the certificate's contents and provenance, without relying on the graduate's honesty and without needing to contact the (possibly remote or no longer existing) university. The use of "self-sovereign identity" systems (discussed later) backed by distributed ledgers can also provide guarantees that the person presenting a verifiable qualification is the person who earned it, preventing false use of another person's credentials.

Initiatives relating to blockchain-verified qualifications (BVQs) include the authors' own OpenBlockchain and LinkChains projects[2], the University of Nicosia[3], Learning Machine[4], the Fraunhofer Institute's FIT4Edu[5], and Sofocle Technology[6], among others.

Reported as the first educational institution to do so, Nicosia issued credentials for one of its Masters programmes using the Bitcoin blockchain as an anchor. Learning Machine uses a similar approach, batching issuances together and issuing an entire batch at once; the Merkle tree data structure used allows any member of a batch to be verified with qualification data and a "proof", both of which the student holds and shares as desired, checked against the relevant Merkle tree root on a blockchain. The cryptographic properties of a Merkle tree are such that only the root needs to be immutably recorded for any associated proof to be reliably verifiable. Learning Machine provide BVQs for, among others, MIT[7] and the US Federation of State Medical Boards[8]. The Open University's OpenBlockchain initiative is testing a number of ways to handle BVQs, from data directly in smart contracts, to the issuing of unique non-fungible cryptotokens with qualification metadata, to Merkle trees representing the structure of the underlying semantic Linked Data. The latter approaches reflect the OU's LinkChains goal of being a general purpose verified Linked Data platform, for which education is one use case. FIT4Edu is also an Ethereum-backed platform.

On top of individual initiatives, a number of countries are investigating or using BVQs. As well as the UK IoC, applying to a specific subject area, both Malta and Armenia are supporting more general solutions.

A step beyond individual qualifications is the notion of combining records to create a "verified CV". Companies such as Appii[9], Gradbase[10], EchoLink[11], Chronobank[12], and Disciplina[13] are seeking to fill a role in the recruitment sphere of helping jobseekers to aggregate verified qualifications and offer job-matching services based on verified CVs.

Verification of qualifications and CVs can offer a number of benefits, as noted in a number of articles and initiatives. We group them here under efficiency, self-sovereignty and identity, and widening access.

3.1.1 Efficiency

The potential to present a digital CV to employers, which can be automatically verified at application time, saves both candidates, recruiters, and employers time and money[14]. Reducing the need for manual, paper-based verification has strong potential to reduce the gap between a job offer being made and productive work beginning, as well as reduce fraud. The estimated cost of a "bad hire" is between $7 000 and $40 000[15]; measures to reduce factors leading to this are likely to have real economic benefits. Such an effect is likely to be even more in the case of job applications across national borders, where there are more points at which manual verification could be slower and more involved.

[2] https://blockchain.open.ac.uk
[3] http://unic.ac.cy
[4] https://www.learningmachine.com
[5] https://dl.eusset.eu/bitstream/20.500.12015/3132/1/escw2018_p7.pdf
[6] https://sofocle.com
[7] https://mit.edu
[8] https://www.fsmb.org/blockchain
[9] https://appii.io
[10] https://gradba.se
[11] https://en.echolink.info
[12] https://chronobank.io
[13] https://disciplina.io/en/technology
[14] https://evolllution.com/technology/tech-tools-and-resources/higher-education-and-the-blockchain-ecosystem-an-overview/
[15] https://nooor.io/blockchain-in-education

Time efficiency gains can also stem from more in-depth analysis of a person's education profile[16]. Brandman University[17] focuses largely on the education of people already in work, aiming to maximise the efficiency of further learning by analysing their records and experience to identify skills which they can already demonstrate they have learned. If a course involves some elements aimed at teaching those skills, then those elements can be skipped, so as not to duplicate learning which has already taken place.

Decentralisation technology has also been proposed as a means for institutions to be more efficient in terms of use of resources. If student and alumni data can be trustably held by individuals instead of by institutions, it has been argued[18] that this could save institutions money, and protect against damage of physical documents, although such data security depends on the form of decentralised storage, and how much redundancy is involved. The total volume of data to be held remains the same, but decentralisation of *who* is holding it may be more efficient.

While greater redundancy (duplication of data across multiple locations) means greater data security, it can come at the cost of at a greater use of storage resources across the decentralised network *as a whole*. The immutability of a blockchain stems in part from the fact that copies of all of the data on the chain are held by many, or all, of the participants in the network. It is not clear how these resources might be funded, nor what the privacy implications might be of such widespread duplication of data. Payable decentralised networks, such as FileCoin[19], have been suggested[20] for student information, but with no discussion of privacy.

3.1.2 Self-sovereignty and identity

One of the affordances of blockchain technology, lacking centralised control and with certain levels of security and immutability of data, is the concept of "self-sovereign identity" (and, indeed, self-sovereignty with regard to data in general)[21]. In currently widely used centralised models, different identity providers (e.g., a university, an employer, a social network) host and control accounts to which individuals hold credentials. To interact digitally in a context which involves identity, a user must authenticate with the relevant identity provider for that context. This requires either multiple identities and sets of credentials for many contexts, each of which is controlled by the relevant provider, or the use of a "central" identity provider (often a social network provider) on whom different services must rely. The latter option grants considerable power to the central provider, who can then keep track of an individual's digital interactions across contexts. Self-sovereign identity is, by contrast, a model in which every user controls their own digital identity, and can present credentials to online services which can be verified against blockchain records in a privacy-preserving fashion, including limiting the chances of being tracked across multiple services. Users therefore have sovereignty over their own digital identities. Similar notions can be applied to user control of their data in general: personal data can be kept by its owner, and shared and used under their control. This is the motivation behind the Solid platform[22] from Sir Tim Berners-Lee, for example.

In education, self-sovereignty is of interest in relation to privacy and reliability. A person's educational history is personal data, and may even reveal sensitive information (for example, political or religious views), for which they may want to control disclosure. In terms of reliability, if the trusted source of truth for their educational history is, as is currently typical, a set of multiple institutions with varying degrees of permanency and potentially located across the world, there are risks that some of that information could become inaccessible or difficult or impossible to verify, or could be disclosed against their wishes[23]. Inaccessibility and difficulty in verification may also make it easier for individuals to use fake qualifications without being discovered, and, without a trustable form of digital identity, it may be possible to make fraudulent use of genuine qualifications belonging to another person.

[16] https://www.forbes.com/sites/oracle/2018/07/12/edtech-startup-to-release-blockchain-based-lifelong-learning-ledger/
[17] https://www.brandman.edu
[18] https://medium.com/universablockchain/blockchain-in-education-49ad413b9e12
[19] https://filecoin.io
[20] https://nooor.io/blockchain-in-education
[21] https://www.computerworld.com/article/3244128/how-blockchain-makes-self-sovereign-identities-possible.html
[22] https://inrupt.com/solid
[23] https://www.ibm.com/downloads/cas/93DDVAKE

Student ownership of lifelong learning credentials may provide data visibility controls, with no need to trust or rely on third-parties, and, conversely, and relating to some of the efficiency concepts above, no need for those third-parties to manage those credentials.

Beyond qualifications, educational institutions may also collect very fine-grained records of student activities during the learning process in order to enable learning analytics, to improve the quality of education offered. The use of self-sovereign approaches to learning activity data, and institutional research in general, has been suggested[24] and it is one of the use cases being investigated in the authors' own LinkChains project.

Privacy and data protection principles of course revolve around consent, and secure collection and verification of consent is a clear instance where blockchains may be useful. One report[25] considers Bitcoin, Ethereum, and Ripple as possible bases for consent management.

The uses of blockchains in education in themselves also attract concerns with regard to privacy; this is a particular focus in the US Dept. of Education Office of Educational Technology[26] Education Blockchain Action Network. Decentralised and widely duplicated data which cannot be edited or deleted easily can, if managed poorly, have great risks for individual privacy.

One motivation for decentralisation of student records (and accreditation) is that it also secures access to credentials for people in vulnerable or unstable situations[27], e.g., in or fleeing war or seeking asylum.

3.1.3 Widening access

A consequence of BVQs making educational qualifications more easily and efficiently verifiable is that it can become more practical to issue qualifications for smaller and more specific units of learning, from competency-based assessment, and from more diverse sources[28], where historically the infrastructure required to give trustable value to qualifications may not have been feasible. For example, while continuous professional learning and development is common, it is rarely possible to prove reliably that it has taken place outside of the workplace where it occurred, as many employers do not have the resources or inclination to provide verification. The idea of microaccreditation is already established – and formed part of the motivation for digital badging initiatives such as OpenBadges[29] – but the verification possibilities which arise from combining blockchains with microaccreditation open significant new opportunities. Indeed, many of the BVQ platforms mentioned earlier use the OpenBadges format for all their BVQs – OpenBlockchain, FIT4Edu, and Learning Machine included, for example.

One motivation for microcredentialling for more diverse forms of learning is to improve the recognition of learning among groups who may be disadvantaged with regard to traditional education. The idea has been proposed[30] of proactive recruitment of students from disadvantaged groups, by automatic analysis of academic records to identify capable students with less of a risk of social bias. This approach, however, does not seem to be compatible with self-sovereign approaches, involving machine analysis of a large set of academic records, and it does not take account of the fact that disadvantaged groups may be disadvantaged when it comes to building up a formal academic record in the first place.

By contrast, the US Dept. of Education EQUIP initiative (Educational Quality through Innovation Partnerships), supports the recognition of a variety of forms of learning for students from lower-income backgrounds, precisely to overcome this issue.

3.2 Disintermediation and collaboration

Collectively, the above possibilities for blockchains and education form a basis for enabling deeper collaboration within, and disintermediation of, the educational landscape[31], with intellectual property protection

[24] https://evolllution.com/technology/tech-tools-and-resources/higher-education-and-the-blockchain-ecosystem-an-overview/
[25] https://www.learnovatecentre.org/using-blockchain-for-consent-management/
[26] https://tech.ed.gov/blockchain/
[27] https://www.cognizant.com/whitepapers/blockchain-goes-to-school-codex3775.pdf
[28] https://edtechmagazine.com/higher/article/2018/08/universities-use-blockchain-streamline-student-services
[29] http://openbadgespec.org
[30] https://www.ibm.com/downloads/cas/93DDVAKE
[31] https://www.cognizant.com/whitepapers/blockchain-goes-to-school-codex3775.pdf

and "trustable mashups" of different aspects of educational processes from different stakeholders, to create a "meta-university"[32].

There are many examples of initiatives in which blockchains are intended to mediate between different participants in education, allowing some form of "mix and match" creation of educational pathways. The Brandman University example mentioned earlier is an instance of this, with recognition of already-learned skills allowing learners to miss out redundant elements of existing courses. LEDU[33] focuses on online tuition in technical subjects, including a cryptocoin which is intended to be used to incentivise participation in learning, teaching, app development, and quality control, with the idea that teaching materials, support, apps, and educational standards could be combined to provide a highly personalised "course". ODEM[34] is similar, including, alongside course provision and certification, payment and recruitment backed by smart contracts on Ethereum, as is BitDegree[35], Open Source University[36] and Woolf University[37]. The latter is aided by a pilot project from the Maltese government[38], and is intended to incorporate face-to-face as well as online education, based loosely on the tutorial model from traditional UK universities such as Oxford.

Automated and verifiable credit transfer is another tool which could support educational disintermediation. An implementation has been proposed[39], following the European Credit Transfer System (ECTS)[40]. The line between credit transfer and microaccreditation is thin; there is little practical difference between recognising sub-course "credits" from another institution, and recognising small sub-course qualifications.

The current model of education and assessment centres around student work being shared within an educational context with a suitable assessor to relate it to some educational standard, leading, if successful, to a specific qualification, with, often, only the qualification itself being shared outside that educational context. Keeping assessment near to direct contact with the student allows the qualification to be determined with some certainty of the student's identity and authorship of their work. Given the verification and identity technologies made available using blockchains, there is potential for disintermediation in this step: for example, ePortfolios anchored on blockchains17 can allow post hoc application of educational assessment/standards – a piece of work can be demonstrated to be the work of a student whose identity can also be verified, and multiple assessors, independently and in different contexts, can examine it and assign possibly different educational values, as relevant to each particular situation individually.

Some proposals which are more radical still include the "Learning is Earning"[41] vision of learning from any source - formal, informal, occupational, and so on, with all records in terms of learning "units", to form a public record of collective learning and working. Significantly, the concept is to track earning related to individual units, in order to support the identification of where the specific earning value is to be found in a particular piece of learning, and enables educational activity to be funded per-unit against the future earnings it is expected to enable. A similar idea has been proposed with regard to self-sovereign educational data: that disclosure of personal data could be an exchangeable asset used to fund an individual's education[42]. The "Youth Education Chain League" proposal[43] from a consortium of Chinese universities is to provide a decentralised model for collaboration and sharing between universities based on the creation of a Distributed Autonomous Organisation (DAO)

[32] *ibid.*, 18
[33] https://ledu.education-ecosystem.com/
[34] https://odem.io
[35] https://www.bitdegree.org
[36] https://os.university/
[37] https://woolf.university/
[38] https://usethebitcoin.com/the-first-blockchain-university-may-open-in-malta/
[39] https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8247166
[40] https://ec.europa.eu/education/resources-and-tools/european-credit-transfer-and-accumulation-system-ects_en
[41] http://www.learningisearning2026.org/
[42] *ibid.*, 13
[43] https://www.coindesk.com/china-universities-plan-blockchain-dao-for-affordable-education

4 Relevance to European context

There are already initiatives at the European level regarding (or considering using) blockchains and digital education, including SEAL[44] (student and researcher digital identities), QualiChain[45] (decentralised qualifications applied to the public sector) and DEL4All[46] (coordinating blockchain and digital learning projects). QualiChain in particular covers many of the areas discussed above, across education, recruitment, and employment, with blockchain-backed microaccreditation, job matching and career analytics. These projects, and the JRC report on blockchain and education in Europe[47], indicate a strong interest in, and relevance of, these topics in the European context.

4.1 Cross-border interoperability

The freedom of movement and employment across the European Union is aided by a common understanding of educational achievement and qualifications. In particular, measures to improve the timeliness of hiring processes, including the verification of qualifications, could be of significant benefit. More fine-grained, trustable, and interoperable recognition of learning also has the potential to improve opportunities for movement cross-border within education and professional spheres, and to widen access to educational opportunities within the Union for a wider range of people. Several current European educational programmes focus on the question of the mobility of educational achievements across borders. The Bologna Process[48] is intended to provide for the structural compatibility of (particularly higher) education across Europe, and for mutual recognition of learning and educational standards. More technically, the Europass initiative[49] establishes standard representations for CVs and records of language, vocational, and academic skills, and of skills learned during time spent abroad in other European countries. The eIDAS regulation[50], while not specifically aimed at education, provides for interoperability of digital identity services.

Neither the Bologna Process nor Europass, at least as currently defined, deal with the *verification* of qualifications, and nor do they or eIDAS address decentralisation for education and educational recognition.

4.1.1 GDPR

Decentralisation carries both potential and risks when it comes to data protection and privacy. Properly managed, self-sovereignty has the potential to simplify compliance with regulations such as the GDPR and to provide individuals with better control of their own data. This has particular value when compliance and control can be enabled at a pan-European level. Making sure that these technologies are in fact properly managed (and ascertaining what proper management means) is a challenge which could also be better managed by sharing knowledge and best practices. Open questions Distributed ledger technology is still in its infancy, but education has attracted significant attention in this area since it became more widely-known. There are nonetheless some questions and issues which may serve as barriers to its adoption as an effective addition to the educational technology toolbox.

5 Known barriers

Governance, data protection & privacy: a number of the initiatives or proposals described here involve differences in the division of responsibility for various tasks, processes, and data, in comparison with currently-used approaches. It is important that governance be implemented appropriately in order to

[44] https://ec.europa.eu/inea/en/connecting-europe-facility/cef-telecom/2018-eu-ia-0024

[45] https://qualichain-project.eu

[46] https://del4all.eu

[47] https://publications.jrc.ec.europa.eu/repository/bitstream/JRC108255/jrc108255_blockchain_in_education\%281\%29.pdf

[48] https://ec.europa.eu/education/policies/higher-education/bologna-process-and-european-higher-education-area_en

[49] https://europass.cedefop.europa.eu/

[50] https://ec.europa.eu/digital-single-market/en/trust-services-and-eid

protect the interests of those who rely on them. A failure to develop appropriate governance models and implementations could have serious consequences for the development of this area and for individual stakeholders. This is particularly relevant when it comes to data protection and privacy, where reliable implementation of principles and legislation is essential, and education and tooling to support users in them will be required.

Interoperability & standards: we have discussed scenarios which admit many new participants to the issuance of educational qualifications (for example, in CPD). The value for existing and new stakeholders can only be realised if the systems for describing, sharing, and verifying qualifications work well together without reintroducing centralisation; this requires openness in technical standards. Beyond the technical, the issue of semantic interoperability is important: the meaning of credentials and identities, and what goes into them, should be understandable by both humans and machines, in order to realise the full benefits. These are not trivial issues to address correctly.

Transition & organisational change: some of the potential for distributed ledgers in education may be highly disruptive to existing ways of doing things. The balance between necessary caution and care, and avoidance of change, is difficult to strike. Even with non-controversial developments, education and employment form a large and complex ecosystem with many interactions between stakeholders, making organisational changes difficult and requiring management.

6 Unknown barriers

Risks of decentralisation: a corollary to the complexity and interdependent nature of the ecosystem in education and employment is that it is very difficult to assess the consequences of changes and new developments. The costs of unforeseen negative consequences in such an important area may be significant, and it is important to identify risks as early as possible.

Technical sustainability and robustness: blockchains are a relatively new technology, and undergoing rapid development. The maturity of the technologies and solutions used is a significant factor.

7 Conclusion and potential actions

Based on the findings here, the following actions are recommended to promote the most effective use and take-up of blockchain-based systems for education in Europe:

- Coordinate existing applied and research efforts at both technical and social levels, including risk analyses and mitigations. As well as avoiding duplication of effort, coordination may help to establish standards and open solutions, and provide a wider view of the risks and difficulties that may arise in practice.
- Promote the extension of existing interoperability standards to accommodate decentralisation and self-sovereign models - for example, qualification and CV standards such as Europass and identity regulations such as eIDAS. Alongside this, it is recommended to ensure that relevant other regulations (e.g., GDPR) are kept up to date with relevant technological developments.
- Take a leadership role in establishing the use of decentralised technologies in education, and develop continent-wide routes for the transfer of beneficial developments to larger-scale use.
- Support research, innovation and development for blockchain-based educational services via programmes relating to the Digital Single Market and the Horizon 2020/Horizon EU programmes.