

Leveraging Blockchain, Analytics and Decision Support to Facilitate Qualifications' Verification, Recruitment and Competency Management: The QualiChain Project and Initial Results

Christos Kontzinos
Decision Support Systems Lab
National Technical University of Athens
Athens, Greece
Email: ckon@epu.ntua.gr

Ourania Markaki
Decision Support Systems Lab
National Technical University of Athens
Athens, Greece
Email: omarkaki@epu.ntua.gr

Panagiotis Kokkinakos
Decision Support Systems Lab
National Technical University of Athens
Athens, Greece
Email: pkokkinakos@epu.ntua.gr

Vagelis Karakolis
Decision Support Systems Lab
National Technical University of Athens
Athens, Greece
Email: vkarakolis@epu.ntua.gr

Panagiotis Kapsalis
Decision Support Systems Lab
National Technical University of Athens
Athens, Greece
Email: pkapsalis@epu.ntua.gr

John Psarras
Decision Support Systems Lab
National Technical University of Athens
Athens, Greece
Email: john@epu.ntua.gr

Abstract—In today's society, digitisation is becoming the new norm for various facets and processes of everyday life, taking advantage of advancements in Information and Communication Technologies and other innovative and emerging technologies. The same cannot be said for higher education and the labour market that still operate with traditional techniques when it comes to the certification, issuance and verification of academic qualifications as well as recruitment and competency management respectively. Lack of technical competencies by supporting staff and security issues regarding personal data are strong disincentives when it comes to reengineering current processes. Under that context, this publication presents QualiChain, an European Union-funded project that aims to revolutionise the domain of public education, as well as its interfaces with the labour market, policy making and public sector administrative procedures by disrupting the way accredited educational titles and other qualifications are archived, managed, shared and verified. QualiChain's technical solution leverages blockchain to improve overall security and data sovereignty and the computational intelligence found in analytics and decision support to develop value-adding components on top of a robust blockchain infrastructure. This publication presents the project concept as well as current progress and initial results relevant to the theoretical background of QualiChain, the development of the QualiChain platform and the scenarios that have been developed to validate the solution in specific pilot contexts. In fact, the first version of the platform proves that blockchain, semantics, and analytics can indeed disrupt higher education and the labour market and lead to substantial efficiency, productivity, and transparency impacts.

Keywords- *qualification verification; recruitment; competency management; blockchain; analytics; decision support.*

I. INTRODUCTION

In an era that every single piece of information around us is digitised and being exploited via innovative technological solutions in a variety of value adding ways [1], education certificates are largely resisting the pull of technology, as they are still held in diverse formats in siloed databases, often involving time consuming manual processes for their verification [2]. In education, certificates verify the achievement of certain learning outcomes and are until today mostly issued on paper or other physical formats [3]. Paper certificates have their advantages, such as being easy to store and difficult to forge due to built-in security features. However, they also create several issues, such as dependence from accrediting authorities for their issuing and verification as well as vulnerability to loss and damage [4]. Additionally, lying about education and employment credentials is a common problem, as it has become very easy to counterfeit academic diplomas and certificates, or even "buy" degrees from fake degree websites [5]. According to a survey by CareerBuilder [6], a staggering 58% of employers have caught a lie on a resume, whereas 33% of them have seen an increase in resume embellishments and fabrications [7]. Similar findings arise from another survey by StatisticBrain [8], according to which over half of resumes and job applications contain falsifications and over three quarters are misleading [9]. Under these circumstances, and although fraud is not

limited to educational awards, trust in the educational certification system is receiving significant blows [10][11].

The aforementioned challenges create problems when education credentials are requested as a means of ratifying decisions regarding either personnel recruitment or individuals' further admission in other educational programmes. The recruitment of personnel by an organisation is a lengthy process that comes along with combing through hundreds of candidates' résumés, weeding out the unqualified ones and narrowing down the rest into a group of potential recruits', whose qualifications and academic degrees have to be checked and validated on a case-by-case basis. These challenges do not limit to the actual task of recruiting but extend to a wider set of processes indicatively encompassing personnel allocation and re-allocation, staff mobility, and skills' development and evaluation, most of which fall under the notion of competency management.

Disruptive technologies, such as blockchain, algorithmic techniques, data analytics, and semantics and innovative concepts like gamification may offer solutions to these challenges. Particularly, blockchain technology, as a decentralised, permanent, unalterable store of information can help with the archiving and trust issues, as well as provide a frictionless method for transacting with others [12][13], whereas computational intelligence found in the technological domains of algorithmic techniques, data analytics, and semantic analysis may facilitate data interoperability, decision making and optimise work practices and procedures. Moreover, gamification practices can help with user engagement and in developing a more user-centric solution [14]. Under these circumstances, this publication presents QualiChain, a project targeting the creation, piloting, and evaluation of a distributed platform for storing, sharing, and verifying academic and employment qualifications that will focus on the assessment of the potential of the aforementioned combination of technologies for disrupting the domain of education.

Section I of this publication introduces the scope of the document and describes the challenges revolving around the verification of education certificates. Section II provides a literature review on the two core domains of QualiChain, Qualifications' certification issuance and verification and recruitment and competency management. Section III introduces the QualiChain concept and the high-level functionalities that it is projected to have. Section IV describes the platform's components and introduces the pilot use cases, in which the platform will be applied. Section V describes current progress in the project and the most interesting results up to this point. Finally, Section VI concludes the document.

II. LITERATURE REVIEW

This section presents the literature review of the two core domains of QualiChain, namely qualifications' certification issuance and verification and recruitment and competency management. In order to perform the literature review and identify current state-of-the-art approaches and solutions the following methods and tools have been used.

- **Keyword search:** Keyword search has been used so that search engines, such as Google, would suggest relevant resources. In particular, not only standalone keywords (e.g., blockchain, education) but also keyword phrases (e.g., innovation to education, blockchain and CVs, and recruitment analytics) were used.
- **Google Scholar:** Searched Google Scholar for papers relevant to the objectives of the QualiChain project in order to better understand how blockchain, analytics, and decision support have already been leveraged to disrupt higher education and the labour market.
- **Scopus:** Also searched Scopus for publications that would be relevant to blockchain, analytics, and decision support as well as the domains of higher education and the labour market.

In order to decide whether a source should be taken into account, several filters were used. In particular, the usage of sources that are quite recent was considered to be of outmost importance. In addition, we also wanted to examine publications presenting applications that would facilitate the understanding of how the aforementioned technologies can be leveraged.

A. Qualifications' Certification, Issuance and Verification

Certification is essential for the educational system as a way of validating and recognising the achievements of learners. Attainment is shown through a collection of certificates, which represent the knowledge that the learner has gained and the skills that they have acquired. The current state of the art in the certification of qualifications still follows traditional practices and manual processes in the general case. Specifically, upon achievement of some specified learning performance goals, formal qualifications are issued to a learner by an awarding educational institution, often subject to a regulatory framework of academic standards. Such certification is generally provided to learners in paper form. In order to prove the existence of a qualification, the paper document can then be provided to, e.g., employers or educational institutions. As an anti-fraud policy, such third parties can typically then verify its legitimacy with the relevant institution or trusted body. For example, the UK (United Kingdom) has already established the Higher Education Datacheck service [15]. The use of this service is chargeable, and the entire verification process can take up to seven days [16].

This process can be applied effectively to receive and verify formal qualifications from institutions, albeit with slow results. However, when it comes to informal education and many Continuing Professional Development (CPD) scenarios, there may be little to no formal documentation of learning, or the ability to prove to third parties that learning activities have taken place. Recent developments in online learning have led to initiatives such as the OpenBadges standard [17], initially developed by the Mozilla Foundation, for informal learning recognition. Badges are verifiable, portable digital certificates with embedded metadata about

skills and achievements [18]. They usually comply with some specification and are shareable across the Web. Badges received increased attention because of the mismatch between skills obtained through university degrees and those that are required in the workplace. By representing small segments of learning, badges reduce the granularity by which attainment can be captured and represented, thus providing a greater reward for achieving particular skills and gaining specific experiences. This can be used to help capture the diversity of activities, in which one may be involved with during any kind of educational course and, at the same time, provide validation to the learner that these activities are contributing to their skillset. There is no formal verification process built-in to the OpenBadges standard, although in principle it could be performed manually. Currently, thousands of organisations across the world issue badges in accordance with the Open Badges Specification, from non-profits to major employers to educational institutions at all levels, including the free OpenLearn platform of the Open University [19].

To provide the verification component for online certification, there have recently been several approaches to using blockchains as stores for certification records. The first attempt at this was carried out by the University of Nicosia, which placed certifications for its Digital Currency course on the Bitcoin blockchain [20]. More recently, MIT collaborated with the company Learning Machine to develop Blockcerts to award diplomas, again using the Bitcoin blockchain, in a learner-controlled fashion [21]. “Blockcerts consists of open-source libraries, tools, and mobile apps enabling a decentralised, standards-based, recipient-centric ecosystem, enabling trustless verification through blockchain technologies” [22]. Both of these approaches use custom (although open) representations for certification data. Since 2015, the Open University has been conducting experiments with a generic framework for using blockchains to store and verify OpenBadges, as a means of making standards-compliant educational certification available in an automatically verifiable manner [23]. Moreover, the Government Technology Agency of Singapore has initiated OpenCerts [24], an academic certification standard that leverages the Ethereum blockchain [25] for the issuance and verification of OpenCerts certificates. OpenCerts certificates are JSON objects defined by the OpenCerts schema following the Open Attestation framework. Finally, the European Blockchain Service Infrastructure (EBSI) is developing standalone components based on blockchain for degree and other qualification certification and validation [26].

B. Recruitment and Competency Management

Competency management is a technique used by HR (Human Resources) departments in the process of identifying, further developing, improving, and evaluating the abilities and key skills required to fulfil the needs of every job position inside their organisation. Each position inside an

organisation requires a set of key abilities, knowledge, experiences, and skills. A competency management system is composed of the following four step process:

- Competencies’ acquisition that involves the recruitment and selection of personnel, both for internal and external purposes, based on the matching of job description requirements and individual demonstrated competencies.
- Competencies’ evaluation, both in terms of actual and potential competencies that refer to the yearly/monthly evaluation of personnel, analysis of gaps in the competencies, and diagnosis of needs in terms of skills development.
- Competencies’ development, which includes the training in and off-job that is used to overcome the gaps identified in the evaluation process.
- Competencies’ retention, which relates to motivating the individual by compensation in terms of leadership, rewards, incentives, promotions, and carrier prospects.

Today’s modern HR suites, used in the process of competencies acquisition step collect applications from multiple locations, classify successful candidates automatically, and offer services such as onboarding, video interviewing, and many more. According to recent studies [27] “Recruitment Management software is expected to reinvent its capacity, boost efficiency with more personalised and candidate-centric recruiting, streamlined interfaces, and automation of more HR-related processes that are currently performed manually”. In this context, verifying job candidates’ learning certificates and achievements is still a challenging task, typically based on manually verifying information included in CVs and traditional degrees’ certificates awarded by recognised academic institutions.

The process of competency evaluation is usually a yearly process performed also manually by the person that is directly above the one that is being evaluated, in the hierarchy of a company, being most of the times a direct association between the ability of the person in executing his assigned tasks, and the evaluation of the individuals’ behaviour when executing them. Also, a self-evaluation is required. These factors are quantitatively measured by some formulas used by HR departments and a grade is attributed to the worker. A positive grade is most of the times translated into a promotion or a bonus, and a negative one could be reason enough to fire the employee. The challenge that HR departments face in this process is the lack of transparency in the evaluation. It is a highly human influenced process, in which misleading feelings about a worker by its direct superior can lead to unfair situations. Individuals’ soft skills are also hard to measure, since these are not usually taken into consideration by the quantitative formulas used.

In order to improve the capabilities of the employees, learning is one of the fundamental methods used in the competency development process. Training not only improves the skills of the employees but also refreshes their knowledge and improves their performance in current

positions. It also offers a means for progressing one’s career and thereby fulfilling a need inside the organisation. The training programs are usually designed according to the business goals of the organisation. The aim is to ensure that the organisation as a whole and its employees have consistent progress on competency improvement and their growth paths. But encouraging the employees to carry the training programming until the end is a challenge for organisations that require therefore creative ways to increase the engagement of the employees in training programs and to motivate them to continue the process. Another challenge with training programs is that they are oftentimes presented in such a way that it becomes too formal for the learner to use. The learners might not understand the objectives of the program or become bored of using it during the time.

To keep employees motivated rewarding strategies have been used in the competency retention processes. A rewarding strategy includes the definition of ratings or evaluation measures for satisfying the required level of capabilities and skills for a certain competency. Five-star rankings are the most common rewarding systems used in evaluation methods as well as points, levels, badges and medals [28][29].

III. THE QUALICHAIN CONCEPT

QualiChain is a project that aspires to investigate and provide evidence on the transformative impact of disruptive technologies, such as blockchain, semantics, data analytics, and gamification in the domain of public education, as well as the interfaces of the latter with the fields of private education, the labour market, and public sector administrative procedures. The concept and focus of the project lie more specifically in the design, implementation, piloting, and thorough evaluation in terms of benefits, risks, and other potential implications of the QualiChain technological solution, a distributed platform targeting the storage, sharing, and verification of academic and employment qualifications. At this point, attention has to be drawn to the fact that although originally inspired from the field of public education and the need to transform certificates’ archiving and management, as well as to fight fraud around education awards, QualiChain concept has practically a much larger scope, as its services transcend the mere validation of training certificates and bring forward solutions to major challenges of both public and private interest, such as those of lifelong learning, recruitment, mobility, better linking education with the labour market, etc., thereby accommodating the needs of several stakeholders (see Figure 1).

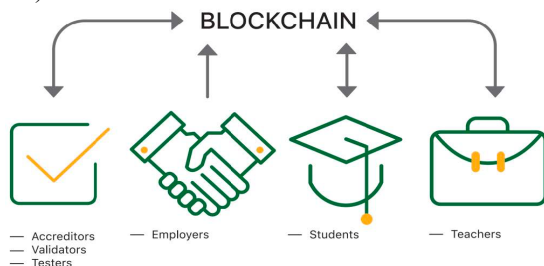


Figure 1. The value of blockchain to QualiChain stakeholders [3].

In fact, QualiChain services will be structured along two main pillars.

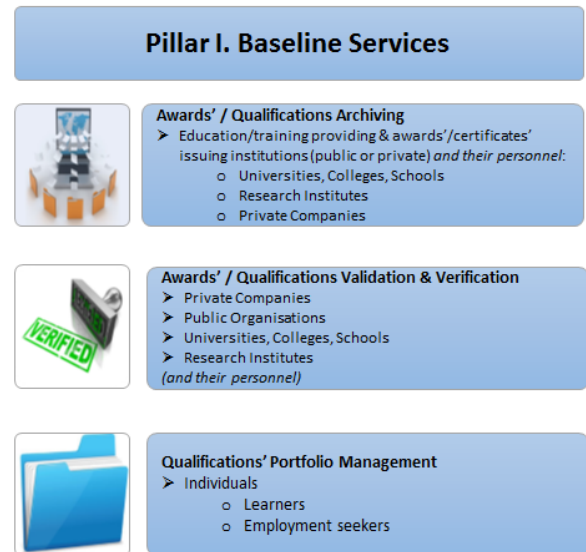


Figure 2. QualiChain Baseline Services

The first pillar (see Figure 2) will be grounded upon QualiChain main technological foundations, namely blockchain and semantics, enabling educational awards’ and other qualifications’ archiving and storing, awards’ verification, the latter incorporating equivalence verification, as well as qualifications’ portfolio management.

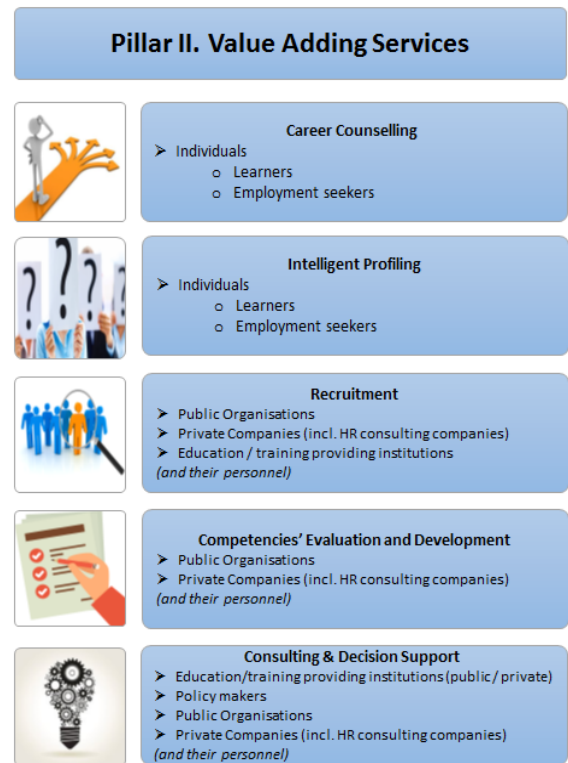


Figure 3. QualiChain Value Adding Services

The second pillar (see Figure 3) will build upon QualiChain baseline services to offer with the help of the computational intelligence, embodied in data analytics and decision support algorithms, as well as gamification techniques, a set of more advanced services, including career counselling, intelligent profiling, and competency management and within the context of the latter recruitment and evaluation support, and consulting.

IV. FUNCTIONAL OVERVIEW AND PILOT CASES

A. QualiChain Components Functional Overview

QualiChain will deliver an open source solution, comprising of stand-alone components and an integrated environment to facilitate its adoption by the different stakeholders according to their needs. To deliver the services and functionalities prescribed in the QualiChain concept in the previous section, the envisaged QualiChain platform logic layer consists of 3 main components, namely a *Validation and Verification Engine*, a *Profiling and Career Management Engine*, and a *Recruitment and Competency Management Engine*, composed in turn by 11 modules (see Figure 4).

The *Validation and Verification Engine* will be responsible for registering from scratch newly awarded certificates and achievements as well as for ratifying claims around the possession of certain awards and qualifications. Thus, it will feature an *Awards' Registration Interface* that will enable issuing and accrediting organisations to register new verified qualifications' records in blockchain's distributed ledger, as well as a *Validation Query Builder*,

through which all issuing institutions, public and private organisations, as well as individual users can set up appropriate validation queries. In greater detail, the *Validation and Verification Engine* is made up of the following sub-components: i. an *Equivalence Verification Module* that supports the identification and verification of equivalent degrees (or even skills, achievements and training courses), issued by different institutions, ii. a *Translation Module*, capable of translating certificates from one language to another, in case a both validated and translated version of a certificate is required, and iii. a *Credentials' Auditing and Verification Module*, responsible for accommodating new awards' registrations and thus adding new blocks to the blockchain database, as well as for receiving users' queries on the validation of awards and other qualifications.

The *Profiling and Career Management Engine* will be responsible for the functionalities required for the management of individual users' digital portfolio, aka digital learning ledger where the latter can archive and access their achievements, qualifications, and work experience with the purpose of showcasing them to third parties. The specific component's functionalities are made accessible through a *Portfolio Manager Interface* and are brought to life with the help of the following modules: i. a *Verification Request Module*, enabling individuals to submit to accrediting organisations requests for the confirmation and formal verification of their achievements, ii. a *Career Advisor Module*, capable of crawling world wide web resources and applying data mining techniques with the goal of identifying

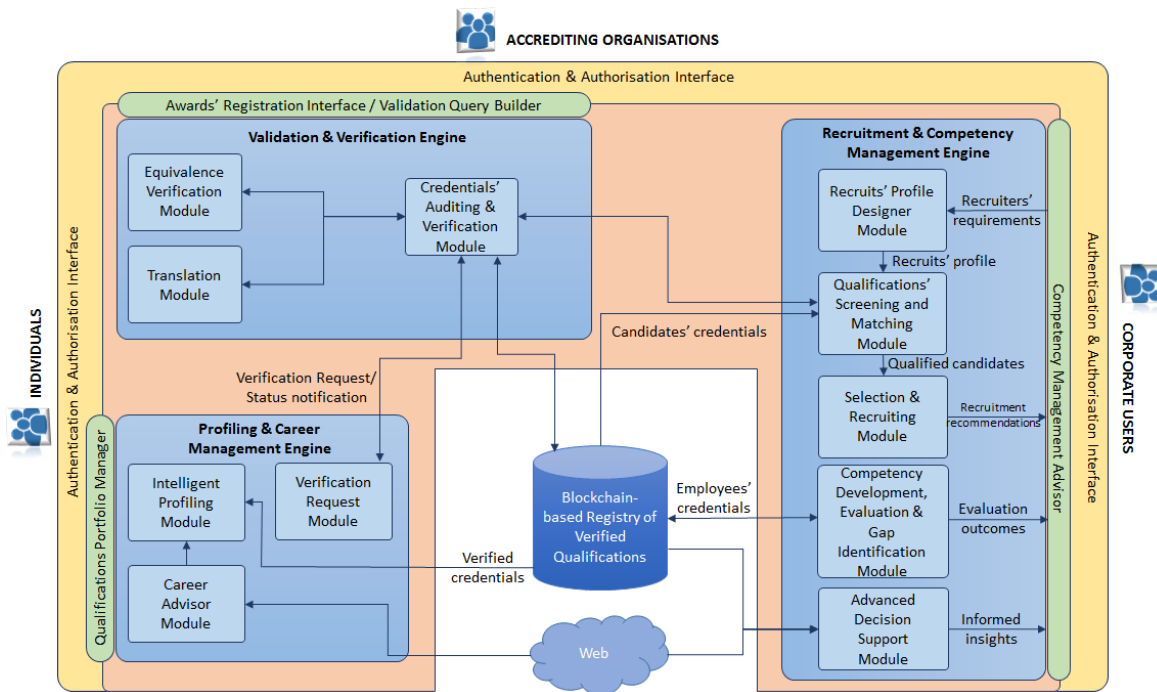


Figure 4. QualiChain Value Adding Services

and bringing into the individuals' attention job vacancies that match their profile, and iii. an *Intelligent Profiling Module*, that leverages job vacancies' elicited requirements and synthesises accordingly individuals' base profile information to deliver multiple, customised versions of their curriculum vitae.

Finally, the *Recruitment and Competency Management Engine* will include functionalities for competency management at both strategic and tactical level addressed to corporate users, the latter including not only education providing institutions, but also public authorities, private companies and policy makers. The Recruitment and Competency Management Engine exposes its functionality through the *Competency Management Advisor Interface* which makes up the entry point to the following sub-components: i. a *Recruits' Profile Designer Module*, enabling recruiters to designate the criteria that candidates should meet, and thereby specify the type and level education, work experience, and the rest of qualifications that they should possess as well as any other conditions and requirements they ought to fulfil, ii. a *Qualifications' Screening and Matching Module*, capable of retrieving applicants' credentials and juxtaposing these with recruiters' criteria to sort out a subset of appropriate candidates, iii. a *Selection and Recruiting Module*, applying advanced decision support algorithms on the subset of qualified candidates, to optimise candidate selection and allocation in corporate positions, iv. a *Competency Development, Evaluation and Gap Identification Module*, responsible for keeping track of employees' qualifications records and identifying competency deficit in relation to organisations' mid and long-term horizon goals and v. an *Advanced Decision Support Module*, featuring a variety of sophisticated data analytics, i.e., data mining, statistics' calculation, pattern/trend recognition, data visualisation and other functionalities of both descriptive and prescriptive character, to support insights acquisition and informed decision making.

From an end-user perspective and regarding the QualiChain platform presentation layer, the solution lays emphasis on intuitiveness and features beside the aforementioned management interfaces, appropriate authentication and authorisation interfaces for all targeted stakeholder groups, namely accrediting institutions, individuals and corporate users. Finally, the QualiChain data access layer envisages storage and retrieval of data from blockchain records regarding awards and qualifications, as well as from the web to the extent related statistics, job postings and other learning and career development opportunities are concerned.

B. QualiChain Pilot Use Cases

To test and validate the projected platform in its respective domains, it will be implemented in four distinct pilot use cases split between academia, private and public organizations. Specifically, the QualiChain pilots are the following:

1) Cross University Degree Equivalence Verification

Within this pilot use case, QualiChain will develop a methodology for representing the semantics of educational credentials, to support cross-institution and cross-context mapping between different forms of certifications. Existing vocabularies that describe learning goals and topics will be reused and extended to build a detailed knowledge model describing the entities relevant to educational accreditation and their relationships to each other, in the form of an ontology. This pilot will engage lifelong learners, students, job seekers and educational institutions.

2) Smart Curriculum Design and University Process Optimization

This use case will be implemented in the School of Electrical and Computer Engineering of the National Technical University of Athens (NTUA). It will take advantage of QualiChain's analytics and decision support capabilities to analyse the current skill level of students, the school's curriculum, and the labour market's requirements for the school's graduates to provide decision support for optimizing the school's curriculum. Additionally, this pilot will leverage the blockchain ledger to verify student skills and qualifications with smart badges. This pilot will engage undergraduate and Ph.D. students of the school as well as professors and administrative bodies.

3) Staffing the Public Sector

This pilot use case lies in using the QualiChain platform and services for supporting and simplifying public sector recruitment and competency management procedures. Given that recruitment in public administration must be based on the principles of impartiality, transparency, and fairness, this pilot will leverage the platform's blockchain to manage and verify the applications and other supporting documents submitted by candidates. Additionally, the recruitment and competency management services of QualiChain will be used to automate applications' checking and candidates' assessment and selection procedures, and respectively for supporting decisions related to the allocation of human resources within the public sector or employee mobility issues. This pilot will engage public administrations, recruitment firms, employees, job seekers, and issuing organisations.

4) Provision of HR Consulting and Competency Management Services

This pilot will explore blockchain for easily checking and ensuring the availability of certain competencies in an individual curriculum. Also, data analytics methodologies and algorithms will be applied for the effective matching of skills, qualifications, and competencies with job description requirements, not only for external selection, but also for internal mobility. Semantic technologies will be used to support corporate training and career management, throughout the entire individuals' job evolution. This pilot

will engage public entities looking for new applicants, candidates, and public workers.

V. PROGRESS AND RESULTS

This section describes the progress and current results stemming from QualiChain's operations up to this point. Since QualiChain is a multi-disciplinary project involving various partners from the education and employment sector, multiple technologies, pilots and actions, the current results will be split in four categories: theoretical results, legal and ethical landscape, technical results and development, and finally pilots' execution and early feedback. The progress and results are presented in the following sub-sections.

A. Theoretical background

One of the main objectives of QualiChain entailed the performance of an extensive analysis of the socio-economic landscape and market, by reviewing and updating the state of practices in terms of technologies' potential for QualiChain, and state of the art in qualifications certification and human resources management. The analysis entailed two levels regarding the aforementioned domains of interest: related national and European projects and initiatives and commercial tools and applications with both analyses yielding very interesting results. The criteria for both analyses were the following: target users, blockchain usage, personalisation approach, semantics usage, gamification approach, qualification certification and competency management. As expected, not every project/commercial tool included all the aforementioned functionalities. However, the results helped identify the state-of-play of current approaches and their usage of the aforementioned technologies to distil good practices, identify shortcomings, and ultimately assess the potential of QualiChain to address the challenges in both domains.

The first analysis was performed on 14 projects from various European countries. The focus was mainly on European initiatives due to the common challenge of GDPR compliance and what lessons can be derived from existing approaches. While most projects that were reviewed are focused on specific applications and do not holistically address the needs and challenges in qualification certification and competency management, the analysis also helped uncover interesting approaches that are currently being developed. More specifically, the EscoBadges [30] and OPENSIMR (Open European Skill Match Maker) [31] projects present great interest as they link user skills and qualifications to the ESCO ontology and offer added value services for matchmaking and recommendations of jobs and proper education, based on the talents' skill sets dynamics. In addition, the SEAL project [32] is unique in the domain as it implements trust management over blockchain via use of Self Sovereign Identities (SSI) and Verifiable Claims (VCs). These projects were thoroughly assessed to identify good practices and knowledge that can be extended under the context of QualiChain. In addition, QualiChain has

synergized with the SEAL project in an official capacity for knowledge and technology exchange and also to leverage SEAL's SSI infrastructure for QualiChain's role-based authentication component.

The second analysis was performed on 19 commercial tools/applications and yielded similar results. Most applications that were reviewed offer very specific functionalities that can be applied in specific EU countries (e.g., certification of teachers in the UK, certification of ICT employees on specific skills and qualifications etc.) and most of them do not leverage the possibilities that blockchain, semantics, data analytics, and gamification can offer. Despite the shortcomings of some of the approaches, the analysis also uncovered various interesting micro-services and solutions, such as the Higher Education Degree Datacheck [33] that provides advice and guidance on degree fraud, NOKUT [34] that performs periodic supervision of universities' curricula as well as Blockcerts [22] and Diplome [35] that leverage blockchain to produce verifiable credentials that are managed by the holders of such certificates in a decentralised manner.

The aforementioned analyses helped distil QualiChain's potential in the domains tackled, focusing on advancements that will be based on blockchain, semantics, data analytics, and gamification, which also produced an analysis of those technologies' potential to disrupt the field. In combination with feedback received from the project's pilot partners the outcomes of these analyses were translated into user requirements and stories that have shaped the platform's development. Another pertinent result of QualiChain's theoretical framework was the development of an implications' assessment framework that focuses on the short- and long-term implications stemming from the implementation of QualiChain and other similar solutions in the field of education and the labour market, in the form of PEST (political, economic, social, and technological) analyses for every stakeholder identified. Under this context, the recent Covid-19 pandemic was also taken into consideration to uncover additional challenges and opportunities that this new reality has created. The overall conclusion of QualiChain's theoretical framework is that the project is ideally situated in terms of timing, technologies used, and challenges addressed, a fact has been validated numerous times with project partners (interviews, questionnaires, focus groups) and the research community (scientific conferences, project synergies).

B. Legal and ethical landscape

The QualiChain technical solution includes components that will store and process user data that are considered personal and are thus protected by the General Data Protection Regulation. As such, a comprehensive analysis of the European legal and ethical landscape was performed focusing mainly on the GDPR, national legislations (concerning pilot countries) and ethical aspects that need to be taken into consideration for the development of the QualiChain platform. The main GDPR articles and

regulations that need to be taken into account under the context of QualiChain refer to users' rights for data erasure and the right to restrict data processing. In addition, there are rules and obligations that QualiChain must adhere to such as the development of an informed consent form (for informing platform users on their rights concerning their data), a Data Protection Impact Assessment (DPIA) (risk assessment focusing on security and privacy issues) and the appointment of a Data Protection Officer (DPO). In addition, the analysis of the ethical landscape also uncovered various ethical requirements relevant to the platform development that need to be addressed. The most important of them include the data minimisation principle (only necessary user data will populate the system) as well as applying privacy-by-design principles during platform development. In other words, the analysis of the ethical landscape uncovered that all security and ethical aspects of the technical solution must be set out and addressed before platform development is underway, which is a rule that has been followed by the technical team.

As already mentioned, one of the most important results of these tasks was the creation of the informed consent/assent form that informs users on the following:

- Data collected
- Usage of users' data by third parties
- Users' rights concerning their data
- Explanation of why QualiChain processes user data
- Cookie details
- DPO Contact details

In fact, QualiChain's consent form has been validated by the DPO of the project and the legal departments of every consortium partner and has already been used in an official legal capacity to bring in data from students, job seekers, professors, employers and so on.

The general consensus stemming from the legal and ethical analysis is that QualiChain is a low-risk project when it comes to security issues and personal data. Despite that fact, it was considered imperative to perform a DPIA so that any security issues are identified and addressed from the early stages of the project, along the lines of the privacy-by-design principle. Security risks identified and resolved so far are the following:

- Risk of compliance with the right-to-be-forgotten: Given that blockchain is immutable and no data can be deleted from it, most of the datasets that are either collected or generated by the QualiChain platform, including any personal data, will be stored in the platform's non-blockchain, database repository. In this way the project can ensure compliance with the "right-to-be-forgotten" requests by the research participants. The blockchain will only be intended to be used to provide guarantees that the non-blockchain data has not been tampered with or faked by utilising strong encryption mechanisms with multiple confirmations on each of the executed transactions that guarantee transparency, data privacy, and security.

- Risk of malicious third-parties maintaining copies of user data even after users have requested their deletion: As also stated in the project's consent form QualiChain is not liable for malicious third-party actions but will address any such issues that are uncovered by following the respective procedures (informing the organisation that the data must be deleted, informing the respective legal authorities).
- Potential data breaches: QualiChain is based on blockchain, which is a decentralised approach, meaning that there is no single point of failure in the system and that each user is responsible for the safety of their personal data that they keep off-chain.

All in all, the assessment of the legal and ethical landscape yielded very useful results for QualiChain and the deployment of its technical solution. While QualiChain is considered a low-risk project (no sensitive data will be stored and processed), every possible measure has been taken to ensure legal compliance. The analysis of the national legislations in addition to the GDPR resulted in the project's declaration of compliance that was a unanimous decision validated by the DPO and other legal entities. One of the objectives of QualiChain is to produce a roadmap for legal and ethical compliance that can be extended beyond the scope of the project (and by extension education and the labour market) and applied in various other initiatives and development efforts that include one or more of QualiChain's core technologies. This roadmap is projected to include step-by-step instructions for assessing the risks associated with a project and achieving legal and ethical compliance under the context of EU regulations.

C. Technical results and platform development

The technical vision for the QualiChain technical solution can be seen in Figure 4, in Section IV and is the first approach to design the platform's architecture. It illustrates a total of 12 components grouped into categories of common functionalities. These modules and categories are functional, in the sense of reflecting the various activities required for the project pilots and vision. Regarding the actual implementation, however, common functionalities across these modules were abstracted to produce a simpler and more general-purpose global architecture, allowing the specific modules to be implemented as specialised instances of more general components. As such, the global architecture of QualiChain that leads the development includes five components which cover the functionalities of the more specific modules, indicated underneath:

- Access Control and Identity Management
 - Authentication and Authorization Interface
- Knowledge Graph Engine and Verification
 - Credential Auditing and Verification Module
 - Blockchain-based Registry of Verified Qualifications
 - Verification Request Module
 - Equivalence Verification Module

- Knowledge Extraction
 - Recruit Profile Designer Module
 - Intelligent Profiling Module
 - Translation Module
- Analytics and Decision Support
 - Career Advisor Module
 - Qualification Screening and Matching Module
 - Selection and Recruiting Module
 - Competency Development, Evaluation, and Gap Identification Module
 - Advanced Decision Support Module
- Dashboard and Frontend
 - Separated from the above backed components to support decentralization and to encourage openness and reuse of platform components

This distinction was done because the functionalities required to implement a Career Advisor module and a Selection and Recruiting Module (for example) are essentially the same - an analytics and decision support architecture making recommendations and suggestions based

on data and a particular set of analytics questions and decision points. By providing the common analytics and decision support component with data related to education, career paths and job markets, or candidates, job requirements and employment criteria, the two distinct decision support modules can be implemented with essentially the same code. Similarly, for the various tasks related to querying verifiable knowledge and populating knowledge graphs with semantic data from various sources - the combination of common functionality into generic components makes the implementation more robust and efficient. The updated QualiChain architecture and the interconnections between the aforementioned components and their respective modules can be seen in Figure 5. That final architecture is the result of the following two actions: i) the technical contributors of the project participated in offline discussions and ii) a workshop took place, during which the technical partners designed the final architecture in detail and decided how the components would efficiently and effectively communicate with each other.

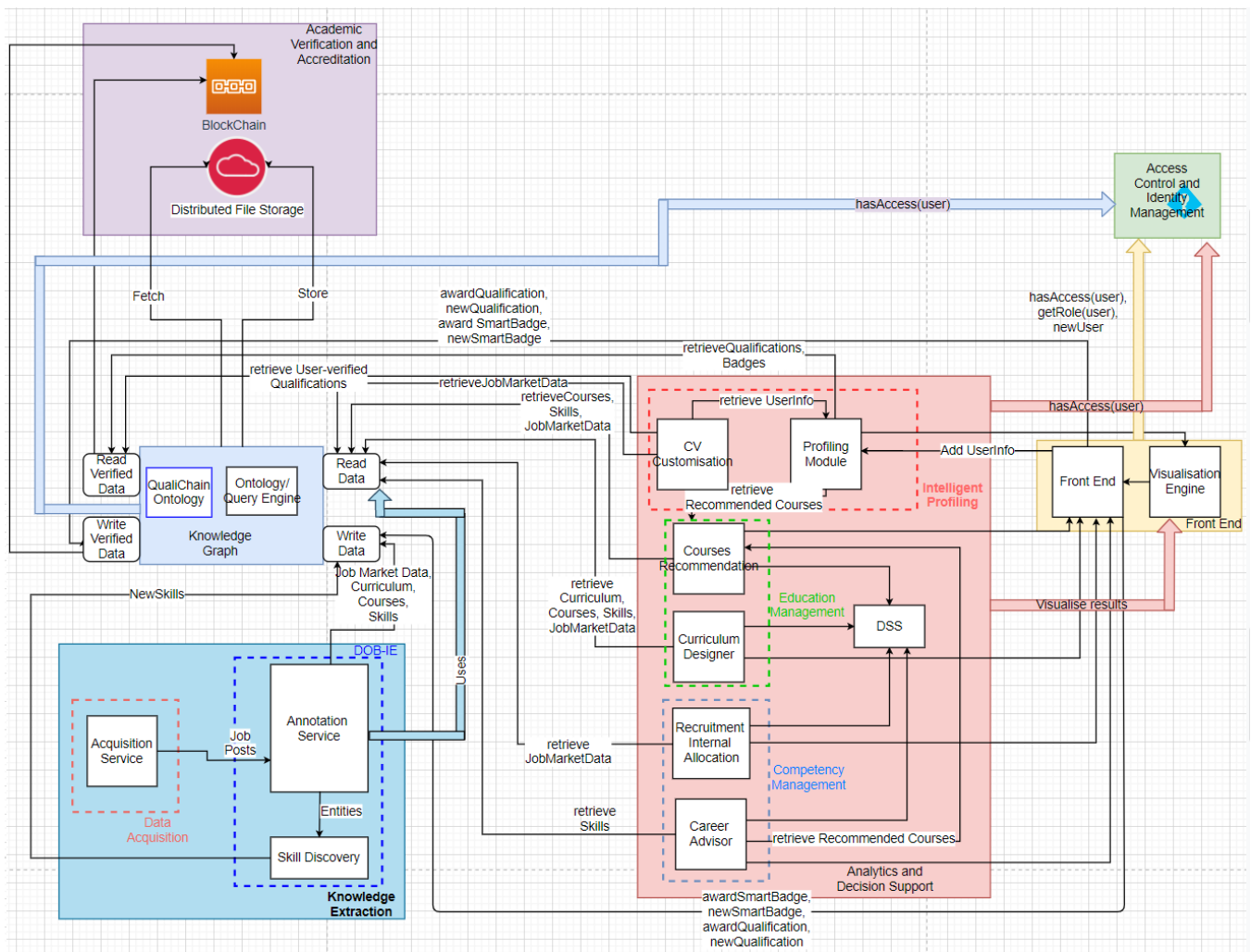


Figure 5. QualiChain Global Architecture

Based on the architecture mentioned above, the components are structured as loosely coupled services. Every component constitutes a service, and all the services together comprise the entire functionality of the QualiChain platform. The fundamental flow is based on keeping knowledge and data relating to each stakeholder with that stakeholder wherever possible, using federated querying to create a “virtual knowledge graph” across the set, and with Access Control and Identity Management processes enforced locally. Distributed storage solutions are used for open (not private) or common knowledge and data. The Knowledge Graph Management Engine handles querying and insertion of knowledge from and to stakeholder sources while respecting access constraints and interacting with the blockchain to store and retrieve verification metadata. The Knowledge Extraction Module takes care of the semantification of data from multiple sources, via the Dashboard/Frontend or from elsewhere online, and passing them to the Knowledge Management Engine to be stored. The Decision Support and Analytics Module works on knowledge retrieved from the federated engine, analysing it on behalf of users, and using the results to provide them with decision support. This module utilizes several Multi-criteria Decision Support and Machine Learning methods in order to produce the desired results. In particular, it leverages the MAUT [36], Topsis [37], Electre I [38], and Promethee II [39] methods to create a general-purpose tool that facilitates decision making as well as Association Rules Mining [40] to discover interesting relations between variables in large datasets. The results of these may also constitute new knowledge relevant to affected stakeholders and may therefore be inserted into the relevant knowledge graph.

Finally, the Dashboard and Frontend provides task-specific user interfaces dedicated to the various activities of users of the platform, interacting with every component: user and public knowledge stores, the Knowledge Extraction Engine, Decision Support module, and the Knowledge Graph Engine, as well as accessing the blockchain for, e.g., verification of retrieved data.

Apart from updating the system architecture and developing each component, the project team has already released the first prototype version of the platform, in which, three basic back-end components have been integrated, namely, the Verification component, the Knowledge Extraction component, and the Knowledge Graph component. These functionalities leverage the blockchain solution for academic verification (the baseline functionality of the platform), as well as the QualiChain Knowledge Graph as the main knowledge base of the QualiChain solution. Additional value-adding services and a well-designed front-end will be integrated at a later step of the development process. At the moment, the QualiChain platform prototype can support the following functionalities:

- Qualification and Smart Badge Verification,
- Qualification and Smart Badge Accreditation

- Addition of new Qualifications and Smart Badges to the system
- Job posting data acquisition, knowledge extraction from the acquired data, and storing the result to the Knowledge Graph
- Querying the Knowledge Graph for specific skills, qualifications, smart badges, or job posting data.

Regarding qualification and smart badge verification, a user interested in verifying if such an asset is valid, sends a verification request to QualiChain and provides a hash for this specific asset. The QualiChain backend via the Academic Verification and Accreditation component, searches for this hash in the blockchain and in case the hash exists, the verified qualification or smart badge is returned to the user (see Figure 6). Otherwise, a message that the hash does not exist is sent.

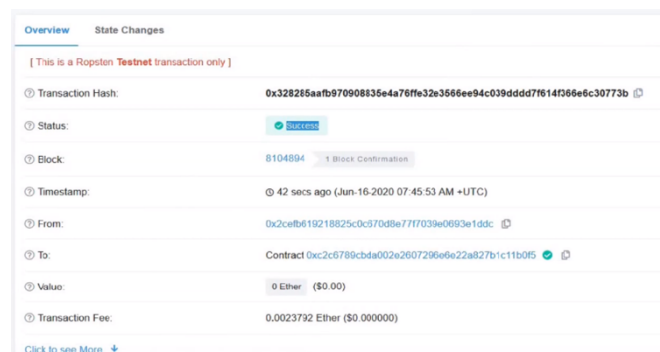


Figure 6. Qualification Verification via transaction hash

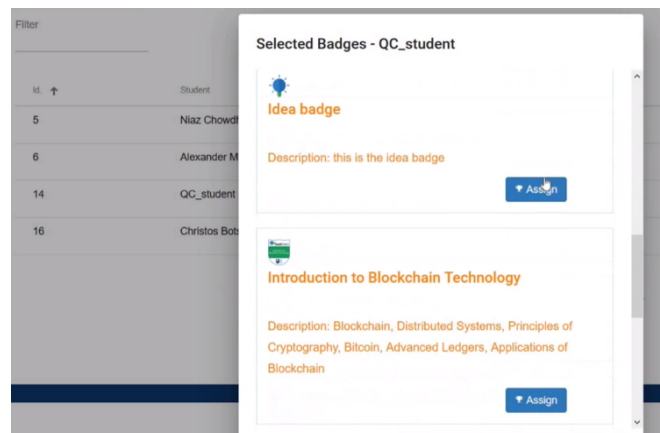


Figure 7. Smart badge accreditation

As far as accreditation is concerned, users authorised to award a badge or a qualification, can choose from the list of the ones available to them in the Knowledge Graph and award it to the user of their choice. The hash of the new asset will be stored in the blockchain and the verified qualification document will be stored in the distributed file storage. The user can also insert new assets into the Knowledge Graph. Specifically, an entity with the authority to create a new qualification or badge (e.g., a higher education institution, an issuing organisation, and a university professor), queries the

Knowledge Graph to find out if it already exists, and if not, requests its insertion via the QualiChain platform. The system stores the new asset into the Knowledge Graph and afterwards, the entity that introduced it can award it to other users.

Except for the blockchain functionality of the QualiChain platform, the Knowledge Graph supports queries to the Knowledge Base. This functionality is not available to the users; however, it is the backbone of the QualiChain platform given that each component that requires data to work properly, must query the Knowledge Graph to acquire them. For now, such data consist of job postings, skills, qualifications, and smart badges. However, as the platform grows both in terms of functionality and variety of services, more types of data will be introduced.

Jobs

Filter

Title	Employment type	Seniority Level	Action
Solutions Architect	Full-time	Senior	View
Software Engineer	Contract	Senior	View
Data Scientist	Contract	Entity level	View
Frontend Developer	Temporary	Associate	View
Data Scientist	Volunteer	Senior	View

Items per page: 5 1 - 5 of 18

Figure 8. Knowledge graph recommended jobs

The last functionality that is supported by the platform concerns the data acquisition and the ontology population. Data are extracted from job posting web sites, processed, and stored in the Knowledge Graph. Apart from already existing services that need this information, this functionality will also facilitate the Analytics services in the future, which will be able to provide meaningful suggestions based on large volumes of actual job market data and the required skills for specific job positions.

D. Pilots' execution and early results

This sub-section provides a summary on the operation and execution status of each pilot case. After the initial stage of pilot preparation, in which all pertinent stakeholders for each pilot were identified, requirements were elicited based on bibliographic research and stakeholder engagement, and each pilot concept was validated, the pilot partners started working on specific scenarios that will be used to execute each pilot case, gather feedback, and ultimately assess its usefulness in addressing current challenges. In addition, pilot partners organized various workshops, stakeholder interviews and questionnaires to gather early feedback on each pilot case as well as the QualiChain solution as a whole.

1) Cross University Degree Equivalence Verification

The use case for this pilot can be summarized as follows. Lifelong learners are earning smart badges upon reaching certain milestones in their studies, e.g., completing part of a course or a whole course. Smart badges are stored on the Blockchain, thus ensuring the validity of the awarded accreditation and eliminating the risk of fabricated qualifications. Smart Badges include data about the key skills that learners have acquired upon obtaining these badges. As learners continue to earn these badges, they start receiving personalized recommendations about the latest job offers that match their skills. They also receive recommendations about what to study next, based on the skills needed for the job market. The process workflow designed for the scenario of this pilot case can be seen below in Figure 9.

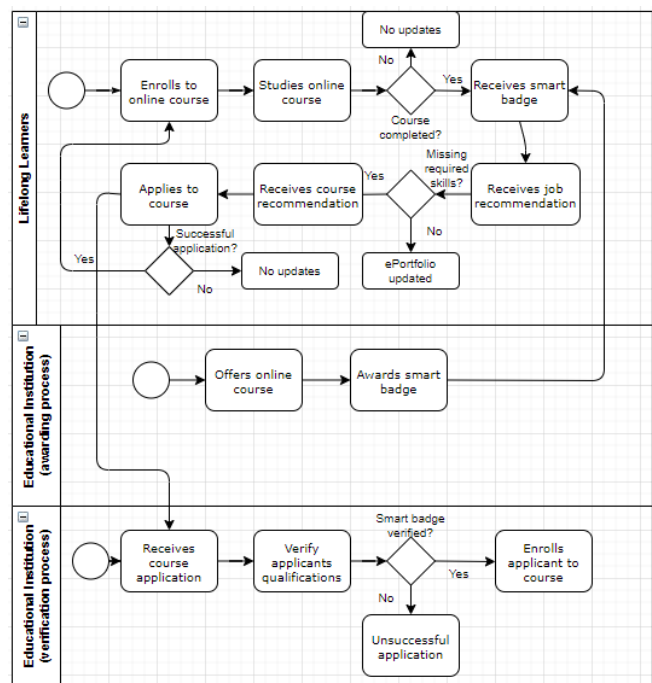


Figure 9. Workflow for lifelong learners

2) Smart curriculum design and university process optimization

The use case and respective scenarios developed for this pilot can be summarized as follows. In the first scenario that is tailored for university students, they use the QualiChain Intelligent Profiling mechanism (IPM), which draws data from the platform's database and the web to help them create their personal profile that is then saved in QualiChain. When the student's profile is created, the analytics and Decision Support System (DSS) modules of the QualiChain platform will analyse the student's personal data, course-related data, job market data etc. to provide recommendations and suggestions to the student concerning courses, seminars, hackathons etc. The overall process flow can be seen in Figure 10.

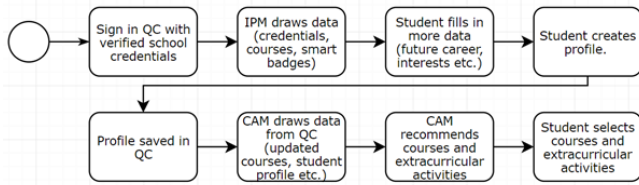


Figure 10. Workflow for university students

The second scenario is tailored for university professors who will first sign in in QualiChain with their school credentials and create their profile that will include information about them and their courses. Such data will then be analysed in conjunction with labour market data, technological developments and popular professions for the school’s graduates to identify gaps in courses (and by extension the entire curriculum) and provide recommendations for filling those gaps. The updated course is then saved in QualiChain and the recommendations that the DSS mechanism provides are updated (based on the needs that were covered in this specific course). When professors update a course based on such recommendations, QualiChain will update the suggestions to take into account more general curriculum gaps that were addressed. In the end, the sum of updated courses, knowledge gaps, similar subjects taught in different courses etc. are synched with the Advanced Decision Support Module (ADSM) tool which will in turn produce recommendations for the school’s curriculum as a whole. The workflow of this specific scenario can be seen in Figure 11.

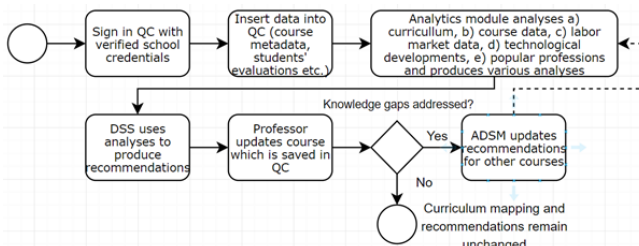


Figure 11. Workflow for university professors

The final scenario of this pilot describes the process of smart badge accreditation in a university setting. In QualiChain smart badges can be awarded in the following ways:

- Professors to students: Given that some courses have group/personal assignments that assign students a number of points, professors of a course can choose to award smart badges of their choice to the students or groups of students that achieved the best results. Such results can include but are not limited to the most efficient algorithms in software related courses, the best results in courses, in the context of which students split into groups and compete with each other etc. Additionally, smart badges can be awarded for the involvement of students in hackathons, special lectures and other activities organized by a professor.

- Lecturers/Ph.D. Students: Several courses are being taught not only by the professors, but also by lecturers (usually Ph.D. candidates) who are not being recognized for their involvement in the course. QualiChain, through this pilot, proposes the following solution: a professor will first verify with a smart badge the lecturer’s involvement in the course. During the course, students will be able to award the lecturer with tokens, e.g., for being communicative during teaching. Thus, the lecturers of such academic institutions can also get recognized for their efforts and contributions and improve their profile in QualiChain as well. A suitable ratio of token to smart badges will be set out to better reflect the skills of the Ph.D. student as a lecturer. The workflow for the use case described above can be seen in Figure 12.

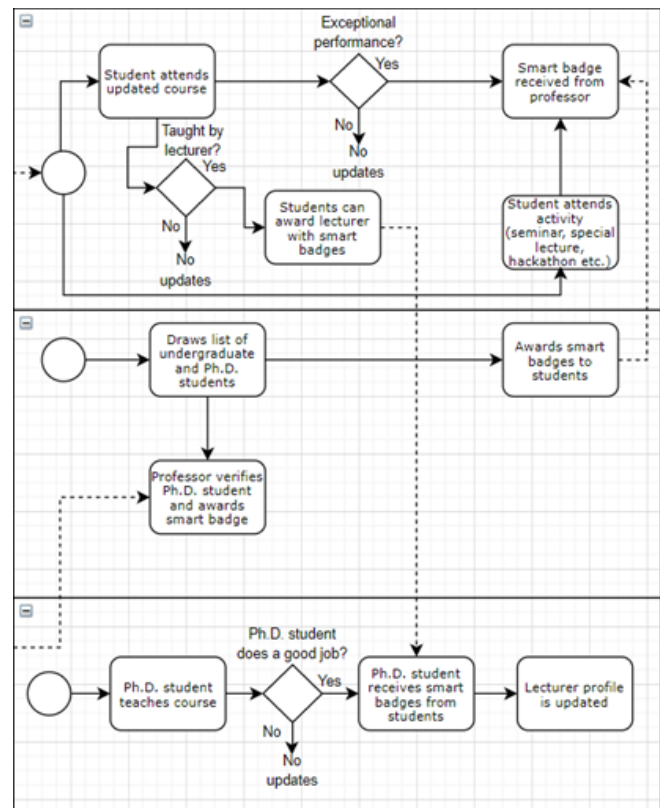


Figure 12. Workflow for smart badge accreditation

3) Staffing the public sector

The scenario developed for this pilot case represents a generic hiring process to fill in a given position in a public sector organization. The process is initiated after a qualification component (e.g., a degree) is published by an issuing organization (e.g., a university) and saved in QualiChain upon obtaining the citizen’s consent. In addition, a public entity will be able to announce job positions/vacancies along with the job description and required qualifications on QualiChain. QualiChain users will receive notifications for new vacancies via the analytics

capabilities of the platform and will be able to fill in their qualifications, upload the relevant proof of qualifications declared (e.g., university degree), and apply for the vacancy they are interested in. With the help of QualiChain, the public entity will confirm the validity of the qualifications declared and use the DSS module of the platform to receive an initial ranking of candidates, based on custom criteria set for the specific job position. Based on this initial ranking, the public entity will then proceed to the stage of interviews. The workflow for this scenario can be seen below in Figure 13.

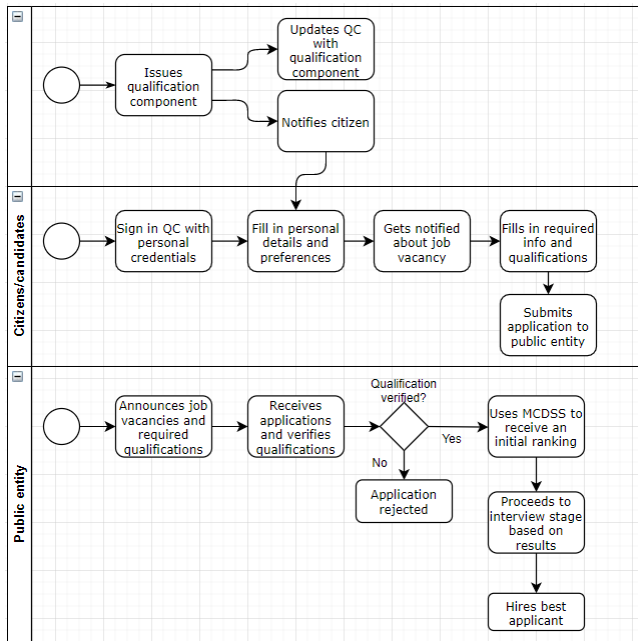


Figure 13. Workflow for public sector staffing

4) Provision of HR consulting and competency management services

The scenario developed for the final pilot case aims to facilitate hiring, human resources, and internal competency management processes for private and public organizations. In this use case, private and public entities will create new job postings or initiate internal competency management processes on the QualiChain portal, either describing a job position or an internal reallocation process and setting the required competencies including experiences, degrees, and hard (technical) and soft skills that they are seeking from candidates and employees. A competency management component will be developed for the purposes of this scenario that will be based on the already implemented decision support capabilities of the platform. The workflow of this scenario can be seen in Figure 14.

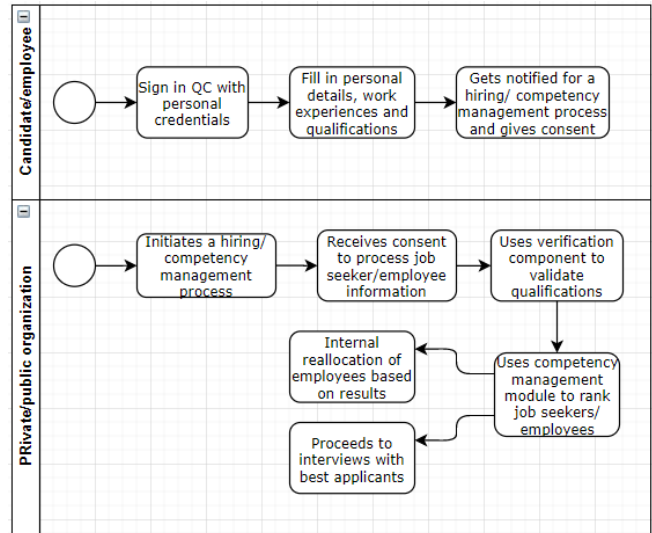


Figure 14. Workflow for competency management

As in the previous pilot cases, job seekers and employees will create a profile in the QualiChain platform and fill it with personal information, work experiences, and qualifications. The competency management system will validate a profile's contents, matching them with the job requirements and ranking the applicants according to the semantic similarity of their CVs to the job posting in order to facilitate candidate's selection and speed-up the recruitment and reallocation process. After the recruitment process is over, candidates/employees will be provided with course recommendations based on their skills to further develop their competencies in their career path or their intra or inter department mobility. Competencies, courses, and evaluation results in an employee's current position will be used by the competency management system to suggest other career paths and potential positions at any time, including required and missing skills for the next job opening.

It is of utmost importance to clearly define how the performance of the pilots will be measured and how they are going to be evaluated. In particular the evaluation of each of the four aforementioned pilots includes the following steps (that are also presented in Figure 15):

- Documentation of the evaluation framework and validation methodology, which will define the practices that will be used in order to obtain feedback from the end-users
- Documentation of the set of scenarios that will run during each pilot, including the involved actors, the key performance indicators, and the time plan
- Reporting of the pilots' operation and execution
- Documentation of the lessons learnt that could constitute methodological adoption guidelines for the utilization of the QualiChain platform.

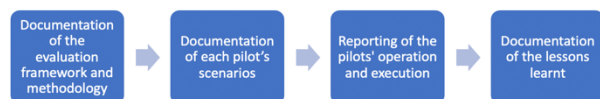


Figure 15. Steps for pilots' evaluation

Currently all QualiChain pilots are on the phase of alpha-testing the QualiChain individual services. Thus, the use case results are focused on: a) (successful) validation of the concept and procedural / methodological aspects; b) data availability and data flows; c) (successful) validation of the complete coverage of use case aspects by the QualiChain individual services.

VI. CONCLUSIONS & NEXT STEPS

This publication presented QualiChain, a project aiming to develop a decentralized platform for storing, sharing, and verifying academic and employment qualifications. A literature review in qualifications' certification, recruitment and competency management is included to assess current approaches and solutions and showcase the added value offered by the QualiChain concept. QualiChain aims to address the challenges of the sectors tackled holistically, by meeting the needs of all possible stakeholders, a fact that is also reflected in the complexity of QualiChain's technical solution and the number of distinct pilot cases in which it will be implemented. When it comes to project results, QualiChain has set up a robust theoretical framework by combining desk research and stakeholder engagement that does not only guide the technical efforts but can also act as a solid foundation for similar projects in the domain. In addition, and given that QualiChain deals with personal data, great effort has been given to analyse the current legal and ethical landscape and perform the necessary actions to remain compliant with European and national legislations, mainly focusing on the GDPR. When it comes to technical results, the first version of the platform has already been released, including the blockchain and semantic infrastructure of the solution as well as a number of components that facilitate smart badge accreditation, qualification verification, and recommendations based on decision support algorithms. The validation of the platform is also underway by the project's four pilots that have already defined the methodology that will be used for the validation of the platform, developed specific scenarios, and began engaging end users. The next steps include the release of the second version of the platform that will include more value-added services as well as the final validation of the platform. All in all, the innovation potential of QualiChain is very strong, as it focuses on a domain, that of education credentials, that has largely resisted the pool of technology and where the improvement potential in the processes of certificates' archiving, management and verification, the information flow amongst stakeholders and the opportunity for offering value adding services on top of

the aforementioned processes and developing new business and education models is literally huge. Disrupting any (or even more than one) of the aforementioned aspects can lead to substantial efficiency, productivity and transparency impacts, which should in turn have noticeable positive societal, economic, political and cultural effects.

ACKNOWLEDGMENT

This work has been co-funded by the European Union's Horizon 2020 research and innovation programme under the QualiChain project (<https://qualichain-project.eu/>), Grant Agreement No 822404.

REFERENCES

- [1] C. Kontzinos, O. Markaki, P. Kokkinakos, V. Karakolis, S. Skalidakis, and J. Psarras, "Decentralised Qualifications' Verification and Management for Learner Empowerment, Education Reengineering and Public Sector Transformation: The QualiChain Project," *Mobile, Hybrid, and On-line Learning (eLmL 2020)*, 2020.
- [2] M. Turkanović, M. Hölbl, K. Košič, M. Heričko, and A. Kamišalić, "EduCTX: A blockchain-based higher education credit platform," *IEEE Access*, 2018, doi: 10.1109/ACCESS.2018.2789929.
- [3] W. Gräther, S. Kolvenbach, R. Ruland, J. Schütte, C. F. Torres, and F. Wendland, "Blockchain for Education: Lifelong Learning Passport," *Proc. 1st ERCIM Blockchain Work. 2018, Reports Eur. Soc. Soc. Embed. Technol.*, 2018.
- [4] A. F. Camilleri, A. Grech, and A. Inamorato dos Santos, "Blockchain in education," *Publ. Off. Eur. Union, Luxemb.*, 2017, doi: 10.31145/1999-513x-2019-6-32-35.
- [5] J. Bear, "Degree mills: The billion-dollar industry that has sold over a million fake diplomas." 2012.
- [6] "CareerBuilder." <https://www.careerbuilder.com/> (accessed Dec. 03, 2020).
- [7] "Liar, liar! You won't get hired | CareerBuilder." <https://www.careerbuilder.com/advice/liar-liar-you-wont-get-hired> (accessed Dec. 04, 2020).
- [8] "STATISTIC BRAIN RESEARCH INSTITUTE - Statistic Brain." <https://www.statisticbrain.com/> (accessed Dec. 04, 2020).
- [9] "StatisticBrain: Resume Falsification Statistics." <https://www.statisticbrain.com/resume-falsification-statistics/> (accessed Dec. 03, 2020).
- [10] G. Mohamedbhai, "The Scourge of Fraud and Corruption in Higher Education," *Int. High. Educ.*, pp. 12–14, 2016, doi: 10.6017/ihe.2016.84.9111.
- [11] D. W. Chapman and S. Lindner, "Degrees of integrity: the threat of corruption in higher education," *Stud. High. Educ.*, pp. 247–268, 2014, doi: 10.1080/03075079.2014.927854.
- [12] M. Sharples and J. Domingue, "The blockchain and kudos: A distributed system for educational record, reputation and reward," in *European conference on technology enhanced*

- learning*, 2016, pp. 490–496, doi: 10.1007/978-3-319-45153-4_48.
- [13] P. Devine, “Blockchain learning: can crypto-currency methods be appropriated to enhance online learning?,” *ALT Online Winter Conf.*, pp. 7–10, 2015.
- [14] A. Darejeh and S. S. Salim, “Gamification Solutions to Enhance Software User Engagement—A Systematic Review,” *Int. J. Hum. Comput. Interact.*, vol. 32, no. 8, pp. 613–642, Aug. 2016, doi: 10.1080/10447318.2016.1183330.
- [15] “Prospects HEDD.” <https://hedd.ac.uk/> (accessed Dec. 03, 2020).
- [16] D. Mathiews, “What blockchain technology could mean for universities.” <https://www.timeshighereducation.com/news/what-blockchain-technology-could-mean-for-universities> (accessed Dec. 03, 2020).
- [17] “IMS Open Badges.” <https://openbadges.org/> (accessed Dec. 03, 2020).
- [18] K. Carey, “A Future Full of Badges’. The Chronicle of Higher Education.” <https://www.chronicle.com/article/a-future-full-of-badges/> (accessed Dec. 03, 2020).
- [19] <http://openlearn.edu> (accessed Aug. 01, 2020).
- [20] <https://digitalcurrency.unic.ac.cy/free-introductory-mooc/self-verifiable-certificates-on-the-bitcoin-blockchain/academic-certificates-on-the-blockchain/> (accessed Aug. 01, 2020).
- [21] “Digital Diploma debuts at MIT | MIT News | Massachusetts Institute of Technology.” <https://news.mit.edu/2017/mit-debuts-secure-digital-diploma-using-bitcoin-blockchain-technology-1017> (accessed Dec. 03, 2020).
- [22] “Blockcerts: The Open Standard for Blockchain Credentials.” <https://www.blockcerts.org/> (accessed Dec. 03, 2020).
- [23] “Open BlockChain.” <https://blockchain.open.ac.uk/> (accessed Dec. 03, 2020).
- [24] “OpenCerts - An easy way to check and verify your certificates.” <https://www.opencerts.io/> (accessed Dec. 04, 2020).
- [25] “Home | ethereum.org.” <https://ethereum.org/en/> (accessed Dec. 04, 2020).
- [26] “Verifiable credentials in European Blockchain Services Infrastructure – Smart Degrees.” <https://www.smartdegrees.es/en/verifiable-credentials-in-european-blockchain-services-infrastructure/> (accessed Dec. 03, 2020).
- [27] J. Bersin, “The HR Software Market Reinvents Itself,” 2016. <https://www.forbes.com/sites/joshbersin/2016/07/18/the-hr-software-market-reinvents-itself/?sh=6f95c4695d0a> (accessed Dec. 03, 2020).
- [28] Y.-K. Chou, *Actionable gamification: Beyond points, badges, and leaderboards*. 2019.
- [29] L. E. Ellis, S. G. Nunn, and J. T. Avella, “Digital badges and micro-credentials: Historical overview, motivational aspects, issues, and challenges,” in *Foundation of Digital Badges and Micro-Credentials: Demonstrating and Recognizing Knowledge and Competencies*, Springer, Cham, 2016, pp. 3–21.
- [30] “ESCO badges.” <http://escobadges.eu/> (accessed Dec. 03, 2020).
- [31] “OpenSKIMR.” <http://openskimr.eu/> (accessed Dec. 03, 2020).
- [32] “2018-EU-IA-0024 | Innovation and Networks Executive Agency.” <https://ec.europa.eu/inea/en/connecting-europe-facility/cef-telecom/2018-eu-ia-0024> (accessed Dec. 03, 2020).
- [33] “Higher Education Funding Council for England (HEFCE): Higher Education Degree Datacheck (HEDD).” <https://hedd.ac.uk/#section-what-we-offer> (accessed Dec. 01, 2020).
- [34] “Nokut.” <https://www.nokut.no/en/> (accessed Dec. 03, 2020).
- [35] “CIMEA: Diplome.” <http://www.cimea.it/en/projects-list/diplome-blockchain4people/home-page-blockchain-2.aspx> (accessed Dec. 01, 2020).
- [36] J. S. Dyer, “MAUT-multiattribute utility theory,” in *International Series in Operations Research and Management Science*, 2005.
- [37] Y. Çelikbilek and F. Tüysüz, “An in-depth review of theory of the TOPSIS method: An experimental analysis,” *J. Manag. Anal.*, pp. 281–300, 2020, doi: 10.1080/23270012.2020.1748528.
- [38] J. Figueira, V. Mousseau, and B. Roy, “ELECTRE methods,” *Mult. Criteria Decis. Anal. State Art Surv.*, pp. 133–153, 2005, doi: 10.1007/0-387-23081-5_4.
- [39] B. Mareschal, “The Promethee Methods for MCDM,” *Readings Mult. Criteria Decis. Aid, Springer*, pp. 216–252, 1990.
- [40] Q. Zhao and S. S. Bhowmick, “Association Rule Mining: A Survey,” 2003.