# Decentralising online education using blockchain technology

Conference or Workshop Item

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**Abstract**

Blockchain technology provides a decentralised peer-to-peer infrastructure, supporting openness, transparency, accountability, identity management and trust. As such, the Blockchain has the potential to revolutionise online education in a number of ways. Blockchain technology offers opportunities to thoroughly rethink how we find educational content and training services online, how we register and pay for them, as well as how we get accredited for what we have learned and how this accreditation affects our career trajectory. This paper explores the different aspects of online education that are affected by this new paradigm. In particular, we investigate the different scenarios where the use of Blockchain technology can make online education more open and decentralised, while placing learners in control of their learning process and its associated data. Additionally, we discuss various approaches to the Semantic Blockchain and the applications of these approaches on online education.

**Keywords:** Blockchain, Decentralisation, Lifelong Learning, Accreditation, Semantic Blockchain.

## 1. Introduction

Education today is still controlled mostly by educational institutions, which offer quality, credibility, governance, and administrative functions. This model is not flexible enough and poses difficulties in recognising the achievements of a lifelong learner in informal and non-formal types of education. As a result, a lifelong learner's transition from formal to informal education and vice versa can be hindered, as the achievements acquired in one type of education are not easily transferable to another (Harris & Wihak, 2017; Lundvall & Rasmussen, 2016; Mayombe, 2017; Müller et al., 2015). Generally, lifelong learners have limited control and ownership over their learning process and the data associated with their learning. This indicates the need for a decentralised model across all types of education, offering learners with a framework for fully controlling how they are learning, how they acquire qualifications and how they share their qualifications and other learning data with third parties, such as educational institutions or employers.

The emergence of the Blockchain promises to disrupt online education by offering the technological means to decentralise it. Blockchain technology offers a decentralised peer-to-peer infrastructure where privacy, secure archiving, consensual ownership, transparency, accountability, identity management and trust are built in, both at the software and infrastructure levels. Although Blockchain technology introduces immutability and trust, we should also take advantage of the vast wealth of existing data and standards for decentralised data publication and consumption on the Web. In particular, one of the core design principles of the Semantic Web is the assumption that data can be published anywhere online, and by anyone, and that it should be possible to query and integrate that data without aggregating it all into a central location. We argue here that a *Semantic Blockchain*, encouraging interoperability between Blockchain platforms and the Semantic Web, is essential to get the most out of both technologies. This is especially important in the education sphere, where learning experiences and accreditation can be acquired from diverse independent sources and according to different learning approaches, contexts and standards, but which still need to be drawn together to form a coherent and understandable picture of an individual's lifelong learning.

The remainder of this paper is organised as follows. First, we present a decentralised approach for online education based on the Blockchain, as well as a scenario showcasing the benefits of this approach for lifelong learners. We then discuss the different approaches to the Semantic Blockchain and their applications on online education. Finally, the paper is concluded and the next steps of this work are outlined.

## 2. A decentralised approach for online education

Within the decentralised model of educational transactions shown in Figure 1, learners create single authored or shared artefacts with their peers. At the same time, learners are enrolled on a number of courses and are making use of additional learning resources. Tutors and other teaching staff are providing informal and formal feedback as the learners complete summative and formative assessment. Central administration bodies are issuing formal certificates according to institutional processes.

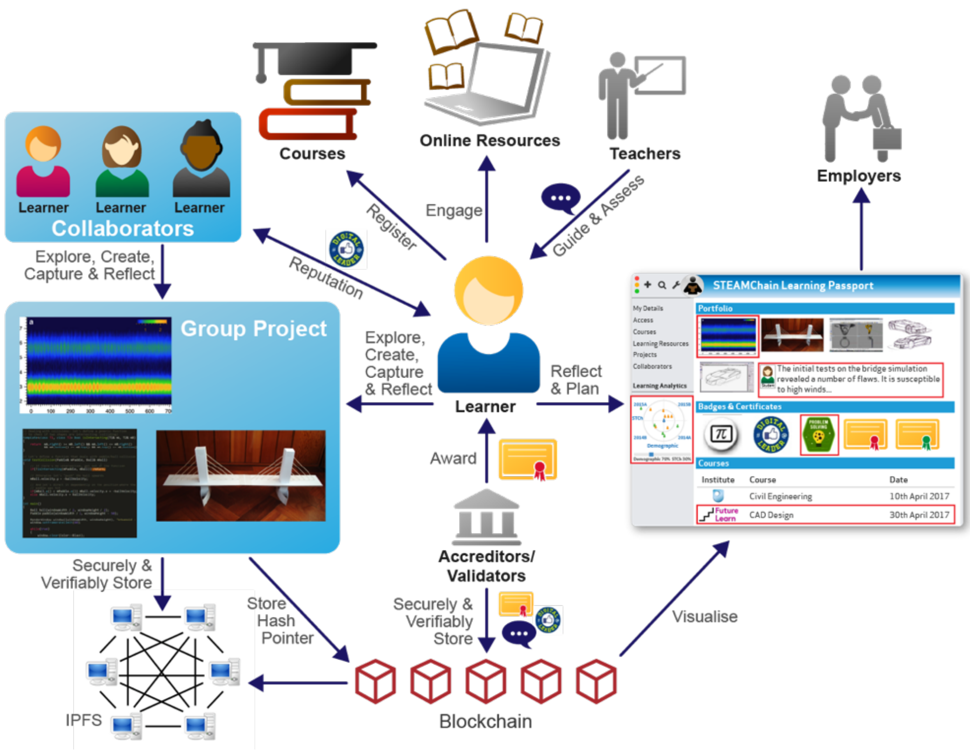


Figure 1: A decentralised model of educational transactions.

On top of these processes, we layer a reputational ecosystem, which allows learners to rate courses, online resources and teachers in terms of ease of understanding and attributes related to their specific learning goals. Learners can also rate each other on a range of qualities including, for example, organisational and communication skills. Our early work in applying this approach to academic reputation can be found at (Sharples & Domingue, 2016).

All data about learners' accreditation, work, ratings, formal and informal feedback are stored within a framework where everything is verifiable via the Blockchain. Because of the associated costs, large data files are usually not stored on the Blockchain. Typically, large files are stored elsewhere (off-chain) and referenced using a cryptographic hash. In the model depicted in Figure 1, we propose the use of IPFS for storing the learner's documents. This solution reduces storage costs and, at the same time, enables the validity of a document to be checked.

The following scenario demonstrates the potential impact of this decentralised approach on lifelong learning. Let us consider Jane, who works as a Junior Data Analyst in a London-based company. She is 30 years old and holds a B.Sc. in Computer Science. She is keen to advance her career in the field of Data Science; however, her demanding work schedule and daily commute do not allow her to return to full-time education for acquiring further qualifications. She is interested in informal and non-formal methods of learning, but she also seeks to acquire some type of accreditation for her learning.

Jane creates her personal Learning Passport, as shown in Figure 2. This is powered by Blockchain technologies and offers, among other things, a learning portfolio, as well as opportunities for social learning and peer mentoring. A core feature of Jane's Learning Passport is the provision of Smart Badges, which allow for detailed recording of accreditation in digital form from both formal and informal learning contexts with additional dynamic features. For example, apart from just recording a learning achievement, a Smart Badge can also offer job or course recommendations (Mikroyannidis, Domingue, Bachler, & Quick, 2018).

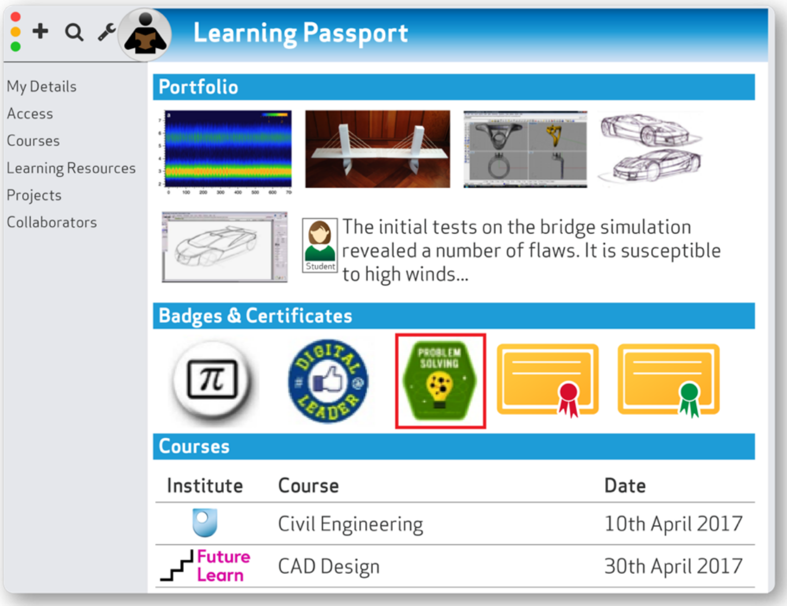


Figure 2: Example of a Learning Passport.

Jane enrols to relevant open online courses offered by Higher Education Institutions (HEIs) in the UK and abroad, as well as relevant Massive Open Online Courses (MOOCs). Upon completion of these courses, she acquires certifications in the form of Smart Badges, which are added to her Learning Passport. Apart from just evidence of learning, the Smart Badges that Jane has earned can be used as dynamic accreditations in a number of ways, thus helping Jane in achieving the following goals:

- Finding new courses based on the gap between Jane's current skills and her desired jobs.
- Finding new job opportunities that match Jane's qualifications.
- Acquiring job promotions based on the new skills that Jane has mastered.
- Networking with other professionals and learners with similar backgrounds and learning goals as Jane.
- Identifying other learners that Jane can mentor and tutor in exchange for money or reputation points.

Jane is building her learning portfolio, which consists of the courses she has enrolled to, her assignments and the results of other exercises she has completed, such as quizzes, as well as the Smart Badges she has earned. All data in this portfolio is owned by Jane, who can also encrypt it or select subsets of it for release to others for a fixed duration. For example, Jane can release parts of her portfolio to potential employers two weeks before an interview. She may also offer access to HEIs, educators, trainers and other learners that follow a similar learning journey.

All transactions associated with Jane's Learning Passport are signed and time-stamped. The fact that the transactional record is visible to all and immutable resolves many of the problems associated with identity and fraud. As all data is permanently accessible, different consensual mechanisms can be put in place to link learner work to formal feedback and assessment. If desired, any principles underlying formal statements can be encoded in Smart Contracts, which allow the encoding of organisational rules, so as to be explicit for any interested party.

Jane finds micro-courses that have been produced by independent tutors and gains access to them via micro-payments, similar to purchasing an app on her smartphone. She studies these micro-courses and offers her feedback via ratings that count as reputation points for the authors of these learning materials. Other tutors can also reuse and repurpose these learning materials, upon agreement with the original authors. Jane decides to produce a free micro-course on the R programming language, based on what she has learned, in order to earn reputation points and enrich her portfolio.

Additionally, Jane has access to a network of learners that study together online and mentor each other. She chooses to mentor an early career data scientist in basic data analytics methodologies. She thus gains reputation points for acting as a mentor in this field. In return, she receives tutoring by an expert in Machine Learning and offers reputation points to her mentor. All these transactions are stored on the Blockchain, thus enabling easy transfer between units or organisations if needed and the automatic detection of any abuse of the system, for example pairs or small groups of employees favouring each other.

Jane is gradually building a strong portfolio in Data Science, with proof that she has gained advanced knowledge based on her earned badges, reputation points, as well as her learning activities and produced artefacts, all of which are recorded and stored in her Learning Passport. Even though she has not returned to formal education, she is now in a much better position to seek a promotion and advance her career.

## 3. The Semantic Blockchain

The Web is ubiquitous and provides one of the primary interfaces for humans to interact with digital data. By combining technologies especially from the Semantic Web with the Blockchain, the resulting *Semantic Blockchain* has the potential to promote highly interoperable trusted data, with significant applications to education.

The Semantic Web[1] is a collection of technologies and standards for the publication and consumption of machine-interpretable data at Web scale and according to the decentralised Web publication model. In particular, Linked Data, most commonly using the RDF data model[2], is intended to serve as a standard for self-describing Web data, encapsulated by the Linked Data principles (quoted here from a W3C design note by the Web’s creator, Sir Tim Berners-Lee[3]):

1. Use URIs as names for things.
2. Use HTTP URIs so that people can look up those names.
3. When someone looks up a URI, provide useful information, using the standards (RDF*, SPARQL).
4. Include links to other URIs, so that they can discover more things.

By using shared *vocabularies* or *ontologies* -- Web documents which can establish shared URIs for common concepts and the semantic relationships between them -- Linked Data can be published in such a way that the *meaning* of data from independent sources can be interpreted by human or software consumers with little need for manual data alignment. Recent developments in the Semantic Web include the advent of decentralised “data pods” in software such as Solid[4], from Sir Tim Berners-Lee, which aims to build a user-centred “human-friendly” Web by, in part, supporting individual hosting and control of one’s own data. Complementary developments towards user-centredness in the Blockchain sphere include work on *self-sovereign identity* (Baars, 2016): technical solutions using Blockchains to manage digital identity in a way which gives users control over their online identity without needing to store personal information in a third-party facility.

The strength of the Semantic Web is in providing an easy framework for *combining* data from multiple sources. Applications of the Semantic Web in education include the Learning Object Metadata for annotation of digital educational material[5], Open Badges[6] (from version 1.1 onwards, Open Badges are Linked Data), the ESCO ontology for annotation of skills, competencies and occupations[7] and Linked Data harvesting of employment opportunities[8]. Initiatives such as these enable new opportunities, particularly for lifelong learning. For example, an individual planning their future career moves could use Linked Data resources based on the skill requirements of job postings and their existing set of qualifications to identify, automatically, learning

[1] https://www.w3.org/standards/semanticweb/data

[2] https://www.w3.org/standards/techs/rdf

[3] https://www.w3.org/DesignIssues/LinkedData.html

[4] https://solid.mit.edu

[5] https://ieeexplore.ieee.org/document/1032843

[6] https://openbadges.org

[7] https://ec.europa.eu/esco/resources/data/static/model/html/model.xhtml

[8] http://edsa-project.eu

materials and opportunities which would be relevant to add to their learning portfolio in order to reach a desired goal. However, the issue of *trust* becomes relevant when data is being drawn from multiple independent sources, particularly when it is valuable. Because of the consequences of one's educational record on career, lifestyle and travel opportunities, there is a strong potential motivation for fraud, for example. How are we to know whether a particular source of data is trustworthy with regard to its contents and history?

We can distinguish different kinds of trust. Let us start with the example of an educational qualification. In order to be able to accept a presented qualification as accurate, it is important to know where it came from - which institution, for example, for which learning opportunity; to whom it applies - the learner identity; and that the qualification presented is the same qualification that was originally issued. In brief, we need to have trust in *provenance*, trust in *identity*, and trust in *integrity*.

Provenance in educational data covers a number of factors. These include: the history of a piece of education-related material or of certification - when was it created, what was the learning context, what or who endorses it, and so on; the identity of learners and of issuing bodies - is the person presenting, or claiming to be the subject of, some educational data the same as the person it is actually about or from; and integrity - after publication, has the data been altered in anyway? For example, has a qualification been altered to show that it was of a higher level than it actually is?

These trust concerns apply generically outside the education sector as well and require a generic solution. The idea of the Semantic Blockchain is to add a trust layer to the Semantic Web in general, motivated initially by our work and applications in the realm of education.

There are a number of different ways in which Blockchain technology can be used to verify the integrity of data. The core idea remains the same: by publishing data on a Blockchain, a transaction is recorded on the distributed ledger. The transaction record will show the data along with a timestamp showing when it was published. By the nature of the Blockchain, this record is immutable, and anyone with access to the chain can verify that the transaction, its timestamp, and its data contents, have not been altered since that time. Anyone carrying out such a check can be assured that data integrity has been maintained: if the data being presented for verification has been tampered with, it will be possible to detect this and to prove that tampering took place. (Third & Domingue, 2017) present a survey of different specific approaches to making data distributed and trusted, varied along several dimensions, from the degree of data replication, to the levels of integrity guarantee provided, to the cost. The simplest model - in which all data is stored on-chain - has a number of disadvantages. One of these is expense - adding data to a public Blockchain costs money - but even without a cost factor, this poses data protection issues. Educational data contains at least some personal data, and it contravenes good data protection practice and law to store such data in a public space, particularly one which does not allow it to be edited/corrected or deleted. As a result, it is preferable to methods which keep actual data elsewhere, and store only verification data on-chain: something such as a cryptographic hash, which takes up little space and which can only be calculated from the actual data it represents, and which cannot be used to recreate that data. Distributed storage networks such as the Interplanetary File System (IPFS) are a practical match for Blockchains, being based on similar hashing mechanisms.

To build a Semantic Blockchain, then, we can integrate personal semantic data pods in Solid, using the IPFS network for larger storage, and with both components connected to a Blockchain infrastructure to provide integrity guarantees. *Provenance* is given by immutable timestamped records (as Linked Data) stored alongside the data and which can be cryptographically proven to be associated with that data. *Identity* (including data access control) is provided by self-sovereign identity systems, and *integrity* is provided by the Blockchain itself.

Collectively, these support *trust* in the data. By using Linked Data throughout, we ensure the maximum potential for learners and educators to connect their data with that from other sources, and so to get the maximum use from their own data; by particularly using Solid data pods, we ensure that data remains under user control. Figure 3 shows the main components of the Semantic Blockchain approach we are pioneering in ongoing work, known as *LinkChains*.

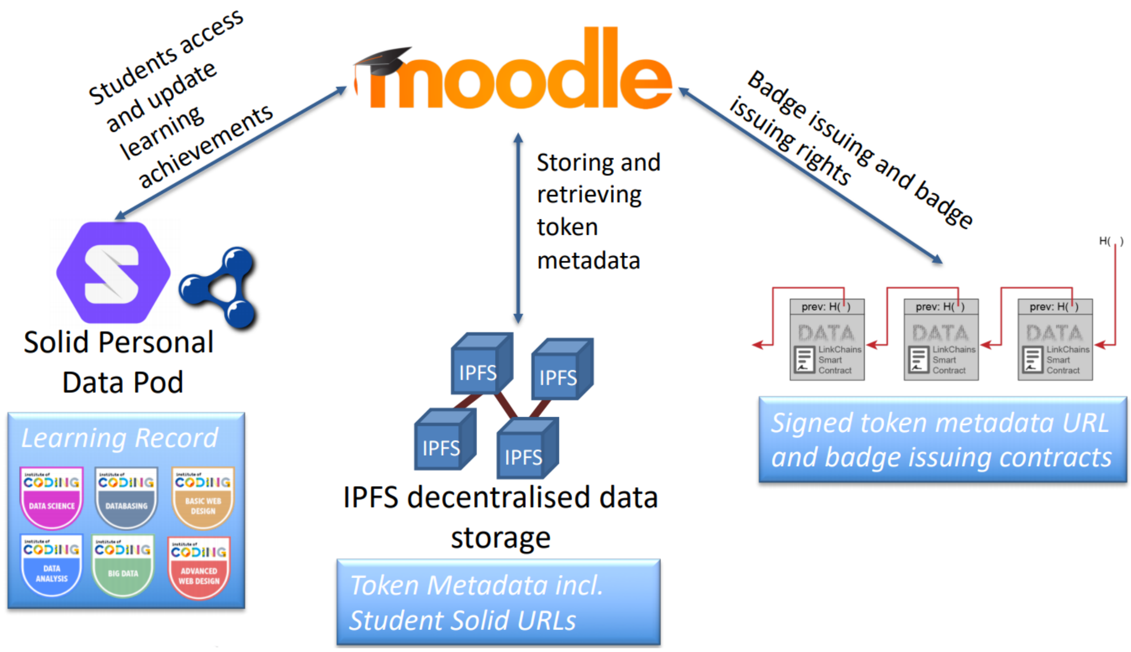


Figure 3: A Learning Management System (Moodle) communicating with the three main components of a Semantic Blockchain.

The focus on personal interoperable trusted data opens up new possibilities for pedagogical technology and approaches. One of the most exciting is the potential for *lifelong learning analytics.* Instead of learning activity data being collected, and analysed, solely within a specific institution, leading to data silos relating to the same learner being spread across multiple institutions across a lifetime of learning, by storing this data with the user and trustable under user control, it becomes possible to perform learning analytics over time and in diverse educational contexts. Tools can be developed to support learners in understanding their own learning approaches from their own data, as well as supporting wider learning analytics carried out across populations, with user consent. The use of Semantic Blockchains makes this possible; without the security and trust, and the common data models enabled by Linked Data, it would be considerably more difficult to carry this out.

## 4. Conclusions

This paper has presented the different applications and impact of Blockchain technology on online education and lifelong learning. We have presented a decentralised approach that enables learners to plan their learning journey more efficiently based on their desired career trajectory and offers them full control and ownership over their learning artefacts and processes. We have also discussed various approaches to the Semantic Blockchain and their applications on online education. The Semantic Blockchain offers a solution for bringing together all acquired learning experiences and accreditation, in order to form a coherent picture of an individual’s lifelong learning. Impact on lifelong learning is significant, as learning experiences and accreditation can be acquired from diverse independent sources and according to different learning approaches, contexts and standards.

We are currently preparing the next steps of this work, which will be conducted in the context of the QualiChain[9] research and innovation project. QualiChain brings together a consortium of government agencies, universities and private companies across Europe, to investigate the technical, political, socioeconomic, legal and cultural impact of blockchain-based decentralised solutions on education. The project is targeting four key areas for exploring the impact of decentralised solutions on education: (i) lifelong learning; (ii) smart curriculum design; (iii) staffing the public sector; (iv) providing HR consultancy and competency management services. Within these key areas, we will be applying the decentralised approaches presented in this paper, in order to develop, pilot and evaluate decentralised solutions for storing, sharing and verifying education and employment qualifications.

## 5. Acknowledgement

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