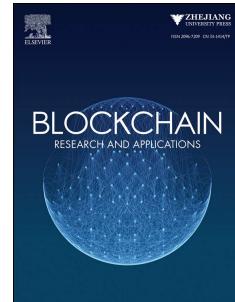


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Integrating an Academic Management System with Blockchain: A Case Study

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ABSTRACT

This paper reports on the design, implementation and experiment phases of the EU H2020 QualiChain pilot “Staffing the Public Sector – The Case of Portugal”. The overall purpose of this pilot is to ensure the authenticity and integrity of the diplomas for all involved stakeholders and therefore to contribute to solving the diploma counterfeiting and/or falsification that is a great threat to the recruitment of qualified personnel. The main innovative aspect of this solution is the integration that is offered between an Academic Management System (the Fenix.edu platform) and a Blockchain (Ethereum) to automatically deploy diplomas. This solution helps the involved stakeholders to trust the diplomas provided. The case study involves four different stakeholders and studies, specifically, the increase of their satisfaction in terms of diploma control, diploma veracity, and diploma credibility. The developed system was tested with external participants who were asked to follow a set of guidelines and complete a survey to assess their perceptions. All system interactions were recorded, and data was analyzed. The results achieved indicate that the participants successfully executed the guidelines and a perception increase toward diploma control, veracity, and credibility is identified.

1. Introduction

Today, the majority of academic certificates are issued on paper and sometimes digitized into PDF or a similar format. The recruitment of professionals for a company or other organization can be a slow and costly process, as it can involve analyzing the documentation of a large number of candidates. Moreover, verifying paper or digitized certificates can be a very time-consuming process, as it can involve manually contacting the Higher Education Institution (HEI) that granted them to check their authenticity. However, the verification of diplomas is a necessity, as there is a vast market of counterfeit academic diplomas and certificates. According to a survey, more than half of curricula and job applications contain falsifications and more than three-quarters are misleading (StatisticBrain, 2022).

In this paper, we describe a case study that integrates a university management system with a blockchain-based application that enables certificates to be deployed on the Ethereum blockchain. In particular, we extend FenixEdu, an academic management system used by several Portuguese HEIs and a few from other countries, so that it can be easily integrated with a blockchain solution for verifiable certificates. The feedback collected from the users suggests that they value the control, veracity, and credibility of the diplomas provided by the solution.

This case study is part of the QualiChain project¹. QualiChain aims at the creation, piloting, and evaluation of a decentralized platform for the storage, sharing, and verification of education and employment qualifications. The project focuses on evaluating the potential of blockchain technology, algorithmic techniques, and computational intelligence to disrupt the domain of public education, as well as its interfaces with private education, the labor market, public sector administrative procedures, and the wider socio-economic developments (Vlachou, Kontzinos, Markaki, Kokkinakos, Karakolis and Psarras, 2020; Keck, Vidal and Heller, 2020; Zarafidis, Siassiakos, Strotos, Deriziotis and Askounis, 2020; Mikroyannidis, Third and Domingue, 2019; Serranito, Vasconcelos, Guerreiro and Correia, 2020).

The project focuses more specifically on the assessment of the implications (technical, political, socioeconomic, legal, and cultural) as well as the impact – in terms of benefits and risks – of the prescribed solution’s utilization, whose disruptive potential lies in the exploitation of the innovative features of the aforementioned individual technologies, as

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¹QualiChain project: <https://qualichain-project.eu>

well as in their unique combination in a new territory for the provision of a set of baseline services (Award/Qualification Archiving, Award/Qualification Verification, Qualification Portfolio Management) and a number of value-adding services (Career Counselling, Intelligent Profiling and Competency Management including Recruitment, Competence Evaluation and Development; Consulting and Decision Support).

This case study corresponds to the project's pilot *Staffing the Public Sector – The Case of Portugal*. This pilot (Rizzo and Cantù, 2013) focuses on the use of the QualiChain platform to staff the Portuguese public administration. Integrating FenixEdu with the QualiChain platform allows the diplomas issued using FenixEdu to be automatically inserted into the QualiChain blockchain, allowing the Portuguese public administration to have access to all diplomas issued by universities that use FenixEdu, within the access limits imposed by students and schools' administrations. The QualiChain platform ensures the authenticity and integrity of the diplomas.

The paper is organized as follows. Section 2 presents the case study that is considered throughout the paper. Section 3 describes the core components of the solution and their integration. After that, Section 4 specifies the methodology used to collect data during the participant involvement. Section 5 evaluates the data obtained. Afterwards, Section 6 discusses the results obtained. Finally, Section 7 identifies the lessons learned by this pilot and Section 8 concludes the paper.

2. Case Study Description

This paper presents a case study focusing on the use of the QualiChain platform to staff the Portuguese public sector. The use case involves the integration of the FenixEdu information system² with the QualiChain platform. FenixEdu is an academic management platform that supports full program and course management, including the issuing of diplomas (essentially PDF documents that are printed, signed, and officially stamped). Integrating FenixEdu with the QualiChain platform allows the diploma hash issued by FenixEdu to be automatically inserted into the QualiChain blockchain. Therefore, this integration allows the Portuguese public administration – represented in the QualiChain project by the Agency for Administrative Modernization (AMA)³ – to have access to the diplomas issued by a HEI that uses FenixEdu. The diploma access limits are imposed by students and school administrations. The goal is that the QualiChain platform is capable of ensuring the authenticity and integrity of diplomas.

To enforce compliance with the General Data Protection Regulation (GDPR), a privacy-by-design approach has been followed, whereby data protection safeguards are built into technology early on (European Parliament and European Council, 2016). According to Art. 4 of the GDPR, “*personal data means any information relating to an identified or identifiable natural person (data subject); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors [...].*”, even when data is encrypted or hashed, it qualifies as personal data under EU law (Jay, Malcolm, Parry, Townsend and Bapat, 2017). Therefore, to be GDPR compliant, full control is given to the diploma holder, allowing the self-sovereign control of the diploma’ hash, *i.e.*, the diploma holder is able to grant or revoke access to the diploma accordingly with his/her desire.

2.1. Stakeholders and use cases

To provide an overall understanding of the case study, Figs. 1 and 2 show the stakeholders and use cases using UML⁴ notation. The actors involved in this pilot are the Graduated Student who finished the University degree and is eligible to request a diploma. Then, the Diploma holder represents the graduated student that received the diploma; and the University secretariat of a certain HEI that issues the diploma. Lastly, the Public Administration body (AMA) is the prospective employer that will benefit from this digital transformation initiative.

The information flow is depicted in Fig. 3 using BPMN⁵ notation. The figure shows the participating groups and the communications between them. Firstly, the graduated student requests the diploma after completing the education program (or post-degree education program). In response to this request, the University employee publishes the diploma in FenixEdu. This results in the diploma file (a PDF file) being generated and saved in a location specified by FenixEdu (e.g., in the file system where the FenixEdu instance is running). Both information flows are operated on

²<https://fenixedu.org/>

³AMA is the Portuguese public entity whose mission is to support the different areas of government in its process of digital transformation, through the internalization of skills and the development of ICT transversal projects.

⁴<https://www.omg.org/spec/UML/2.5/About-UML/>

⁵<https://www.omg.org/spec/BPMN/2.0/About-BPMN/>

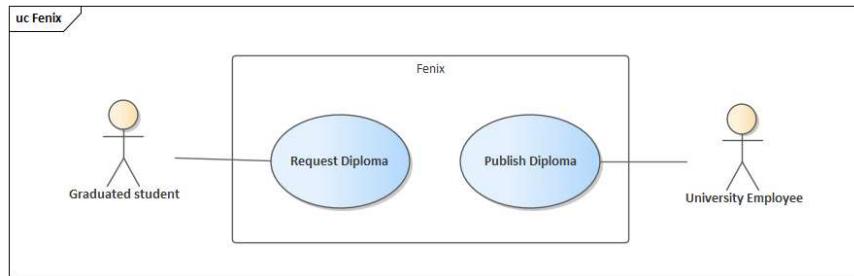


Figure 1: Use case definition of the Fenix system involving the Graduated student and the University Employee. The purpose is to specify the use cases of requesting and publishing the diploma.

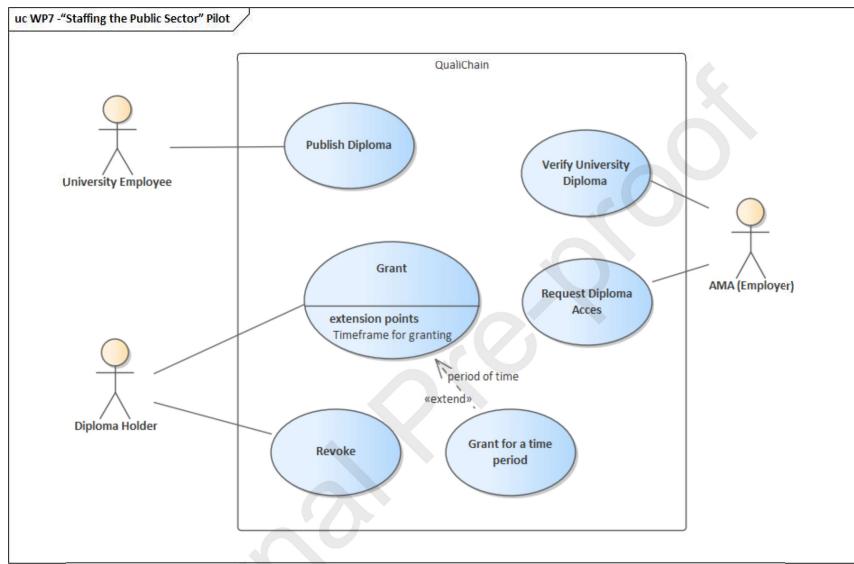


Figure 2: Use case definition of the QualiChain system involving the University employee, the Diploma holder, and AMA. The purpose is to specify the use cases of requesting, verifying, and revoking the diploma.

the FenixEdu platform. This is the usual process that involves the HEI academic management. Given that diplomas are published on FenixEdu, this platform is also responsible for triggering the action of deploying the diploma file in QualiChain: this consists of publishing in QualiChain the hash of the diploma file (Serranito et al., 2020). The objective of this mechanism is to leverage QualiChain to ensure the diploma's authenticity and integrity. From this point forward the Diploma Holder is the owner of his/her diploma, and can grant, or revoke access (forever or within a certain time frame) to a specific Employer using the QualiChain platform.

For this pilot, as depicted in Fig. 3, AMA requests access to the diploma, which needs to be granted by the Diploma holder. After receiving the diploma file, AMA uses the QualiChain platform to verify the authenticity and integrity of the diploma. If the hash of the diploma file is equal to the one stored in QualiChain, then those properties are ensured and it is verified correctly; otherwise, a not verified notification is released (the “not Verified” response returned by step 7 in the figure).

To guarantee personal control, at any time, the Diploma Holder can revoke access to his/her diploma file hash.

3. Integrating Academic Management Solution and Blockchain solution

This section describes FenixEdu, our blockchain solution, and the integration and deployment of these two components.

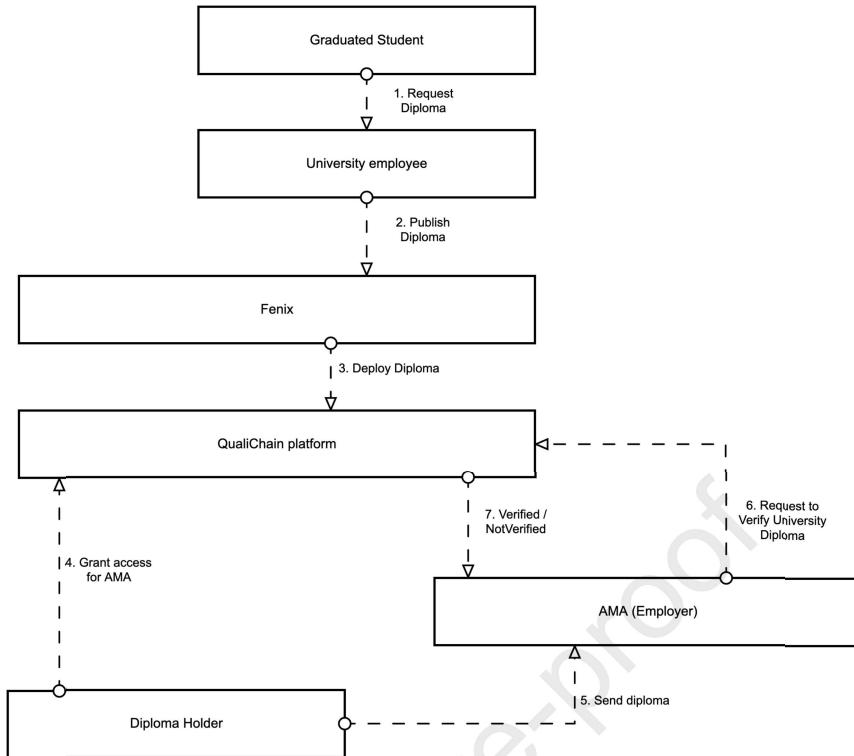


Figure 3: Information flow for a verified and not verified diploma. The diploma hash is stored in the QualiChain platform.

3.1. The FenixEdu System

FenixEdu (also called Fenix) is an academic management system that was created by academics and researchers from Instituto Superior Técnico (IST), Lisbon, Portugal, with the aim of developing an integrated academic information system for higher education. Today, that system is the basis for all academic processes, not only at IST, but also at other universities, schools, and faculties in Portugal. In particular, major implementations of the project are available in all the schools of the Universidade de Lisboa⁶, which is the largest in Portugal, and in ISCTE (Instituto Superior de Ciências do Trabalho e da Empresa⁷). Moreover, since the project was developed from scratch adopting a Lesser General Public Licence (LGPL), there are at least three independent private companies that offer support and contribute to the sustainability of the platform.

3.2. The Blockchain Solution

We use the blockchain solution for verifiable qualifications developed by Serranito et al. (2020). This solution uses blockchain technology and smart contracts, to support decentralized verification of higher education certificates. This section briefly describes this solution.

The solution allows HEIs to register the certificates they issue in the blockchain, and recruiting organizations to check the authenticity and integrity of these certificates. The solution is implemented through five major components: i) the consortium smart contract, ii) the HEI smart contract, iii) the HEI client, iv) the recruiter app, and v) the consortium app.

The solution allows the interaction between one or more consortiums, where each consortium includes a set of HEIs. An ecosystem with a single consortium and three HEIs is represented in Fig. 4. Data about the consortium is stored in the blockchain in a *consortium smart contract*. This smart contract contains data about the HEIs that are part of the consortium and the rules of the consortium (e.g., how a HEI can join). Each HEI is itself represented by a *HEI smart contract* that contains data about the certificates it has issued. In our case study, all these smart contracts are written in Solidity and deployed in the blockchain Ethereum. HEIs run a HEI client, an application, that registers certificates in

⁶<https://www.ulisboa.pt>

⁷<https://www.iscte.pt>

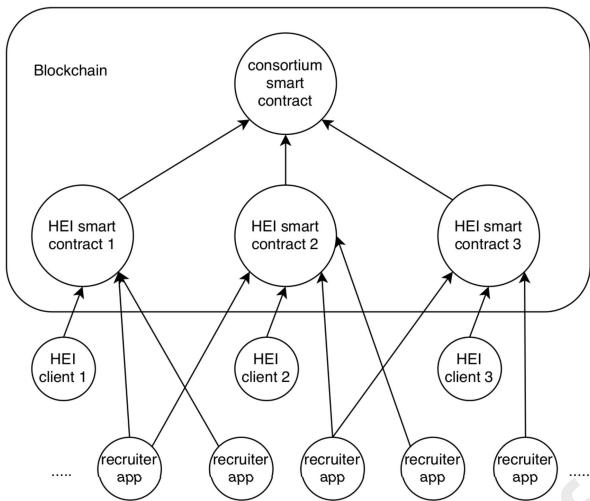


Figure 4: Data flow diagram representation of an ecosystem with a single consortium of three HEIs (Serranito et al., 2020). Each HEI may also run a Consortium App to manage the membership of the consortium (not represented).

the HEI smart contract. The smart contract does not store the files of the certificates (PDF files), so they may be stored by the HEIs and the alumni. Instead, it holds a mapping that associates a job seeker id with the cryptographic hash of his certificate. The HEI smart contract is central to the process, since it is the contract responsible for registering, revoking, and verifying certificates. The HEI client automatically monitors two folders, *registered certificates folder* and *revoked certificates folder*, where certificates are stored in PDF format. In our prototype, these two folders reside in the same instance where FenixEdu is running. However, this is configurable: these folders can be located in any location. Whenever a new education certificate is stored in the *registered certificates folder*, a watcher throws an event that leads to a call to the `registerCertificate(id, hash)` function of the HEI smart contract, where `id` is the graduate/job seeker id (taken from the filename or file metadata) and `hash` is the cryptographic hash of the PDF file⁸. These two fields are the data stored in the blockchain. After the Ethereum transaction is confirmed, the PDF file is stored in a decentralized file system. In our prototype we store the file in IPFS by contacting an IPFS node. IPFS returns a multihash (a self-describing hash) that can be used by anyone connected to the IPFS network to retrieve this file. Finally, recruiters run a recruiter app that allows them to verify if a certificate file was indeed emitted by a certain HEI.

An advantage of having this folder-based solution is that it becomes easy to integrate FenixEdu (or any other academic management system) with the blockchain solution. Since FenixEdu produces the certificate files, we only need to ensure that they are placed in the appropriate folder. Moreover, Serranito et al. (2020) show that the solution is capable of dealing with hundreds of certificates. They calculated the system's throughput by simulating the registration of 100 certificates. They also measured latency, which expresses the interval of time between storing a certificate and the respective transaction being correctly sent to the blockchain network and added to a new block. Their results show that the system can register 42.98 certificates per second. The latency for registration is 27 seconds, but they note that transactions are only executed after a block is inserted in the blockchain, something that happens on average every 20 seconds.

The details related with the implementation of solution for the self-sovereign identity based access control of this platform can be found here in the work of Belchior, Putz, Pernul, Correia, Vasconcelos and Guerreiro (2020).

3.3. Integration

Integration between enterprise application systems is not a new requirement demanded by organizations. Some time ago, Gold-Bernstein and Ruh (2004) presented the classical solutions based on synchronous messaging and data centralization to create a single customer view. Afterwards, approaches based on asynchronous messages (Hohpe and Woolf, 2004) and decoupling of services (Newman, 2021) extend the knowledge of this area to offer resilient and event-driven architectures. Even in the context of blockchain, system's integration is a concern that is requiring

⁸In our prototype, we use SHA256 hashes.

attention (Belchior, Vasconcelos, Guerreiro and Correia, 2022).

In this context, we have extended FenixEdu to allow integration with the blockchain solution described above. We created a new workflow that enables certificates to be saved as PDF files in a given file system folder. When the folder is configured to be the same folder watched by the HEI client application, certificates are automatically registered in the HEI smart contract (as described above). We deployed our solution as a set of Docker containers, as illustrated in Fig. 5.

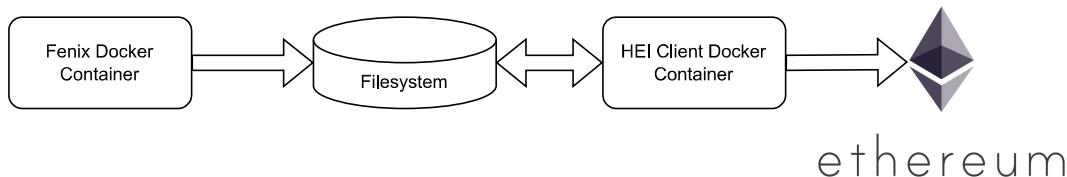


Figure 5: Integration of FenixEdu with the blockchain solution. Certificates issued in Fenix are written to the file system. The HEI client monitors the file system and interacts with the smart contracts.

4. Piloting

According to Rizzo and Cantù (2013), piloting is a process of co-design of solutions that includes future users in the development process, as well as the prototyping and testing system of products and services before their actual implementation.

The pilot presented in this paper aims to answer the following questions:

- (i) How to achieve user satisfaction in terms of veracity? It is expected to acquire and build new knowledge about diplomas authenticity using the new platform;
- (ii) How to achieve user satisfaction in terms of control? We expect to create knowledge related to diploma access control mechanisms; and
- (iii) How to achieve user satisfaction in terms of credibility?

In addition to the previous research questions, it was also expected to increase knowledge related to user perception of credibility compared to non-blockchain solutions. To this end, a set of participants were invited to experiment the developed system following a guideline document that was made available (see Appendix B). A survey has been applied before experimenting the system (see Appendix A), and then in the end the participants were surveyed again (see Appendix C).

The experiment was divided in four test scenarios where the participants were invited to execute the following predefined guidelines:

- (i) A graduated student requests a diploma in the Fenix academic system;
- (ii) A University employee publishes the diploma in the Fenix academic system that has been previously requested by the diploma holder;
- (iii) After deploying the diploma in QualiChain, an Employer who receives the pdf file containing the diploma is able to verify its authenticity; and
- (iv) Diploma Holder revokes his/her diploma in QualiChain.

A sample of the user interfaces provided is shown in Appendix B (guidelines for experimenting).

To better assess the answer to the questions, a set of key performance indicators (KPI) was extracted (see Table 1). The first four KPIs are quantitative measures extracted from the server logs of the provided QualiChain system, and the last two KPIs are qualitative measures obtained from the participant' responses.

KPI name	How is data collected?
Number of certified diplomas/ certificates	From server logs
Number of verification requests to certified diplomas/ certificates	From server logs
Total number of universities issuing verified diplomas/ certificates	From server logs
Total number of courses issuing verified diplomas/ certificates	From server logs
User satisfaction in terms of control	Online questionnaires
User satisfaction in terms of veracity	Online questionnaires

Table 1

KPIs defined for the pilot

5. Evaluation

This section summarises the results collected during the involvement of participants in the pilot. The system has been deployed and showcased to participants, and their activity has been recorded automatically. The data collected is herein analyzed.

Firstly, the qualitative KPIs are assessed to check whether participants are satisfied, or not, in terms of control and veracity when using QualiChain. Then, the quantitative KPIs are presented.

5.1. Result of Questionnaires

The pilot questionnaires assessed the KPIs “User satisfaction in terms of control” and “User satisfaction in terms of veracity”, with 11 eleven questions. Twenty (20) participants agreed to answer the questionnaire.

From the results depicted in Fig. 6, Questions 2.1 and 2.2, an increase in satisfaction has been obtained in terms of the control of the diploma. The increase is mainly due to the users that are slightly or completely satisfied after using the pilot. This result indicates a participant’ positive reaction towards control of the diploma after executing the QualiChain pilot. Control ability is related with ability of the participant to check in the ledger if the diploma hash is available or not, and if it checks with the one that has been received by the recruiter.

From Fig. 6, Questions 3.1 and 3.2, an increase in satisfaction is noticed in terms of veracity. An increase is noticed in the very satisfied and completely satisfied responses. The diploma veracity is also guaranteed by the ledger properties. Participants rely on the diplomas that are deployed in the ledger as a point of truth for the QualiChain system. This result reveals a positive indication to pursue the research of this solution.

In the results depicted in Fig. 6, Questions 4.1 and 4.2, an increase in the perception of satisfaction in terms of credibility is observed. Regarding credibility, an increase is noticed in the completely satisfied choice. However, after the guideline execution, participants reported a decrease in the credibility with more responses choosing not at all satisfied, and slightly satisfied. This result can be related with the absence of signed pdf diplomas. Due to the nature of the data used (diplomas), the pilot setup offers a simulation of the diploma issuing process different from the real one. This simulation setting had limited the credibility evaluation KPI.

5.2. Analysis of KPI evaluation

Table 2 presents the collected quantitative KPIs. We notice that not all the participants successfully followed the pilot guidelines. This data has been stored automatically and retrieved from the server logs of the servers. The collected data is aligned with the requested guidelines. Firstly, most of the participants executed the requested actions apart from 3 participants that had issues revoking the diploma access. On the opposite, accessing and assessing the diploma has been executed successfully by all the participants. This result is promising to a future implementation of this service. Finally, the granting access between the graduated student and the recruiter has also been performed by all participants without any problem reported.

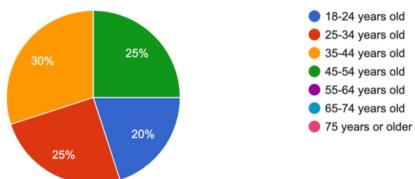
6. Discussion

The following conclusions were obtained during the pilot execution.

No perceived need. Nowadays, both employers and students are not used to requesting or being requested certified diplomas. In part because students come from nearby well-known national HEIs and are working in the same country they graduated. And in part because it is too difficult to verify its authenticity. Nevertheless, online education and higher education and the free movement of citizens across Europe and the world, is creating a need to guarantee an

1.1. Age – What is your age? Choose one option.

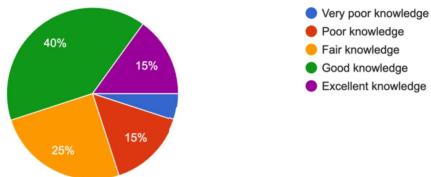
20 responses



- 18-24 years old
- 25-34 years old
- 35-44 years old
- 45-54 years old
- 55-64 years old
- 65-74 years old
- 75 years or older

1.3. How do you classify your previous knowledge with the Diploma issuing process? Use the following five levels scale from very poor to excellent knowledge.

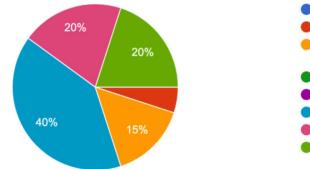
20 responses



- Very poor knowledge
- Poor knowledge
- Fair knowledge
- Good knowledge
- Excellent knowledge

1.2. Education - What is the highest degree or level of school you have completed? Choose one option. If currently enrolled, highest degree received.

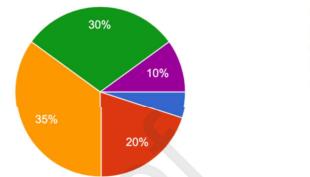
20 responses



- No schooling completed
- Some high school, no diploma
- High school graduate, diploma or the equivalent
- Some college credit, no degree
- Trade/technical/vocational training
- Bachelor's degree
- Master's degree
- Doctorate degree

1.4. How do you classify your previous knowledge related with Human resources recruitment process? Use the following five levels scale from very poor to excellent knowledge.

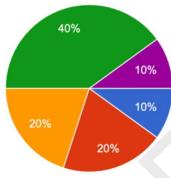
20 responses



- Very poor knowledge
- Poor knowledge
- Fair knowledge
- Good knowledge
- Excellent knowledge

1.5. How do you classify your previous knowledge related with Blockchain technology? Use the following five levels scale from very poor to excellent knowledge.

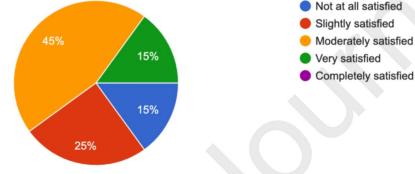
20 responses



- Very poor knowledge
- Poor knowledge
- Fair knowledge
- Good knowledge
- Excellent knowledge

2.1. Before using the pilot, how did you classify your satisfaction in terms of controlling your diploma? The objective of this question is to assess ...e from not at all satisfied to completely satisfied.

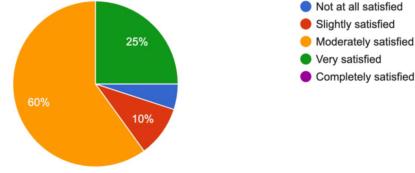
20 responses



- Not at all satisfied
- Slightly satisfied
- Moderately satisfied
- Very satisfied
- Completely satisfied

3.1. Before using the pilot, how did you classify your satisfaction in terms of veracity of the diploma? The objective of this question is to assess ...e from not at all satisfied to completely satisfied.

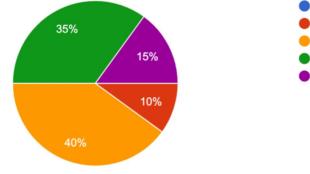
20 responses



- Not at all satisfied
- Slightly satisfied
- Moderately satisfied
- Very satisfied
- Completely satisfied

2.2. Now, after using the pilot, how do you classify your satisfaction in terms of controlling your diploma? The objective of this question is to assess ...e from not at all satisfied to completely satisfied.

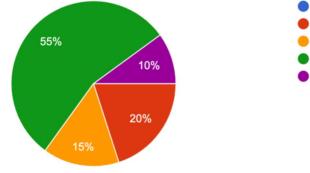
20 responses



- Not at all satisfied
- Slightly satisfied
- Moderately satisfied
- Very satisfied
- Completely satisfied

3.2. Now, after using the pilot, how do you classify your satisfaction in terms of veracity of the diploma? The objective of this question is to assess ...e from not at all satisfied to completely satisfied.

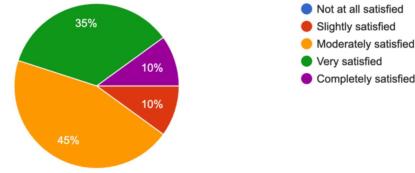
20 responses



- Not at all satisfied
- Slightly satisfied
- Moderately satisfied
- Very satisfied
- Completely satisfied

4.1. Before using the pilot, how did you classify your satisfaction in terms of credibility of the diploma? The objective of this question is to assess ...e from not at all satisfied to completely satisfied.

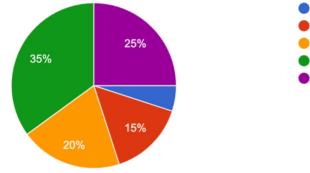
20 responses



- Not at all satisfied
- Slightly satisfied
- Moderately satisfied
- Very satisfied
- Completely satisfied

4.2. Now, after using the pilot, how do you classify your satisfaction in terms of credibility of the diploma? The objective of this question is to assess ...e from not at all satisfied to completely satisfied.

20 responses



- Not at all satisfied
- Slightly satisfied
- Moderately satisfied
- Very satisfied
- Completely satisfied

Figure 6: Results for Questions 1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 2.2, 3.1, 3.2, 4.1, and 4.2.

sum	11	8	22	11
Users	Num. of access requests granted	Num. of access requests revoked	Num. of stakeholder diploma accesses	Num. of times each stakeholder accessed diploma
1	1	1	2	1
2	1	1	2	1
3	1	1	2	1
4	1	0	2	1
5	1	1	2	1
6	1	1	2	1
7	1	1	2	1
8	1	0	2	1
9	1	1	2	1
10	1	1	2	1
11	1	0	2	1

Table 2

KPIs value collected in the pilot (extracted from server logs).

education institution is an accredited one and that a student's diploma is authentic. This has been accentuated by the Covid-19 pandemic. The INESC-ID/AMA pilot also provided for enrolment certificates. Enrolment certificates are presented when moving abroad and asking for a residence permit; to entities where students can apply for study grants, for transportation subsidy or discount, for school material and books with subsidy or discount, lodging and culture activities and any other service such as the ones contemplated by the European Youth Card. By role modelling new HR recruitment processes to other public and private entities, AMA ought to request verifiable high school, professional and higher education diplomas on each job application.

Low usability. On the other hand, even though the core of the engine has been built, there are still some complementary usability issues to be solved. QualiChain is still lacking integration to an authentication solution (eID) that is eIDAS-notified, which would enhance security (beyond username and password) and unambiguously identify a citizen to the future SDGR/OOTs system or to the new EU ID Wallet. Value would be added if that authentication system could rely on certified roles as attributes and if it used a robust authorisation mechanism to grant or revoke access to one's diploma by an employer or other entity. Also, some machine-readable data should be embedded in its certified diplomas to make the process more automated. In the scope of the SDG/OOTs project, or by implementing the new eIDAS regulation or simply on its Digital Transformation role, AMA plans to enlarge its scope of qualified certified credentials in a broad range of sectors, including Education and Higher Education.

Needs adoption. From a sustainability point of view, QualiChain needs massive adoption. It needs a coordinated push on services, issuers, students, and entities that will consume the certified diplomas and enrolment certificates. AMA's opinion is that European pilots and projects and initiatives should take a conjoint approach leveraging on each other, for cross-pollination. Not only on research findings but also on piloting user/ partner base, use cases and reutilisation of components which have already been built on previous or parallel projects.

New revenue streams. More revenue streams should be found through leveraging on the new stakeholders that have been discovered (such as the Central Registries for foreign citizens, employers that have working students, public and city transports, and others).

7. Lessons Learned

This section is dedicated to the lessons learned from the operation and execution of the pilot, which was implemented by AMA and supported by INESC-ID. The following lessons learned were collected during three phases. The first one during the design, implementation, testing, and deployment performed by the development team. The second one while piloting the platform with end users. And the third one as a reflection of the researchers that delivered an argumentative evaluation of the work done throughout this project. These lessons learned represent the core knowledge that can be used to offer reliable and faster implementations in the future.

1. *Learning curve for the technologies related with blockchain* The development team invested a large amount of

time to study and experiment the blockchain technologies used on QualiChain. Moreover, due to the immaturity of such technologies, some issues were found related to the stability of the solutions and to kernel changes during the initial software development process.

2. *End users lack knowledge related to blockchain technology* Despite the great interest and the positive feedback revealed by the end users when approaching the QualiChain concepts and tools, many difficulties to understand how to use them were identified. Specific training was required to communicate the goals and to support their activities, which introduced an overhead to the initial rollout plan.
3. *Clear guideline definitions provided to the end users* A step-by-step approach was presented in the guidelines that were provided to the end users. Including the URLs to be used, the buttons to be clicked, the expected data in each field, and the expected result. This clear definition was of key importance to the success of the end users' activities. The guidelines were provided since the beginning of the end users' experiments. We consider this as a good practice to be followed by other projects in the future.
4. *Few standards and regulations available* Due to the innovative nature of the technological solutions used by QualiChain, there are a few standards and regulations available to support the architectural decisions. For instance, General Data Protection Regulation (GDPR) has many requirements that need to be satisfied for the protection of individuals. Postponing this core architectural decisions could have a negative impact on the stability of a project plan development. We consider that investing more focus and effort to establish standards and regulations can have a positive outcome in future projects.
5. *Lack of integration with eIDAS authentication services* By the time we developed this project, not all QualiChain partners' countries had notified eIDAS eIDs (namely Greece) and there was a lack of persistence on Germany's notified eIDAS eIDs. That restricted the QualiChain project to leverage on eIDAS eIDs, with strong authentication mechanisms. Therefore, QualiChain resorted to username/password and to integration with SEAL⁹ for Education credentials. SEAL project aims at combining the benefits of Member-State backed citizen (natural person identification and authentication through eIDAS) and student and researchers identities (eduGAIN from GÉANT and European Student Identifier from European Student Card) to enable a cross-sector interoperability between eIDAS and Higher Education/Research domains. The reported lack of integration created barriers to using these services in HEI portals and by employers' HR departments, since the credentials are not inter-linked between the different entities, and therefore do not support authentication mechanisms for multiple identities.
6. *The UI could be more intuitive and user-friendly* Providing for an intuitive user-interface makes step by step instructions unnecessary. It also makes its added value more perceptible and attractive to general users and to other ongoing projects with whom QualiChain could cross-pollinate, namely major European initiatives such as the Single Digital Gateway and Once-Only Technical System. The resolution of such shortcomings could further improve QualiChain and increase the added-value that it offers.
7. *Diploma verification automation could be improved* This pilot would have benefited from being able to capture the semantics of the diploma and automatically get its data along with an authenticity and integrity check. For instance, extract the candidate skills from the diploma text. While the degree verification functionality is successful in validating the authenticity of a degree or qualification, a greater degree of automation would make it even more desirable by HEIs and public administrations, with benefits in terms of productivity and less human errors.

8. Conclusion

Project QualiChain developed new decentralized technology for “learner empowerment, education reengineering and public sector transformation”. The project had a few pilots, one of which is reported in this paper: Staffing the Public Sector — The Case of Portugal. The goal of the pilot was to design, implement, and evaluate with end users technology for allowing the fast and reliable verification of HEI diplomas. To achieve this goal in a way that can be adopted by many HEIs, we integrated the system with an open source academic management system, FenixEdu. The objectives of the pilot were fully achieved and important lessons were learned.

⁹<https://project-seal.eu/>

From a practical standpoint, perhaps the main take-away message is that this pilot effectively demonstrates that existing academic management systems can be integrated into Qualichain, making it easier for academic partners to join Qualichain. Moreover, feedback collected for the evaluation of our pilot suggests that users value the control, veracity, and credibility of diplomas provided by the solution presented in this paper.

Considering the specific context for which this pilot was developed, recruitment in the Portuguese public administration, diplomas' veracity checking used to take days and sometimes it would even be skipped due to the time and effort necessary. With the solution that we developed, the process is now much easier and quicker (instead of days, it takes seconds).

As future work, we plan to improve the user interfaces developed so that they become more intuitive and user-friendly. We also plan to conduct more experiments with our prototype, including a longitudinal study to measure long-term impact of the solution in AMA recruitment.

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