Supporting Lifelong Learning with Smart Blockchain Badges

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Abstract—**This paper presents the initial implementation, deployment and evaluation of a pilot case study, aiming at supporting lifelong learning through the use of Blockchain technology. This pilot case study uses Blockchain technology for decentralising lifelong learning and providing lifelong learners with transparent and immutable educational accreditation in the form of Smart Blockchain Badges. At the same time, lifelong learners are provided with personalised recommendations that help them reach their personal and professional learning goals. This paper presents a web-based prototype implementing the main scenario of this pilot case study, as well as the initial deployment and evaluation phases conducted with stakeholders from the education community.**

Keywords-lifelong learning; blockchain; decentralisation; smart badge; personalised recommendation.

I. INTRODUCTION

In this paper, we investigate how Blockchain technologies can help realise the decentralisation of lifelong learning, via a pilot case study for offering support to lifelong learners in various stages of their learning journeys and of their career trajectories. This paper builds upon and extends our previous work [1], where we first introduced the lifelong learning pilot case study.

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 [2-5]. 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 [6, 7].

The remainder of this paper is organised as follows. Section II discusses related work in the areas of Blockchain technologies and Open Badges. Section III introduces the overall framework of the QualiChain project. Section IV presents the pilot case study for supporting lifelong learning, its scope, the stakeholders involved, the main scenario, as well as a prototype implementation and its initial deployment and evaluation. Finally, the paper is concluded and the next steps of this work are outlined.

II. BACKGROUND

A. Blockchains and associated technologies

It is important to distinguish between the terms 'distributed ledgers' and 'blockchains', which are often incorrectly used as synonyms. Distributed ledgers are replicated, shared and synchronised digital data geographically dispersed over multiple sites possibly including multiple institutions. A peer-to-peer network is required for communication and a consensus algorithm to ensure replication and synchronisation across multiple nodes.

There are key differences between applications that run on standard platforms and those that run on top of distributed ledgers. Rather than connecting from a device (e.g., a mobile phone) to a central server, which holds all the required data (possibly including private customer data), every player or volunteer in the network gets a complete copy of all the data. This changes a fundamental dynamic. The notion of centralised control disappears completely, rather data and computation are evenly owned, controlled and shared across the peer network.

A Blockchain is a specific type of distributed ledger where an ever-growing list of records, called blocks, are linked together to form a chain – hence the term 'Blockchain'. The first Blockchain was conceived by Nakamoto [8] as the basis for Bitcoin the most famous Blockchain based crypto-currency. The main idea behind Bitcoin was to create a currency specifically for the Internet rather than (as is the case in all fiat currencies) mapping an originally physical currency to the global communications infrastructure.

The first issue that arises with internet-based currencies is what is called the 'double spend problem' [9]. This is the case when a digital 'coin' is spent, by an individual, for some service or good, and then the same coin is spent again by the same individual, for example by copying or duplicating the relevant data. The Blockchain addresses this problem by providing an immutable public ledger of all historical transactions. Once processed and stored within a block, a transaction cannot be altered even by the transaction owners.

Within a Blockchain, immutability is provided through a number of related mechanisms:

- *Timestamp* – Each block has a unique timestamp.
- *Cryptographic hash* – Each block is linked to the previous block through a crypto-graphic hash [10]. A cryptographic hash function is a hash function that takes an input of any size and returns a string of fixed size. Small changes in the input result in large changes in the output. It is this last feature that guarantees that changes to the input can be easily detected, as the hash function will no longer be verifiable. Additionally, it is not easy to regenerate the input from any given output. This aids in use cases involving an element of privacy or security.
- *Cryptographic puzzle* – In order to gain the right to create the next block, a participant (often called a 'miner') has to be the first to solve a cryptographic puzzle. This feature prevents a malicious attack aiming to re-write the history of a set of transactions, since this would require many cryptographic puzzles to be solved, as the hash of each block would have to be altered.
- *Participant network* – Since the data related to all the transactions are copied across all participants (miners) in the network, all miners are able to check if any protocols or rules have been violated.

Figure 1 (Appendix) shows a Blockchain containing three blocks. Starting from the right, which is the newest block, each block points to its predecessor using a hash function. Additionally, each block contains the solution to the cryptographic puzzle, termed 'nonce' and a timestamp. Transactions are stored in a Merkle Tree [11] - a tree of hashes - where the leaf nodes contain the transactions. This structure allows for efficient retrieval and ensures the veracity of the individual transactions in addition to the block, i.e., if a transaction is altered then the hash will no longer be valid.

The proof of work consensus mechanism, which involves solving the cryptographic puzzle before anyone else, has led to the growth of the computing power and electrical consumption associated with Blockchain networks. Estimates are that by 2020 the Bitcoin network will expend as much electricity as the whole country of Denmark [12]. This has led to several Blockchain platforms exploring other consensus mechanisms, such as:

- *Proof of stake [13]* – where the chances of being selected to produce the next block depend on the value of a 'stake' stored by a miner in a specific location. Variants of this take into account the 'age' of the stake.
- *Proof of capacity* – rather than the chances of being selected being related to the amount of computing power, as for proof of work, here the probability is related to the amount of storage a miner holds.
- *Proof of burn* – sending coins to an irretrievable address ('burn') gives one the right to be selected. The chances of being selected to mine the next block are related to the value of the burn.
- *Proof of elapsed time* – Intel has produced a special processor capability to implement this mechanism which relates elapsed time to the probability of being selected [14].

Ethereum [15] is currently the most well-known and widely used Blockchain platform. Rather than serving as a platform for a crypto currency, the underlying aim for Ethereum is to be an open Blockchain platform to support the development and use of decentralised applications. Unlike Bitcoin, the programming language available on the Ethereum platform is Turing complete so that general applications can be run on what the founders call a 'world computer'.

At the core of the Ethereum concept are two types of accounts:

- *Externally Owned Accounts (EOAs),* which are controlled by private keys. A private key is a cryptographic mechanism allowing for individuals to unlock data that has been secured by a corresponding public key. EOAs are controlled by individual users or organisations.
- *Contract Accounts*, also termed 'Smart Contracts', which can be defined as "automatable and enforceable agreements" [16]. Smart Contracts constitute one of the main features of current Blockchain platforms, such as Ethereum. They are controlled by contract code and are activated by EOAs.

When ether, the currency used within Ethereum, is sent from an EOA to a Contract Account, the contained program is executed. This can result in further transactions and payments and additional Smart Contracts being invoked. Through these chains of invocation, connected Smart Contracts form the basis of Ethereum applications which are called 'DApps' (short for 'Distributed Applications'). A number of high-level languages exist for writing Smart Contracts, including Solidity [17] (similar to C and JavaScript), Serpent (similar to Python) and LLL (a low-level lisp-like language).

From and end-user point of view, Ethereum, like Bitcoin, can be accessed through a number of implementations. It should be noted that the term 'Ethereum Client' includes software able to create transactions and mine new blocks, as well as wallets that manage private and public keys associated with an EOA. A screen snapshot of such a wallet that can be used for both Ethereum and Bitcoin is shown in Figure 2. As in many banking apps, users of this wallet are able to select accounts, view balances and transfer funds to other accounts. Other wallets also allow DApps to be managed in a fashion similar to Apple's iTunes application.

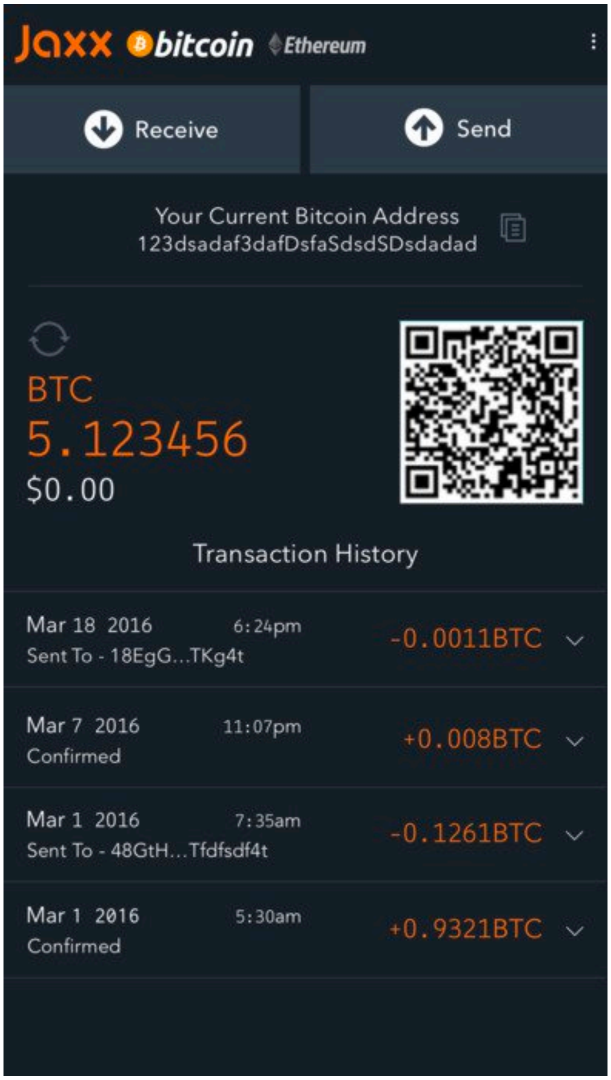

Figure 2. Snapshot of a Jaxx wallet used for both Bitcoin and Ethereum [18].

One of the first main problems that Ethereum faced was how to prevent arbitrary programs hogging the combined computational power of the mining community. A developer may inadvertently or maliciously create a program that never halts or eats up CPU or space resources. The solution to this is a transaction pricing mechanism, based on the concept of 'gas'. Every transaction request must be accompanied by a maximum amount of gas that a user is willing to be spent on a transaction. Miners execute transactions until they complete, or the gas runs out. Insufficient gas will result in a failed transaction and all of the fee lost. Otherwise, the remaining gas is returned to the user. Gas is paid for in ether with the purchase price fixed by the Ethereum mining community.

Because of the associated costs, large data files are not stored on the Ethereum platform. Typically, large files are stored elsewhere (off-chain) and referenced using a cryptographic hash. This solution enables the validity of a document to be checked (by comparison with its hash), whilst dramatically reducing storage costs. The peer-to-peer storage system IPFS (Inter Planetary File System) [19] is often used in conjunction with Ethereum.

B. *Open Badges*

Open Badges [20] allow for detailed recording of accreditation in digital form from both formal and informal learning contexts. Figure 3 shows the metadata stored in an Open Badge, including its name, criteria, image, issuer, recipient, etc. Open Badges were initiated by the Mozilla Foundation in 2010 [21] as a way of providing a verifiable digital recognition of learning across a wide variety of contexts, including:

- *Capturing a learning path* – in essence breaking up a single large qualification, such as a degree, into constituent parts giving a detailed account as to what has been achieved. The learning path may cross institutions.
- *Achievement signalling* – indicating to the outside world specific skills or achievements. For example, enabling recruiters to identify suitable candidates.
- *Motivation* – through intrinsic feedback encouraging continued engagement and retention. Additionally, badges can enable awareness of or grant specific privileges.
- *Innovation and flexibility* – enabling the capture of skills which may be missed or ignored within formal accreditation and newer emerging skills for example, related to particular forms of digital literacy. Badges provide a flexible channel to recognise new or currently unrecognised skills.
- *Identity/reputation building* – badges can promote identity and reputation within learning and peer communities. Any existing individual and aggregate identity and reputation can be made explicit and portable across communities and peer groups.
- *Community building/kinship* – membership of a community can be signalled enabling peers with similar interest to be found or potential mentors or teachers. Badges are a mechanism for providing social capital and the formalisation of camaraderie and communities of practice.

Since 2010, millions of Open Badges have been awarded [20] and have been taken up by a number of organisations including the Clinton Global Initiative [22] and NASA [23]. Although in extensive use, a number of problems have been articulated with the use of Open Badges. Belshaw [24] notes that often complaints are made on how the value of a badge can be judged. With an Open Badges infrastructure, there are no gatekeepers, meaning that anyone is allowed to issue a badge for anything.

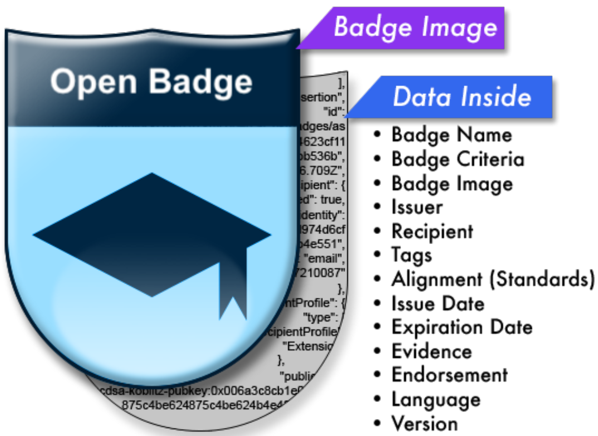

Figure 3. The structure of an Open Badge.

In their assessment of 29 badge development efforts, Hickey et al. [25] found that unsuccessful projects were hindered by problems of interoperability and integration between badging systems and institutional platforms. On the other hand, successful badge deployments layered badges on top of existing content and infrastructure, were tied to public student ePortfolios and used a mix of automated and human expert issued awards. They also found key to success were the embedding of badges in more social learning forms and ensuring that the badges contain unique non-redundant information. The most promising route for badges, they argue, is to link to formal externally recognised certificates whilst adding additional claims and evidence.

Badges are usually stored in what are known as backpacks. Backpacks give the user complete control over their achievements by allowing them to organize, display and manage their badges in one place. Until very recently, Mozilla ran the biggest badge portfolio system called 'Mozilla Backpack'. Mozilla have now closed their service down and handed over the running of a backpack service to Badgr [26]. A snapshot of a Badgr backpack is shown in Figure 4 (Appendix). Badgr backpacks allow someone to store and organize their badges into collections and shared badges or collections with others. Badgr allows a person to share badges via URL links, via social media, as well as via embedding.

III. The QualiChain Project

The emergence of the Blockchain promises to revolutionise not only the financial world, but also education in various ways. 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. This technology offers opportunities to thoroughly rethink how we find educational content and tutoring 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.

The QualiChain [27] research and innovation project focuses on the assessment of the technical, political, socio-economic, legal and cultural impact of decentralisation solutions on education. As shown in Figure 5, QualiChain is targeting four key areas for exploring the impact of decentralisation: (i) lifelong learning; (ii) smart curriculum design; (iii) staffing the public sector; (iv) providing HR consultancy and competency management services.

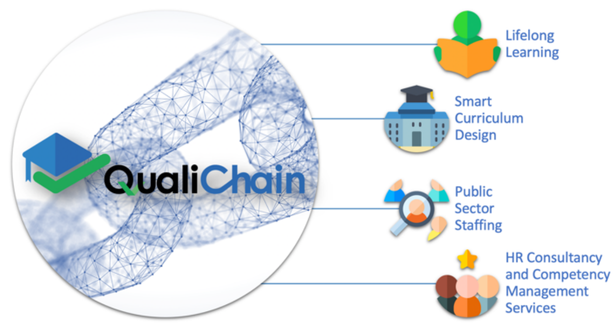

Figure 5. The key areas targeted by the QualiChain project.

QualiChain investigates the creation, piloting and evaluation of decentralisation solutions for storing, sharing and verifying education and employment qualifications and focuses on the assessment of the potential of Blockchain technology, algorithmic techniques and computational intelligence for disrupting the domain of public education, as well as its interfaces with private education, the labour market, public sector administrative procedures and the wider socio-economic developments.

IV. Supporting Lifelong Learning

As outlined in the previous section, lifelong learning is a key area targeted by the QualiChain project. We are therefore aiming to provide support to lifelong learners in various stages of their learning journeys and of their career trajectories. In the context of this pilot case study, we investigate how Blockchain technologies can support lifelong learners in their learning journey and in advancing their career. Figure 6 illustrates the main goals of this pilot, which are the following:

- Awarding lifelong learners with **transparent and immutable educational accreditation.**
- Offering lifelong learners **personalised recommendations** based on their learning achievements.
- Supporting lifelong learners in reaching **their personal and professional learning goals.**

The next sections describe the scope, stakeholders and main scenario of this pilot, as well as the outcomes of a series of consultation workshops about this pilot.

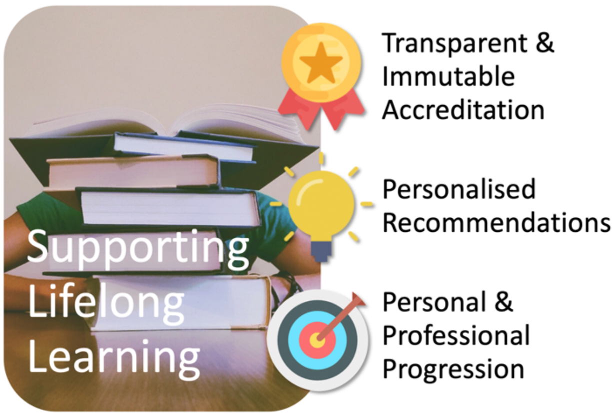

Figure 6. The overall goals of the pilot on supporting lifelong learning.

A. Scope

The scope of this pilot case study spans across the following:

- We are targeting both **formal and informal learning**. While formal learning typically happens inside the classroom, for example in a traditional university lecture, informal learning happens outside of the classroom, for example by studying free online courses.
- We are targeting both **academic degrees and other forms of educational accreditation**. For example, open badges have emerged as a new form of certifying that someone has acquired certain skills and has gained specific knowledge upon fulfilling certain criteria, e.g., by completing an online course.
- We are supporting the **learning journey and career trajectory of learners**. We are aiming to support the whole learning journey of learners by offering them recommendations on what to study next. We are also offering recommendations about their next career steps, based on the educational credentials they have acquired.

B. Stakeholders

The two main categories of stakeholders involved in this pilot are the following:

Lifelong learners. The concept of "lifelong learning" is based on the fact that learning is not confined to childhood or the classroom, but can take place throughout life and in a range of situations. Lifelong learners pursue learning throughout their lifetime, for either personal or professional reasons. They may study to develop new skills that they need in their professional life, for example to advance their career by finding a new job or by being promoted in their current job. They may also study to acquire skills and knowledge for personal reasons, for example as a hobby of theirs. Lifelong learners may engage either formal or informal education, or both, depending on their current learning goals and personal or professional circumstances.

Lifelong learners face various challenges associated with the recognition of their learning achievements, for example when transitioning from formal to informal education or vice versa. In this pilot, we seek to support them in various ways, for example by verifying their learning achievements on the Blockchain, or by offering them personalised recommendations about what to study next or which job position might be suitable for them. In this way, we aim to help lifelong learners reach their personal or professional learning goals.

Educational institutions. These are institutions that provide education or training services, either paid ones or free. The offerings of educational institutions can vary from conventional offline degrees to online free or paid courses, such as Massive Open Online Courses (MOOCs) or Open Educational Resources (OERs) [28].

In the context of this pilot, we seek to make the awarding of accreditation by educational institutions transparent and immutable with the use of Smart Badges [29]. Smart Badges are dynamic records of accreditation that follow the same principles as Open Badges and offer the same benefits in recording accreditation. However, Smart Badges are immutable and easily verifiable as they are stored on the Blockchain. The other novelty of Smart Badges lies in their dynamic features. For example, apart from just recording a learning achievement, a Smart Badge can also offer job or course recommendations as described in the next section.

C. Scenario

In this section, we present the interactions between stakeholders in the context of the main scenario of this pilot, as illustrated in the workflow of Figure 7 (Appendix). Let us consider a lifelong learner, who is looking to expand her knowledge and skills on data science and has thus enrolled to a number of courses offered online, including MOOCs and OERs. Each time the learner completes a course, she is awarded a Smart Badge by the educational institution that offers the course. This Smart Badge includes data about the skills that the learner has acquired upon completion of the course. Each Smart Badge the learner earns is verified and stored on the Blockchain as part of her personal ePortfolio.

After studying for several months, the learner has mastered some basic data science skills, including various computer science topics such as databases. Based on these skills, the Smart Badges generate recommendations about jobs that may be suitable for the learner. The learner receives personalised recommendations about jobs that fully match her skills, as well as about jobs that match her skills partially. The learner may also further personalise these recommendations and filter them according to her specific criteria, such as the location of the job, salary, employer, etc.

The learner is interested in one of the jobs that matches her skills partially. She then receives recommendations about courses that will give her the additional skills required for this job. The learner enrols for these courses, in order to acquire the needed skills. When she has acquired them, she proceeds to apply for her desired job and allows the prospect employer to access the relevant Smart Badges from her ePortfolio. By using this Blockchain-based infrastructure to support her in her studies, the learner has adopted a more efficient and targeted approach to learning, towards achieving her desired career trajectory. Figure 8 shows a more detailed view of the workflow associated with this scenario.

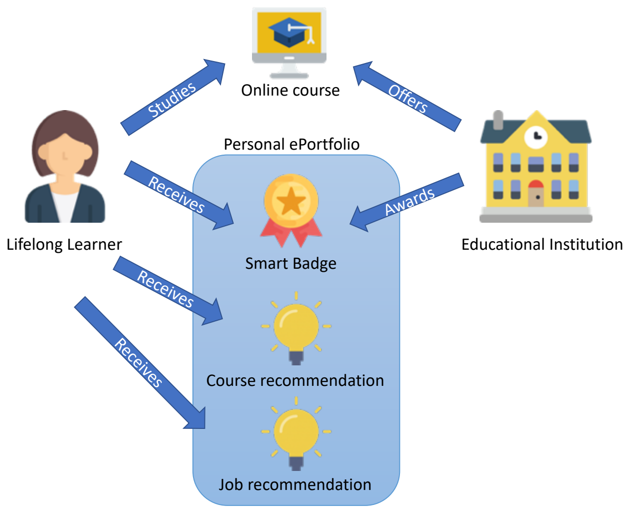

Figure 8. Stakeholder interactions in the main scenario of the lifelong learning pilot.

Our early work on implementing this scenario can be found at [29]. This implementation has been based on the use of Smart Contracts for the Ethereum Blockchain platform. In order to collect job market data, we are harvesting datasets of current job offers and their associated skills from a job aggregator that has been developed by the European Data Science Academy (EDSA) project [30]. These datasets are placed in Smart Contracts on the Ethereum Blockchain and are then used for matching jobs with a learner's badge-based skills. In this way, the awarded badges are smart, in the sense that they are being used to offer recommendations to learners.

D. *Implementation*

In this section, we provide an overview of a prototype platform that implements the basic functionalities for supporting lifelong learning through Smart Badges. It should be noted that this platform is only a proof of concept developed for the early deployment and evaluation of the lifelong learning pilot of the QualiChain project. The platform that will implement all pilots of the QualiChain project, conducted in the 4 key areas of the project, is currently under development, with both its front-end and back-end scheduled to undergo extensive updates before large-scale deployment takes place.

Figure 9 (Appendix) shows the educator's homepage view on the prototype platform. In this scenario, we assume that the educator is also the issuer of Smart Badges to lifelong learners. The homepage offers the following options to the educator/issuer:

- *View Badges:* This option allows the educator/issuer to view a list of the Smart Badges available to issue via the platform.
- *Manage Badge Issuing:* This option allows the educator/issuer to issue Smart Badges either to individual students, or to cohorts of students.
- *Manage Claimed Badges:* Through this option, the educator/issuer can view the Smart Badges claimed by learners.
- *Manage Badge Recipients:* Through this option, the educator/issuer is able to manage the registered learners that will be receiving Smart Badges.
- *Recipient Groups:* This option allows the educator/issuer to manage the groups that learners can be assigned to.
- *Recipient Groupings:* This option allows the educator/issuer to add or remove learners from groups. Each learner can be assigned in more than one group.

Figure 10 (Appendix) shows the options available to the educator/issuer for managing the recipients of Smart Badges on the platform. In particular, clicking the "Create Recipient" button expands a form at the top of the page with the relevant fields for adding new recipients individually. Clicking the "Import Bulk Recipient" button expands a form at the top of the page with instructions on what is required to bulk import recipients, rather than adding them individually.

Figure 11 (Appendix) shows the options available to the educator/issuer for managing the issuing of Smart Badges on the platform. More specifically, the educator/issuer is able to initialise a badge issuance to a recipient, add evidence to a badge issuance and then issue a badge. The educator/issuer is also able to revoke badges that have already been issued. The information is displayed in 3 different tables: Pending, Issued and Revoked. On initial load of the page, a form at the top of the page shows for "Create a Badge Issuance". The educator/issuer is required to select a recipient name and then the badge they wish to issue to the recipient. A dropdown at the top of the form allows the educator/issuer to select a group, which will filter the recipient name list to only show recipients within that group, thus narrowing down the list, rather than having to scroll through all recipients. Only recipients with accounts, and therefore verified email addresses, will appear in the recipient name dropdown list. Only one of each badge can be issued to a recipient. Therefore, if a badge has been issued already or revoked, it cannot be re-issued to the same recipient.

Figure 12 (Appendix) shows the detailed view of a Smart Badge on the platform. From this view, the user is able to see all relevant information relating to a particular Smart Badge, including:

- Issuer details
- Badge details
- Event details
- Alignments
- Endorsements

Finally, Figure 13 (Appendix) shows the verification of a Smart Badge on the platform. This function can be executed by any third party wishing to verify a Smart Badge and does not require having an account on the platform. Such a third party can be, for example, an employer who wants to verify the qualifications submitted by a job applicant, or an educational institution wanting to verify the qualifications of a student applicant. In order to perform the verification, the third party needs to upload the badge and enter the email of the recipient of the badge. The checks performed against this data and their results are shown at the bottom of the page.

E. *Initial deployment and evaluation*

In order to initiate the deployment and evaluation of the lifelong learning pilot, we have introduced a series of pilot workshops, where participants (learners, educators, researchers and practitioners) acquire hands-on experience with Smart Badges. This series of pilot workshops serves a two-fold purpose:

- Dissemination of the QualiChain framework and the use of Smart Badges.
- Collection of evaluation data via logs, questionnaires, and face-to-face feedback from participants.

The first pilot workshop took place in the context of the 9th eSTEeM Annual Conference [31] organised by The Open University on April 29-30, 2020. Although this was originally planned as a face-to-face event, it had to take place online because of the COVID-19 pandemic. During this pilot workshop, we piloted the prototype platform presented in the previous section of this paper. Participants were first introduced to the QualiChain project and the lifelong learning pilot and were then asked to perform the following sequence of activities on the prototype platform:

- Register an account on the platform.
- Receive a Smart Badge.
- View and download their Smart Badge.
- Verify their Smart Badge.

Figure 14 shows the Smart Badge awarded to participants of this workshop. The badge contains the title of the workshop, together with the QualiChain, and The Open University logos. The JSON data of the badge also contains the following tags: blockchain, decentralisation, lifelong learning, ePortfolio, and accreditation. These tags represent the skills participants have acquired from the workshop. These skills will be used at a later stage to provide job and course recommendations.

After the end of the workshop, participants were asked to respond to a short questionnaire, in order to collect evaluation data about the perceived usefulness and usability of the platform, as well as the overall QualiChain approach. Regarding the approach of the QualiChain project, participants recognised its potential for lifelong learning and education in general. Some participants stated that the purpose of introducing blockchain technologies in education needs to be made clearer, for example by defining the USP (unique selling proposition) of the QualiChain platform and Smart Badges over other badge approaches and platforms.

As expected, the feedback received from this first pilot workshop has been mixed, mainly due to the early prototype status of the piloted platform at the time of conducting this workshop. Overall, participants appreciated the potential of the QualiChain project and the lifelong learning pilot. However, they pointed out that the QualiChain platform as an integrated product has to be further developed prior to detailed review. As the maturity of the QualiChain platform improves with additional functionalities, more positive feedback from subsequent pilot workshops is expected.

Figure 14. The Smart Badge awarded to the participants of the lifelong learning pilot workshop.

V. CONCLUSIONS AND NEXT STEPS

This paper has presented a pilot case study for supporting lifelong learning via Smart Badges and personalised recommendations. The pilot case study employs Blockchain technology for providing lifelong learners with transparent and immutable educational accreditation. It also uses personalised recommendations for helping lifelong learners reach their personal and professional learning goals. This pilot is part of the QualiChain initiative for decentralising education and employment qualifications using Blockchain technologies.

The next steps of this work will be focused on further engaging the communities of stakeholders, in order to better understand the lifelong learning challenges that they face and their proposed solutions. This will help us further shape the scenario to be implemented in the context of this pilot. We will continue consulting with the communities of stakeholders throughout the implementation, deployment and evaluation of our pilot, so as to better understand and address their needs.

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APPENDIX

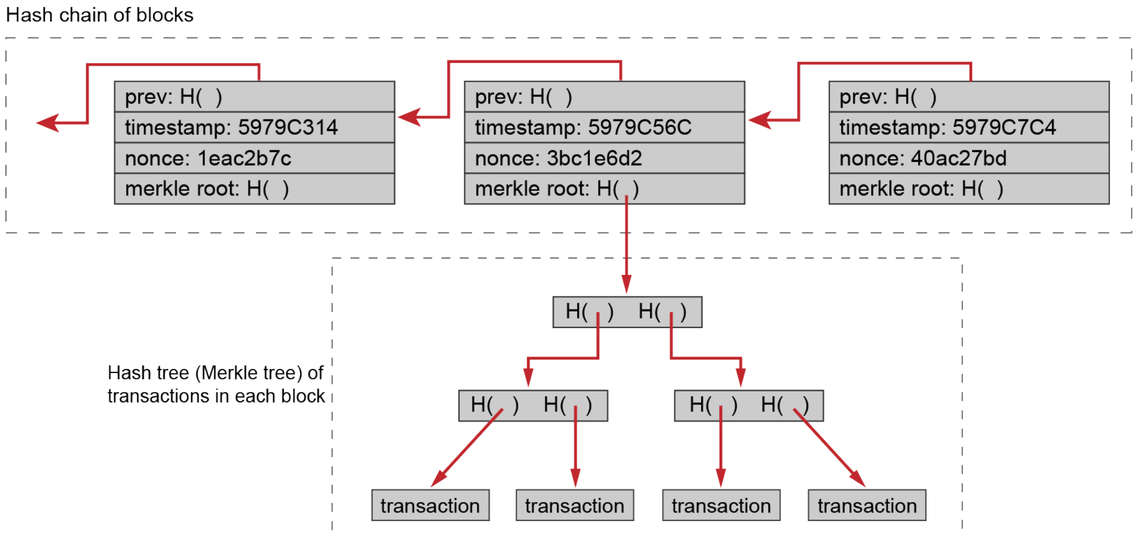

Figure 1. Example of a Blockchain consisting of three blocks.

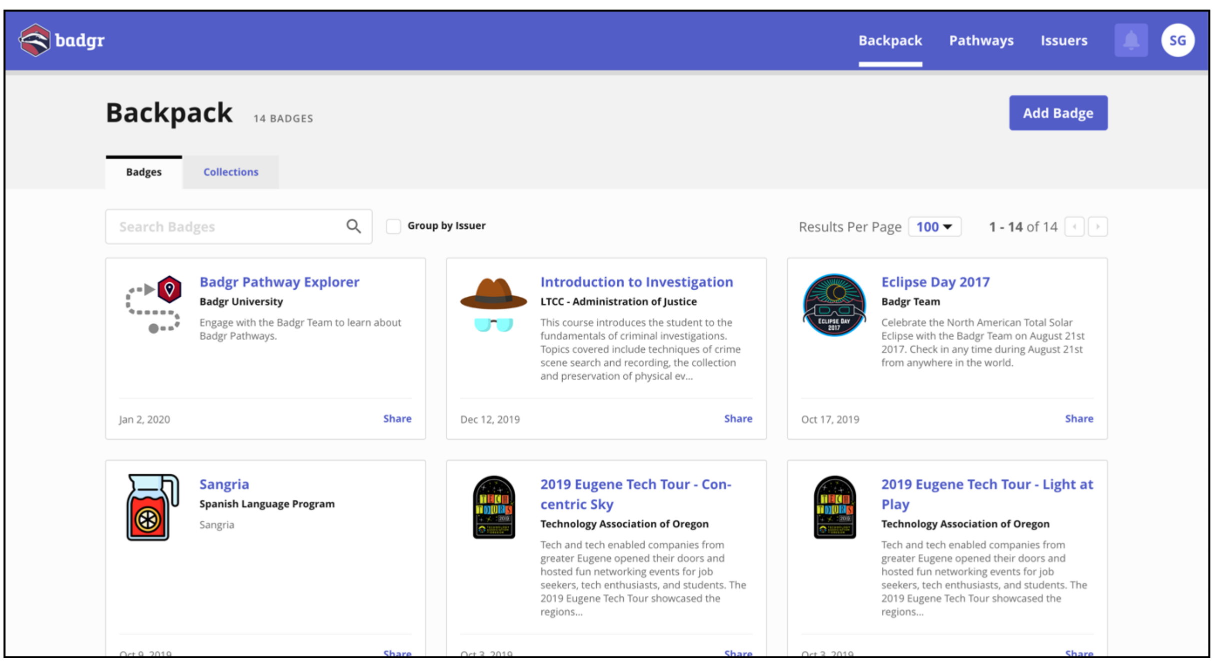

Figure 4. Snapshot of a Badgr backpack [26].

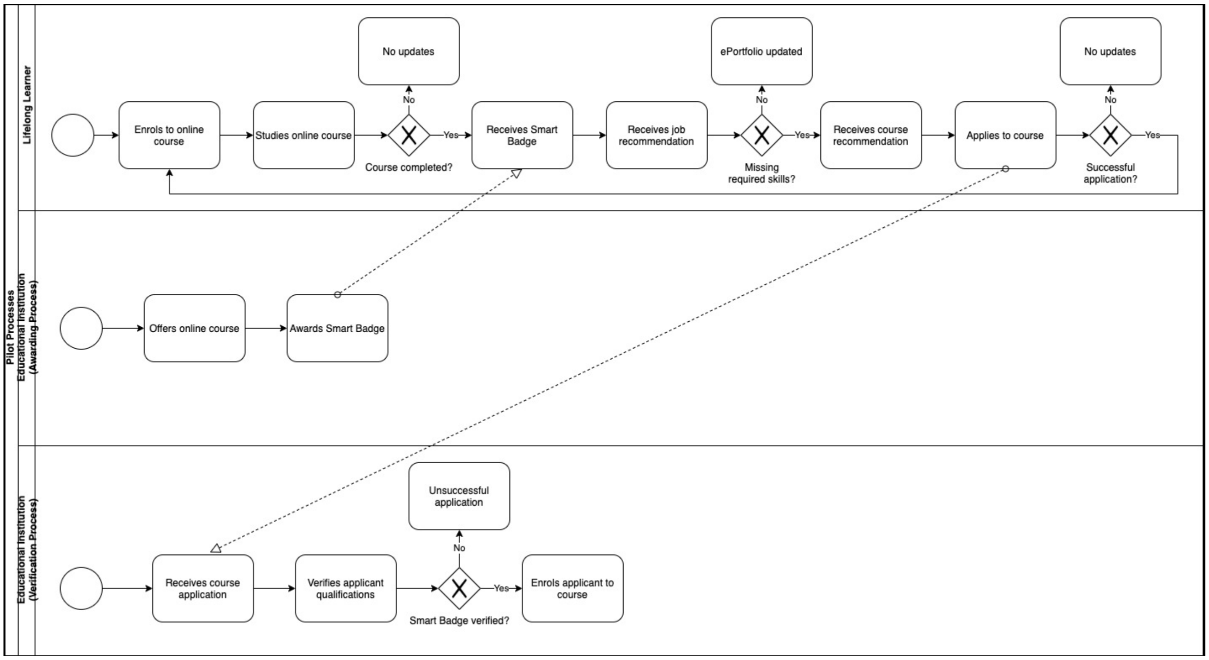

Figure 7. Workflow of the lifelong learning pilot scenario.

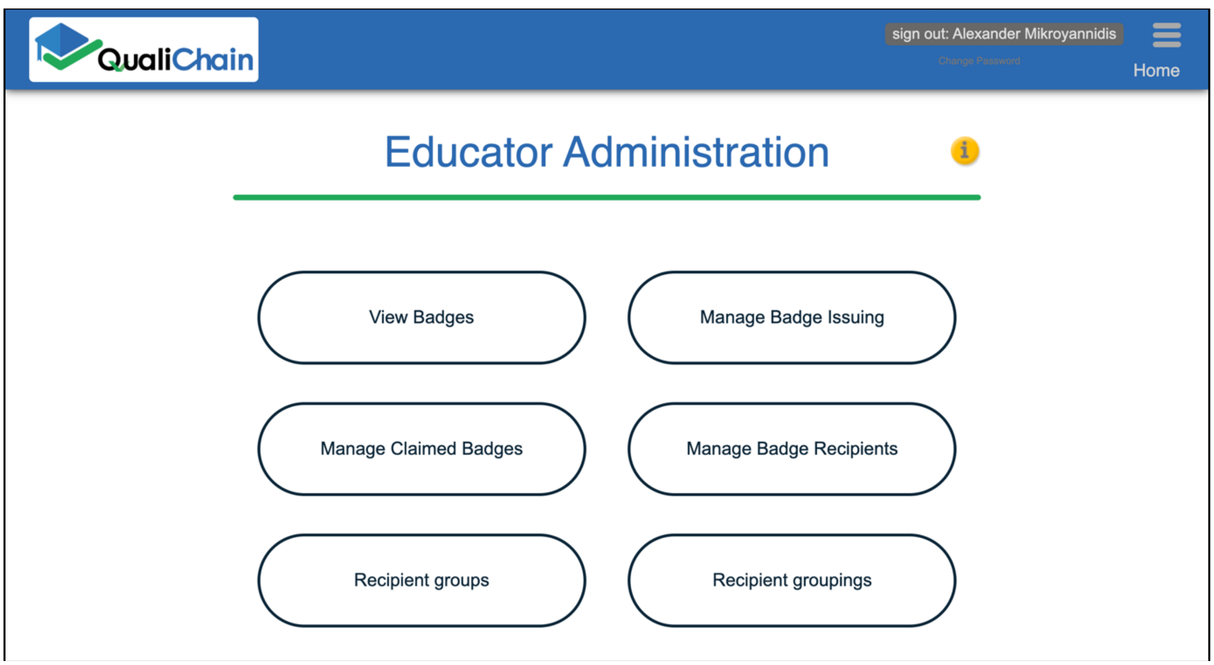

Figure 9. Snapshot of the options available to the educator/issuer of Smart Badges.

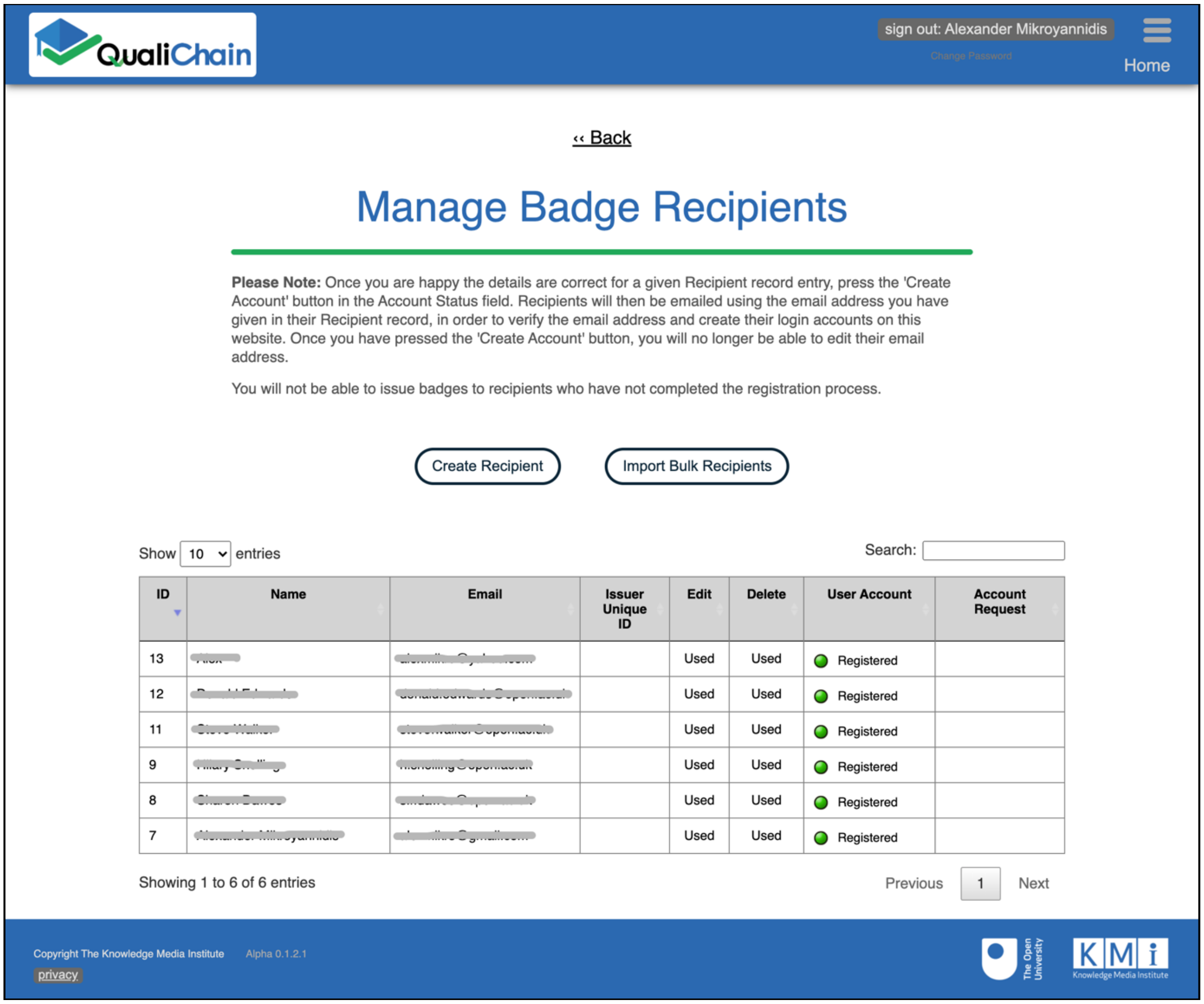

Figure 10. Snapshot of managing the recipients of Smart Badges.

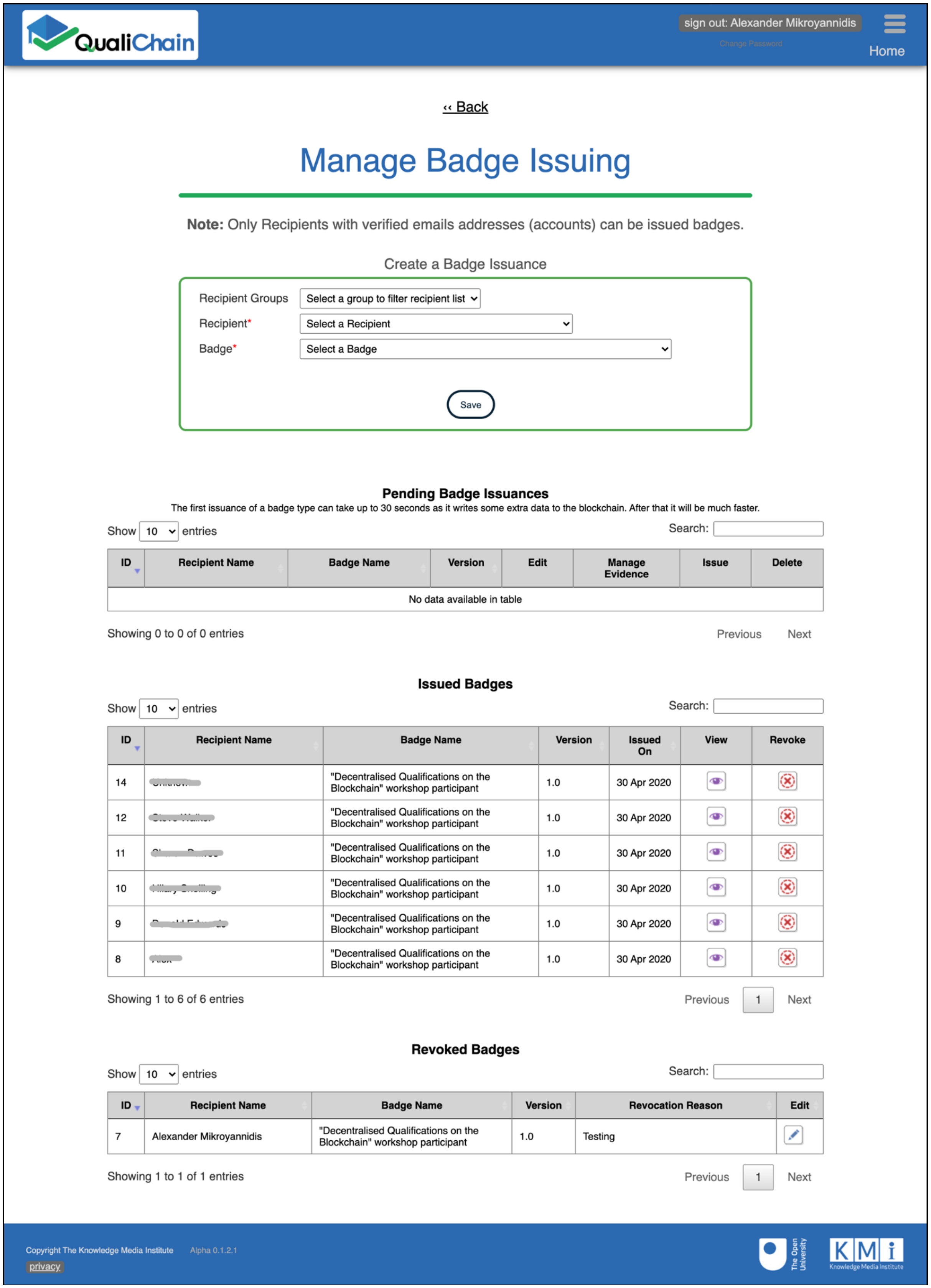

Figure 11. Snapshot of managing the issuing of Smart Badges.

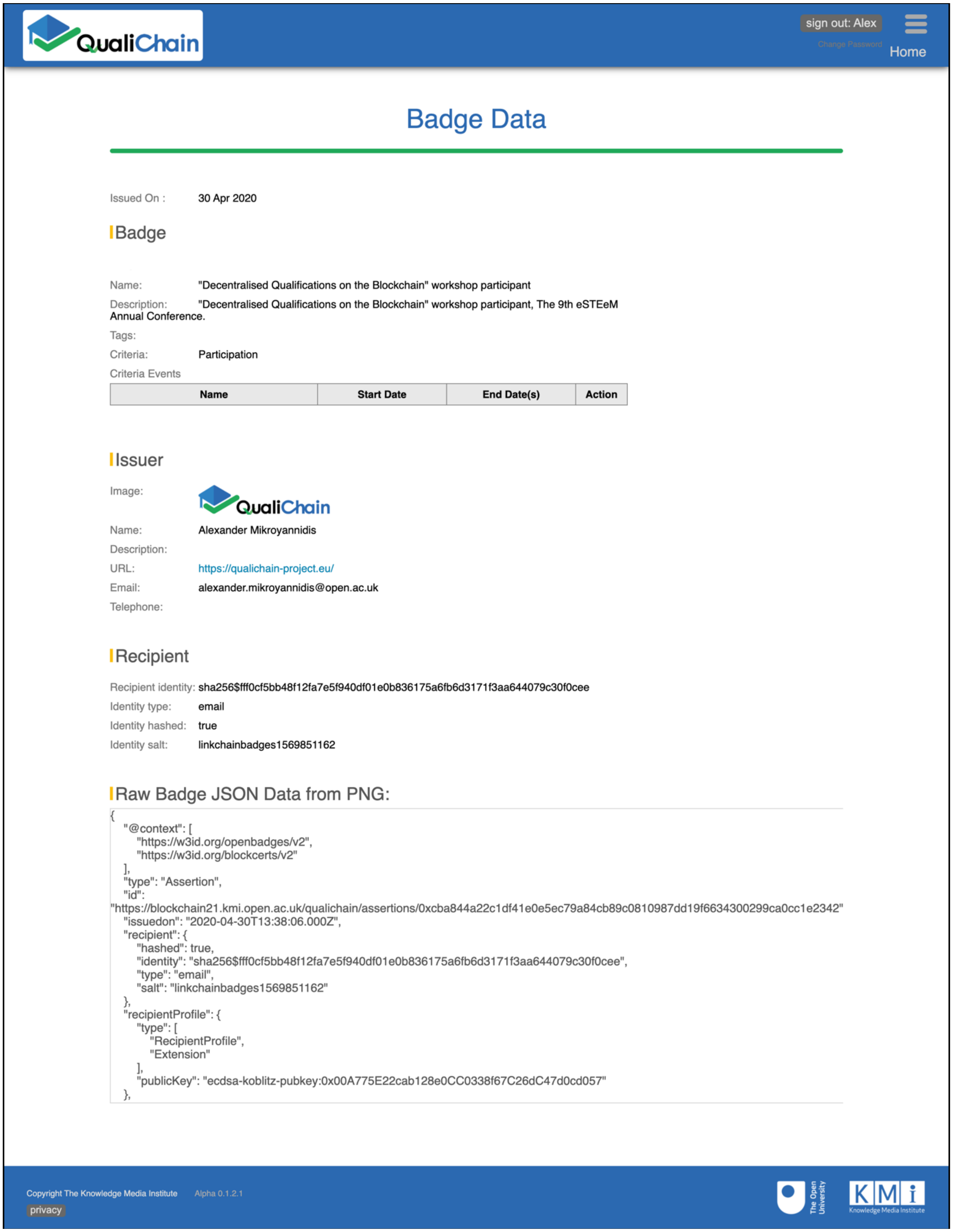

Figure 12. Detailed view of a Smart Badge.

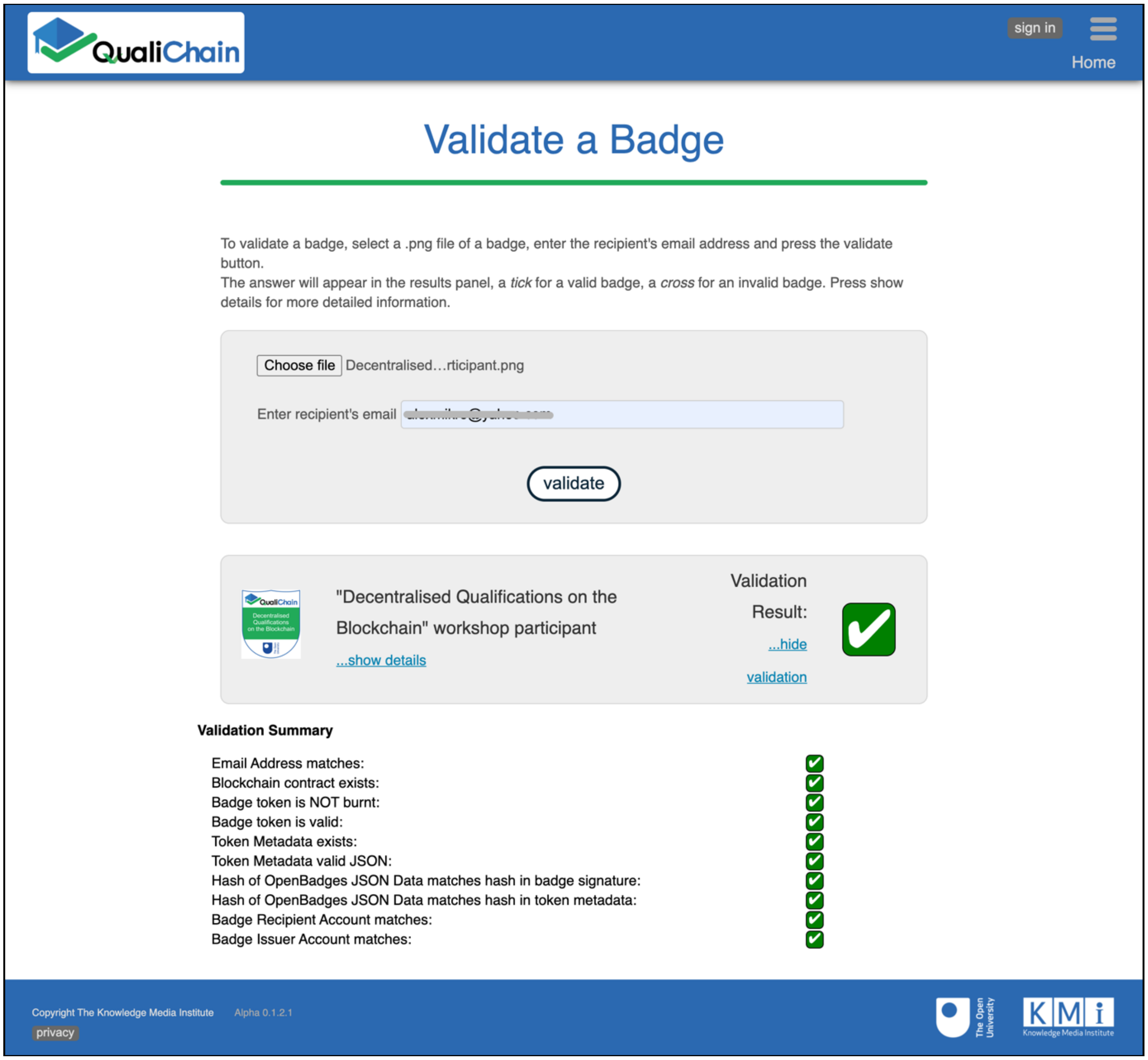

Figure 13. Verifying a Smart Badge.