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CONTENTS

Supporting Lifelong Learning with Smart Blockchain Badges

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

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

I. INTRODUCTION

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

Education today is still controlled mostly by educational institutions, which offer quality, credibility, governance, and administrative functions. This model is not flexible enough and poses difficulties in recognising the achievements of a lifelong learner in informal and non-formal types of education. As a result, a lifelong learner's transition from formal to informal education and vice versa can be hindered, as the achievements acquired in one type of education are not easily transferable to another [2-5]. This indicates the need for a decentralised model across all types of education, offering learners with a framework for fully controlling how they are learning, how they acquire qualifications and how they share their qualifications and other learning data with third parties, such as educational institutions or employers [6, 7].

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

II. BACKGROUND

A. *Blockchains and associated technologies*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

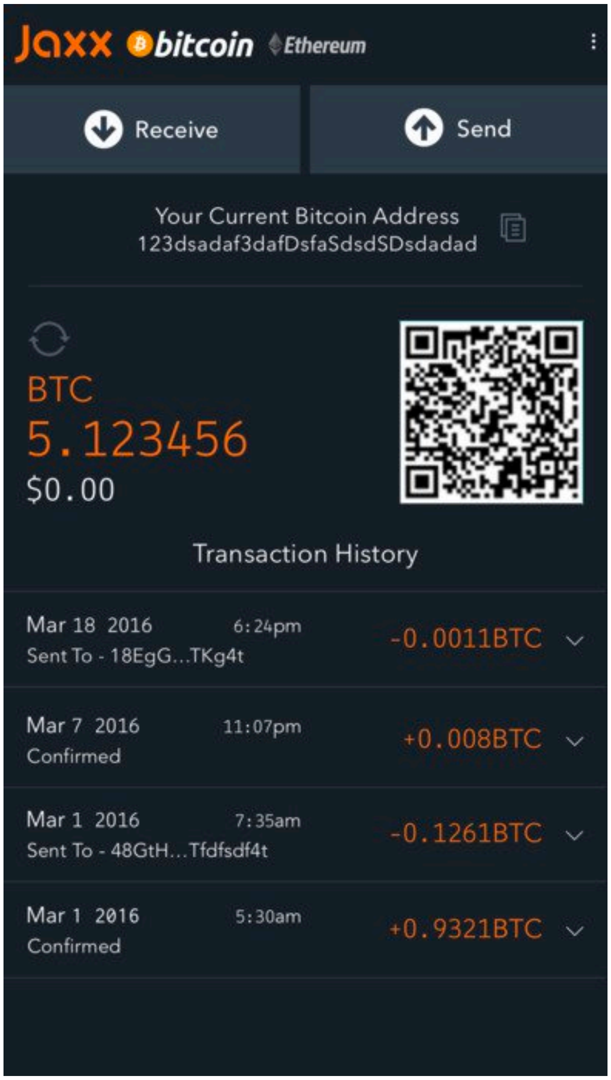

Figure 2. Snapshot of a Jaxx wallet used for both Bitcoin and Ethereum [18].

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

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

B. *Open Badges*

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

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

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

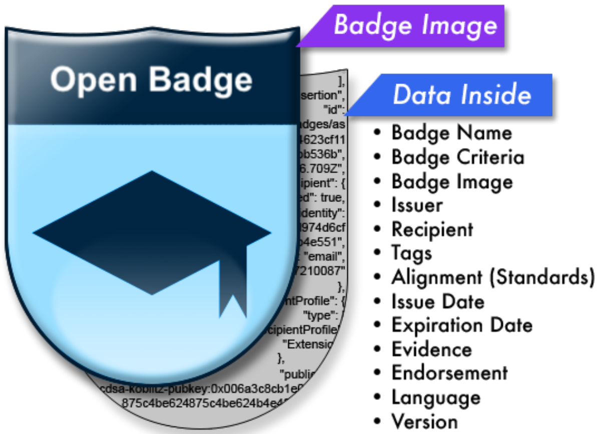

Figure 3. The structure of an Open Badge.

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

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

III. THE QUALICHAIN PROJECT

The emergence of the Blockchain promises to revolutionise not only the financial world, but also education in various ways. Blockchain technology offers a decentralised peer-to-peer infrastructure, where privacy, secure archiving, consensual ownership, transparency, accountability, identity management and trust are built-in, both at the software and infrastructure levels. This technology offers opportunities to thoroughly rethink how we find educational content and tutoring services online, how we register and pay for them, as well as how we get accredited for what we have learned and how this accreditation affects our career trajectory.

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

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

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

IV. SUPPORTING LIFELONG LEARNING

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

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

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

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

A. *Scope*

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

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

B. *Stakeholders*

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

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

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

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

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

C. *Scenario*

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

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

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

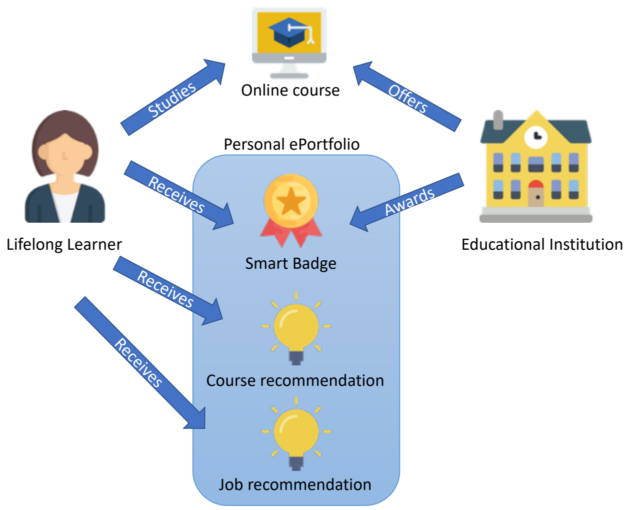

Figure 8. Stakeholder interactions in the main scenario of the lifelong learning pilot.

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

D. Implementation

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

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

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

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

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

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

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

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

E. *Initial deployment and evaluation*

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

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

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

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

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

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

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

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

V. Conclusions and Next Steps

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

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

Acknowledgment

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APPENDIX

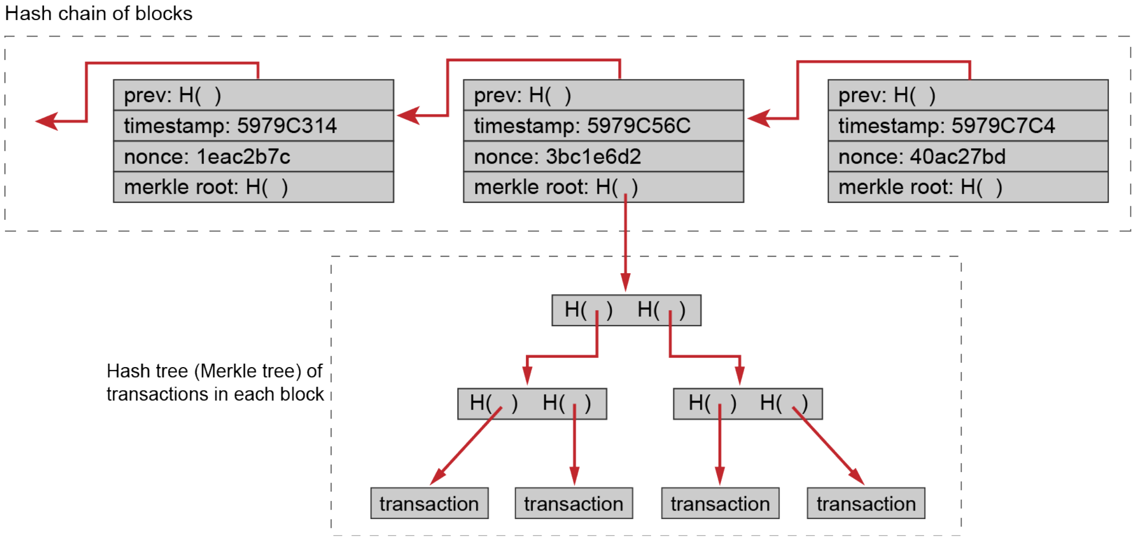

Figure 1. Example of a Blockchain consisting of three blocks.

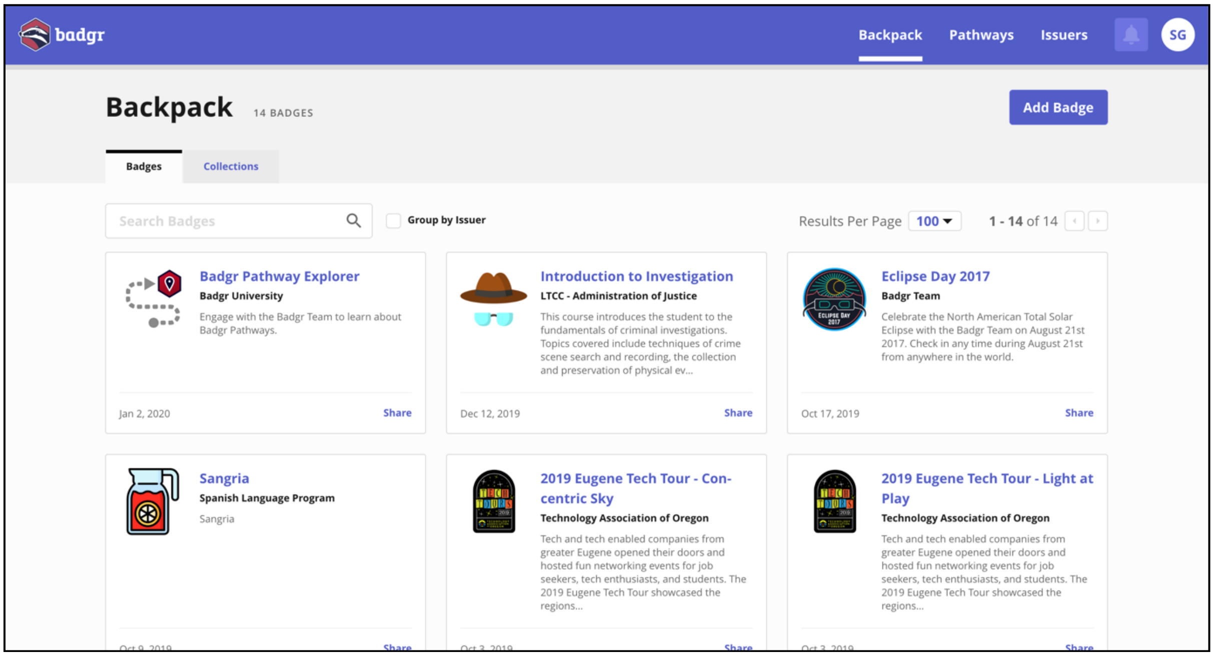

Figure 4. Snapshot of a Badgr backpack [26].

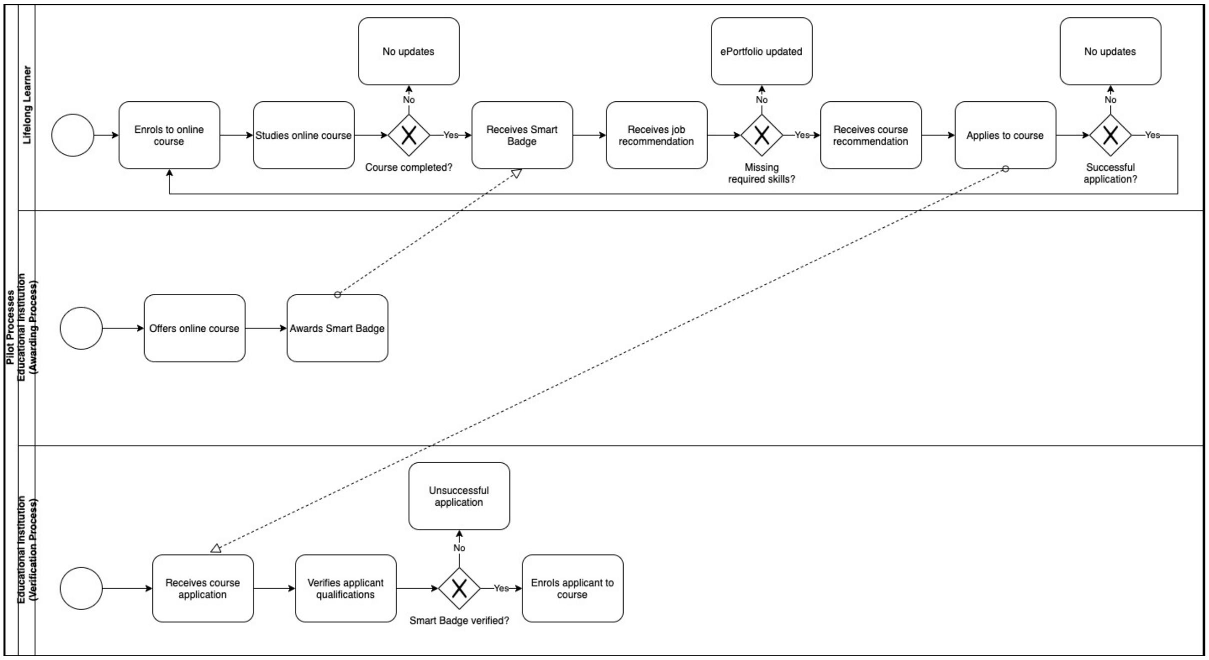

Figure 7. Workflow of the lifelong learning pilot scenario.

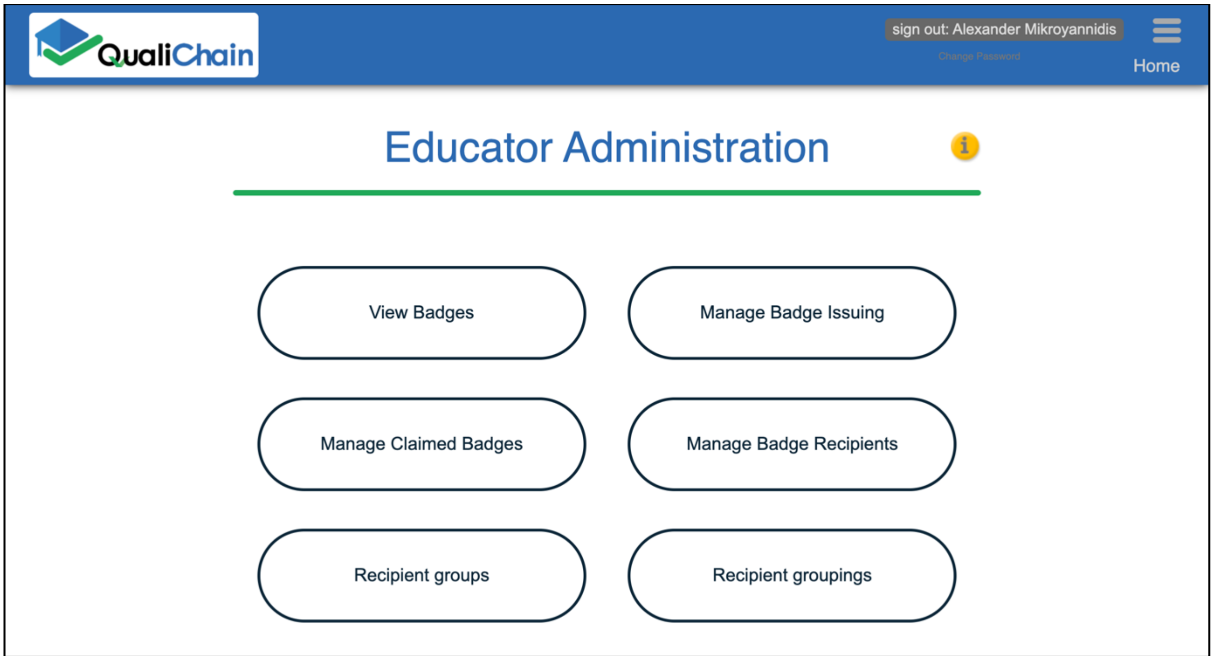

Figure 9. Snapshot of the options available to the educator/issuer of Smart Badges.

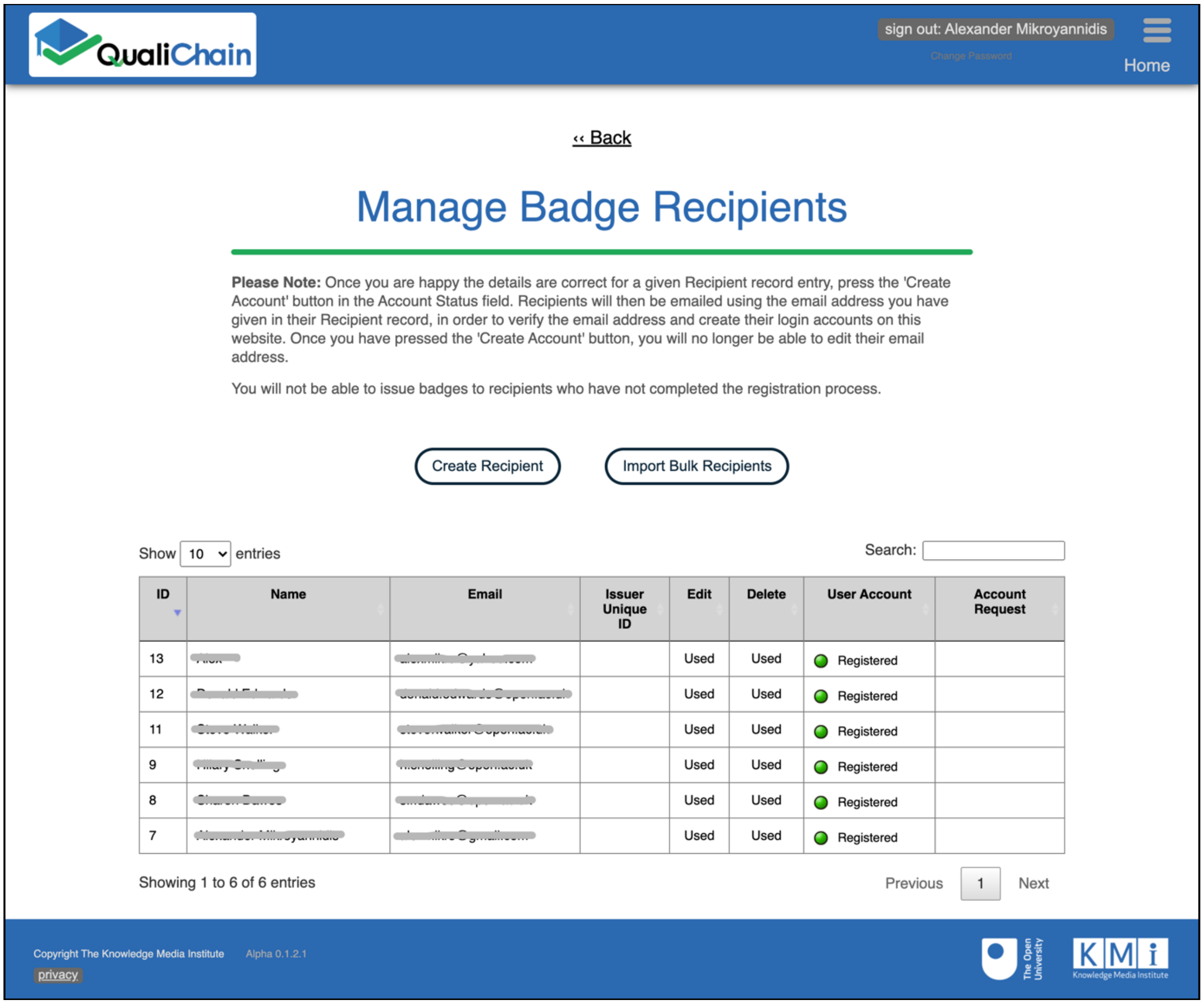

Figure 10. Snapshot of managing the recipients of Smart Badges.

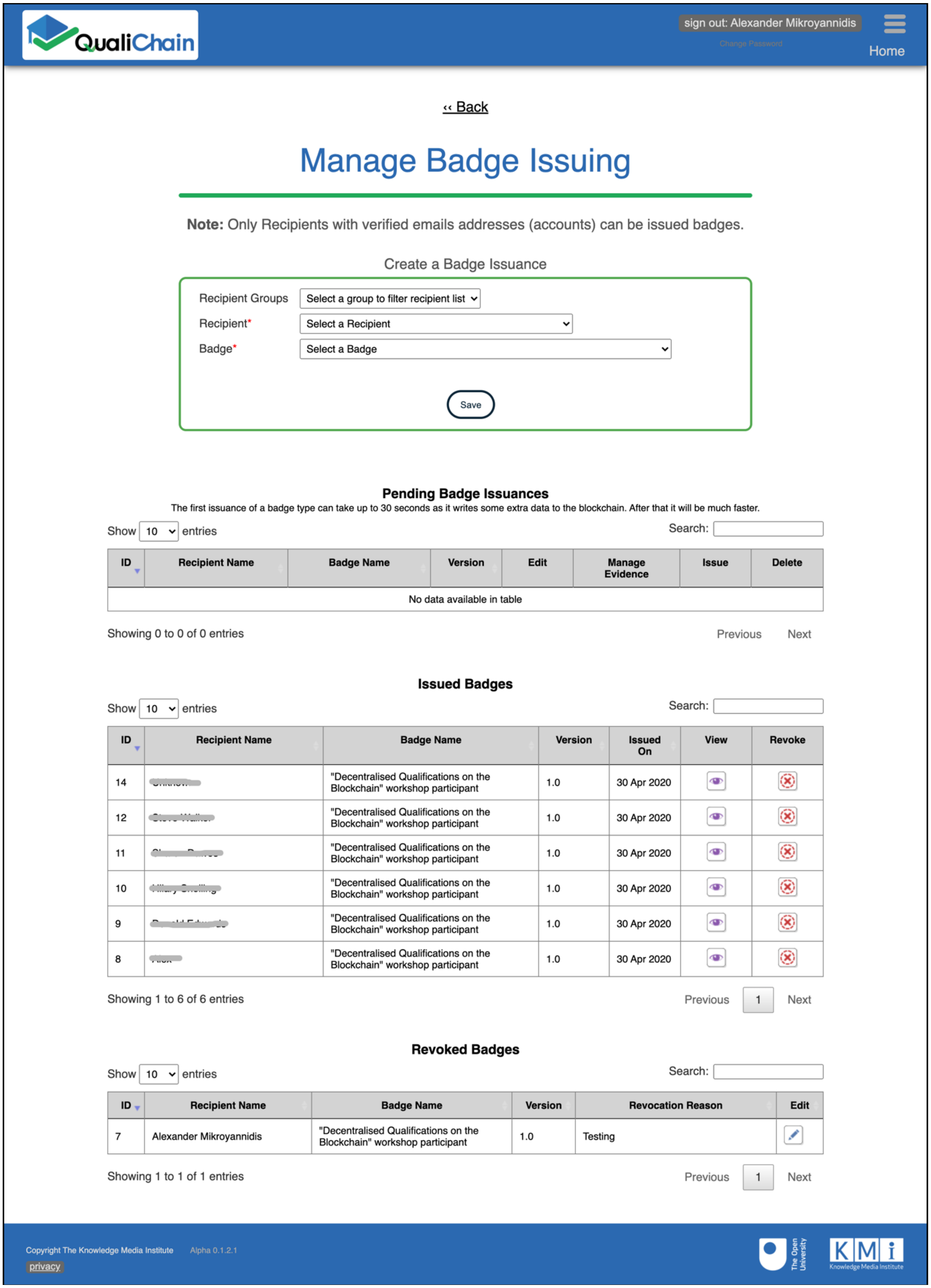

Figure 11. Snapshot of managing the issuing of Smart Badges.

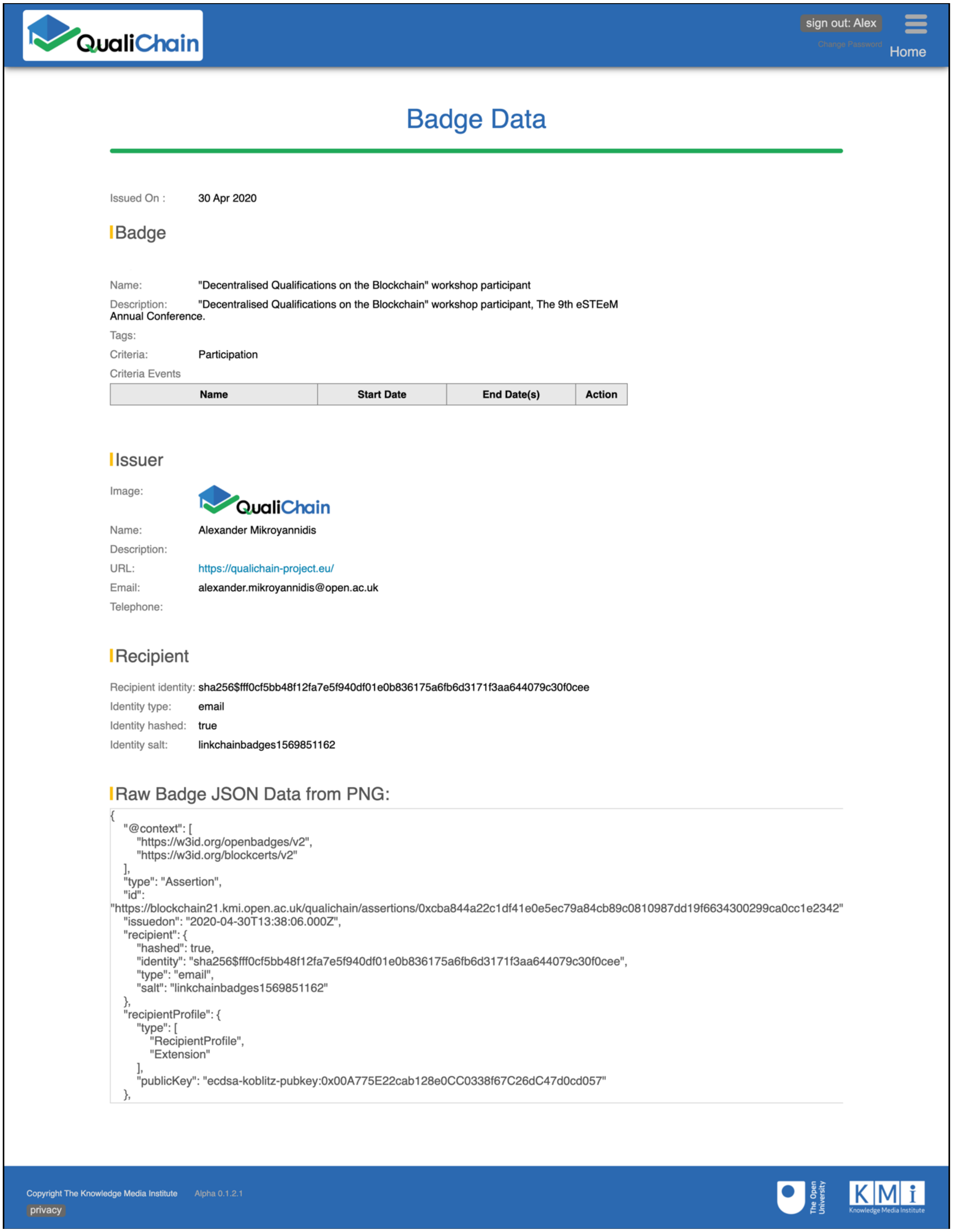

Figure 12. Detailed view of a Smart Badge.

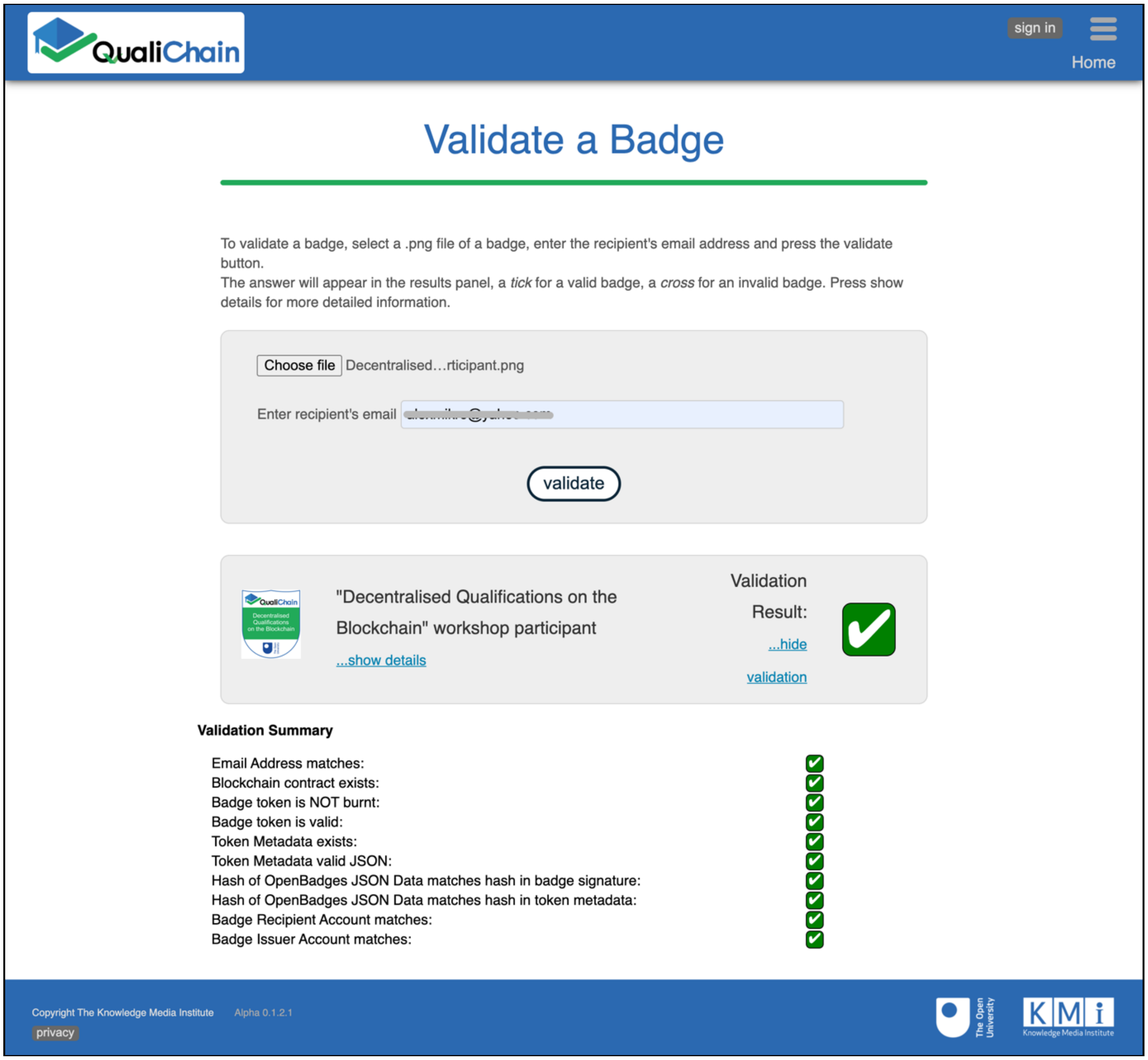

Figure 13. Verifying a Smart Badge.

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

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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 Governement 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).

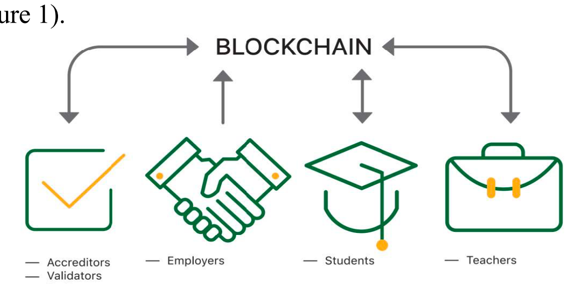

Figure 1. The value of blockchain to QualiChain stakeholders [3].

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

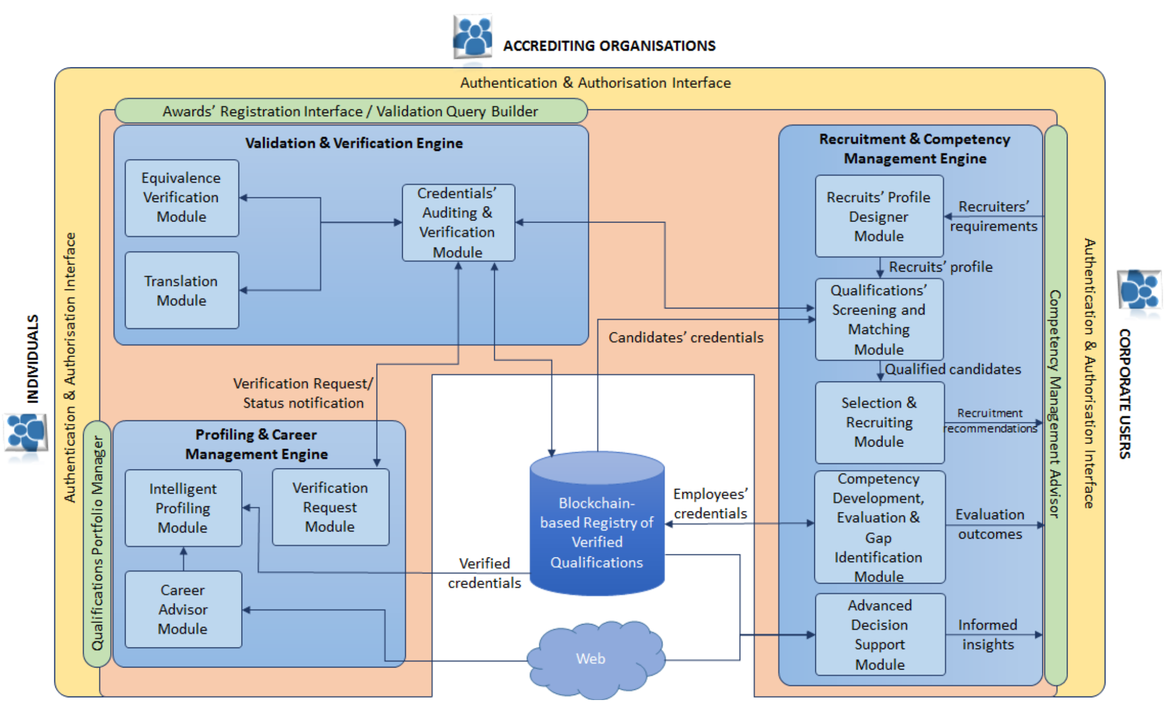

Figure 4. QualiChain Value Adding Services

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 OPENSKIMR (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.

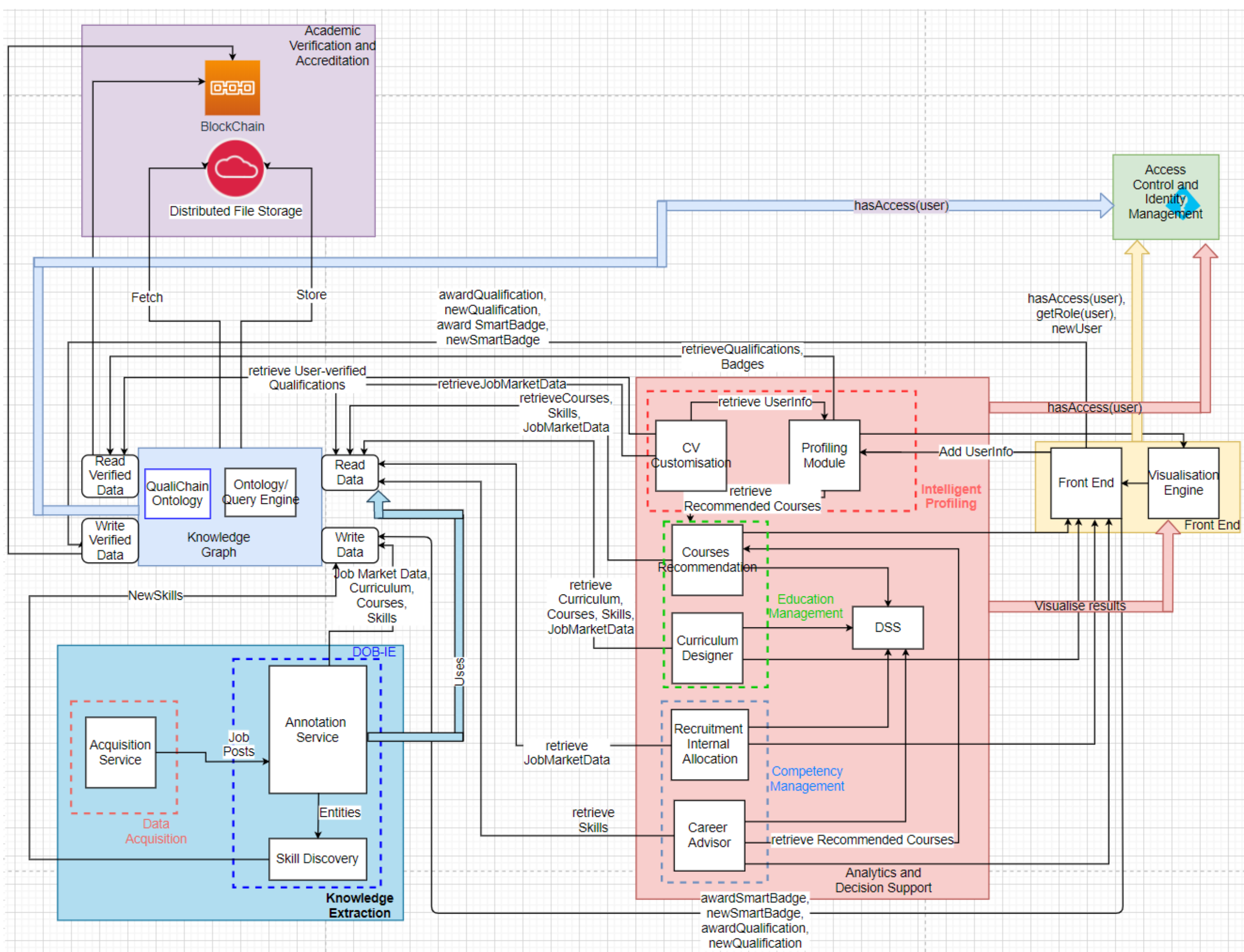

Figure 5. QualiChain Global Architecture

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.

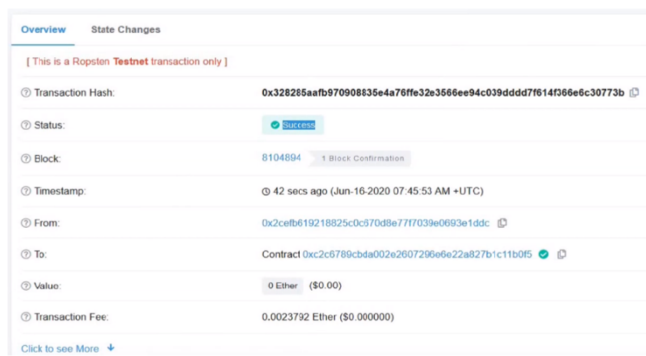

Figure 6. Qualification Verification via transaction hash

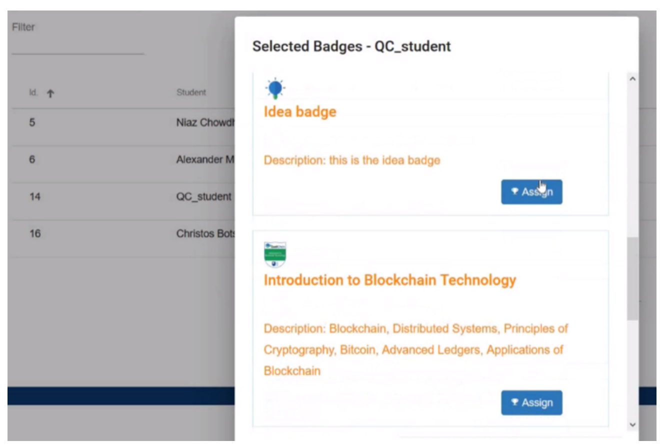

Figure 7. Smart badge accreditation

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.

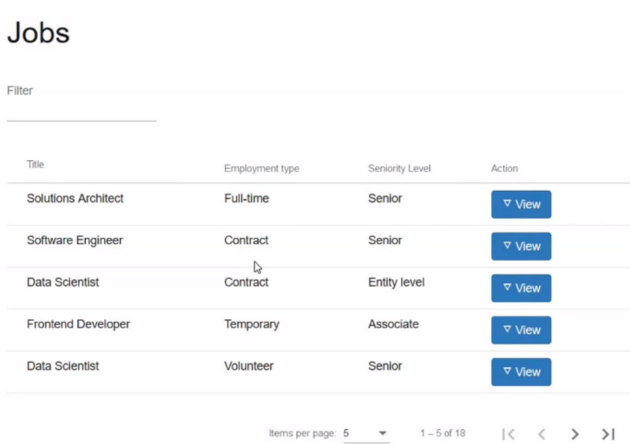

Figure 8. Knowledge graph recommended jobs

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.

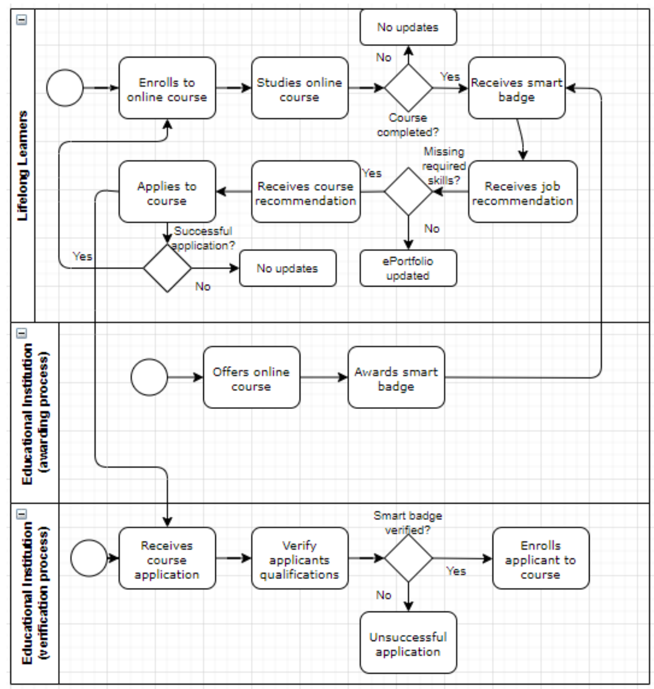

Figure 9. Workflow for lifelong learners

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.

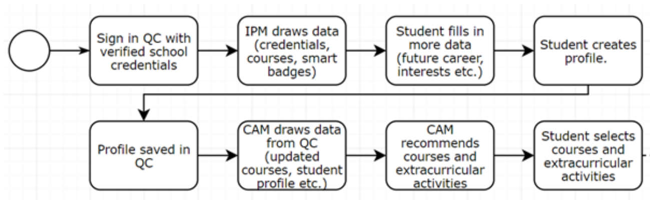

Figure 10. Workflow for university students

The second scenario is tailored for university professors who will first sign in 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.

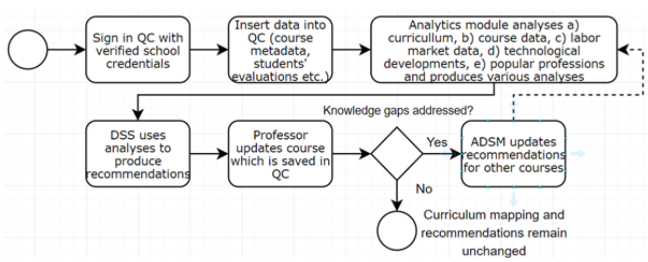

Figure 11. Workflow for university professors

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.

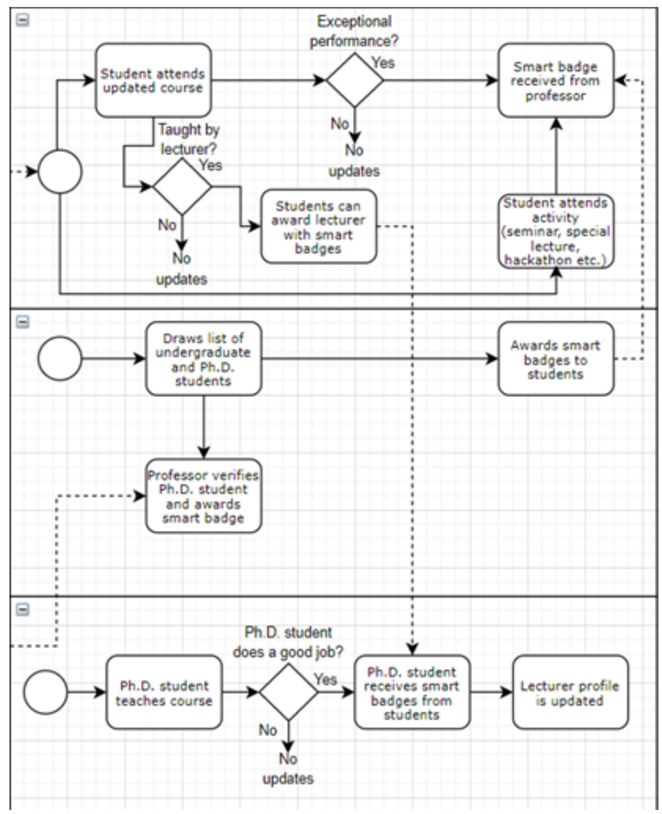

Figure 12. Workflow for smart badge accreditation

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.

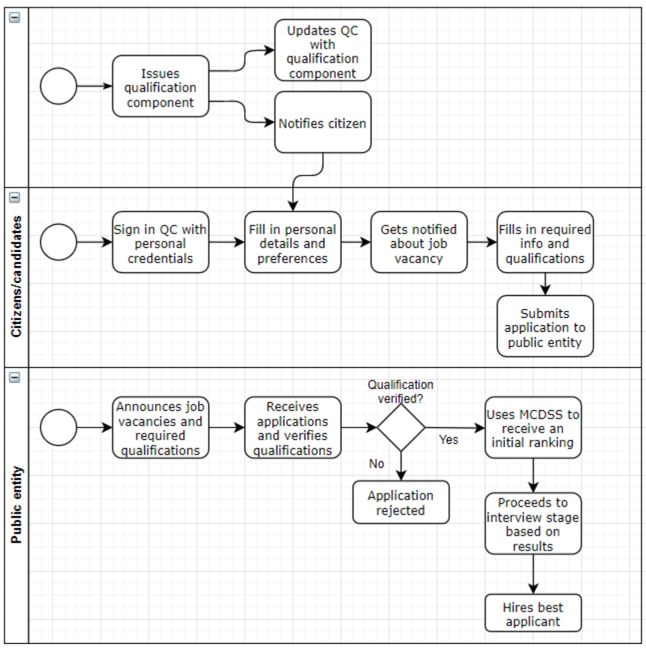

Figure 13. Workflow for public sector staffing

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.

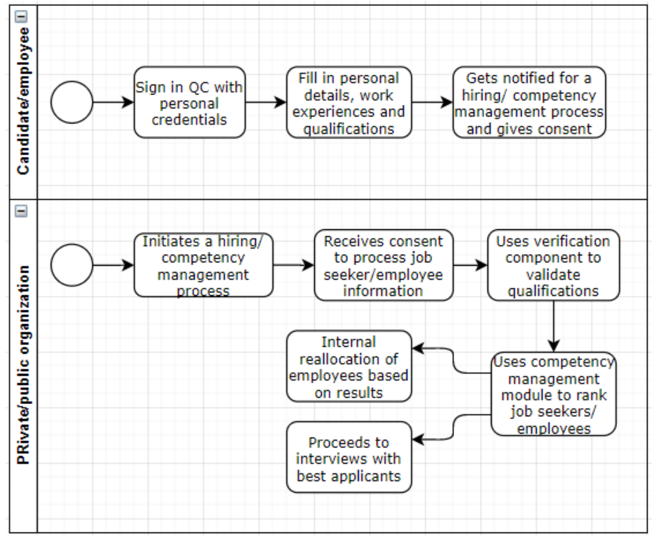

Figure 14. Workflow for competency management

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 outmost 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.

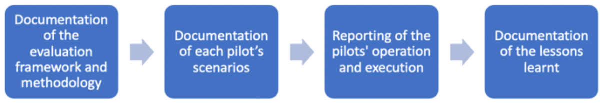

Figure 15. Steps for pilots' evaluation

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

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Exploring Blockchain, Semantics and Decision Support to Optimise Qualification Certification, Recruitment and Competency Management: an Assessment of Challenges, Current Practices and Opportunities

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Abstract—**In the era of digitisation, innovative information and communication technologies have transformed many areas and domains. The same cannot be said for Higher Education, especially as this concerns the certification of degrees, qualifications, and other accreditations of students and job seekers. Such certificates are still largely in paper form and require manual and time-consuming processes for their verification. The inability to effectively verify academic skills and qualifications also affects labour market processes, such as recruitment and competency management. In addition, current ICT solutions in the domain do not leverage emerging technologies that can offer solutions to existing challenges. Innovative technologies such as blockchain can offer an additional level of security and traceability of actions and data transactions, while semantics can provide the necessary data interoperability that is required for more effective analyses of data. The computational intelligence found in data analytics and decision support systems can facilitate the generation of useful knowledge and recommendations, while gamification can be used to transform processes, like recruitment, that are normally stressful and boring into something that can be intriguing, motivating, enjoyable and engaging. As such, this publication aims to assess blockchain, semantics, data analytics and gamification as four potential game changers that can be used to develop innovative solutions in the domain. Under that context, the potential of these four technologies will be evaluated as well as their current usage in existing solutions in the field. In addition, this publication is written under the context of the EU-funded project QualiChain that aspires to investigate the impact of the aforementioned technologies, 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. As such, the second part of this publication focuses on the prospective QualiChain solution and its potential advancements in the four technologies mentioned, taking into account the increasing need for digital solutions in the domain, as a result of the recent Covid-19 pandemic and the emergence of remote working and learning as the new paradigm.**

Keywords - higher education; recruitment; competency management; blockchain; semantics; data analytics; decision support; gamification; Covid-19.

I. Introduction

When referring to a qualification certificate, the most common understanding is a higher education diploma, namely a piece of paper that proves the knowledge that has been acquired in a scientific field, or the skill to develop a certain task [1]. The certification body is the entity that provides a certificate for the acquired diploma and is the legal recogniser of the knowledge. In most cases, a paper-based education certificate denotes that a person has received a specific education and may even include information about the expected learning outcomes. Education certificates are used for various purposes, such as the recognition of the completion of a degree and the development of certain skills.

Although education certificates are being utilised in various educational and work-related processes (e.g., individuals' admission in other educational and training programmes, personnel recruitment), they are largely resisting the pull of technology. In particular, such certificates are still held in diverse formats in siloed databases and usually their verification requires paper documentation and extremely time-consuming manual processes [2]. Moreover, most HEIs (Higher Education Institutions) operate in isolated environments instead of collaborating with the respective industry that their graduates are projected to join. As such, in most cases there are no tools that can facilitate the transition of a person from being a student to a job seeker and the connection between academic institutions and the labour market is in most cases non-existent. Consequently, there is a clear lack of a trustworthy and automatic solution when it comes to archiving, managing and verifying educational qualifications that can operate in various settings and provide added value to users.

The slow digitisation of the education sector [3] in conjunction with the lack of suitable ICT (Information and Communication Technologies) solutions for the verification of academic credentials, results in the holders of such titles being dependent from issuing/accrediting authorities every time they want to verify their degrees. This fact does not only affect academic institutions but also private and public organisations in their tasks that are related to HR (Human Resources). For instance, recruitment in an organisation requires from the recruiters to examine hundreds of candidates' résumés, filter out the unqualified ones and identify the candidates whose qualifications and degrees should be validated. However, difficulties in the public and private sector also extend to a wider set of processes that follow contracting activities, indicatively encompassing personnel allocation and re-allocation, staff mobility, and skills' development and evaluation. What the aforementioned challenges have in common is the general lack of digital equivalents for academic and other qualifications that can be validated by universities, recruiters, public and private organisations without the involvement of the issuing authority. In fact, the recent Covid-19 pandemic made such challenges even more apparent, since the general lockdown in most countries also affected the administrative bodies of universities that have the task of issuing a student's academic qualifications in a verifiable form. Under normal circumstances paper-based qualifications are indeed an inconvenience. However, the lack of verifiable digital certificates during the pandemic affected many students, job seekers and employers who had no other way to receive or verify a university degree and other types of academic credentials, which had a negative impact in student mobility, recruitment and competency management.

Solutions to the aforementioned difficulties require fundamental changes in work practices and processes that extend beyond the transformation of the recruitment procedure and trace back to not only the way education and employment credentials are archived, managed, and used, but also the way the educational and other accrediting organisations operate. Disruptive technologies, such as blockchain, algorithmic techniques, data analytics and semantics as well as concepts like gamification have the potential to provide solutions to these challenges. More specifically, blockchain, as a decentralised and unalterable store of information can help with the archiving and trust issues, as well as provide a frictionless method for transacting with others. At the same time computational intelligence has the potential to facilitate decision making and optimise work practices and procedures.

In order to fully understand and assess the value that the combination of the abovementioned technologies could provide, it is essential to evaluate similar frameworks and tools that are being utilised by higher education and the labour market to provide solutions for the validation of certificates, the recruitment, and the competency management. This paper presents a state-of-play analysis of 19 tools and frameworks used in these domains. This analysis was performed under the context of the EU (European Union) funded project QualiChain, whose goal is to combine blockchain, semantics and other technologies to provide a holistic, trustworthy and automatic solution in the challenges presented above.

Section I introduces the scope of this paper by presenting the current landscape and the challenges arising from the lack of technical solutions for qualification certification. Section II focuses on the potential of blockchain, semantics, data analytics and gamification to revolutionise Qualification Certification, Recruitment and Competency Management. Section III presents the QualiChain project and describes the platform's functionalities. Section IV presents the criteria used for the analysis and provides a short description of each tool and framework that was analysed, while Section V presents the conclusions of the analysis. Section VI includes an assessment of how the Covid-19 pandemic affected higher education and the labour market. Section VII presents the advancements of QualiChain that can potentially disrupt and revolutionise the aforementioned domains. Finally, Section VIII concludes the document and provides ideas for future work.

II. Technologies Potential for Qualification Certification, Recruitment and Competency Management

In this section, four core technologies, i.e., blockchain, semantics, data analytics and gamification are discussed, focusing on the potential they bring to Qualification Certification, Recruitment, and Competency Management. The purpose of this section in not to perform a State-of-the-Art analysis but to discuss on the benefits and risks that these technologies bring with their application in the domains that are discussed.

A. Blockchain

Blockchain is a decentralised, permanent, and unalterable information storage technology that offers trusted archiving, and a frictionless method for information transactions and verification [4]. In blockchain, trust is ensured via cryptographic algorithms and mathematical methods based on achieving system consensus and not a centralised authority. A distributed approach can also greatly improve data safety as there is no single point of failure. As such, blockchain can improve the entire management of the certification lifecycle, including the archiving, management and verification processes [5]. Consequently, HEIs, recruiting companies, public and private organisations can take advantage of this technology to setup distributed platforms for storing, sharing and verifying academic and employment qualifications. Decentralisation also means that users (i.e., students, job seekers, employees) will have ownership of their data by keeping a decentralised copy that they can manage as they like. Moreover, through the use of blockchain, verification can become more secure, traceable and transparent for the benefit of all stakeholders involved (learners, education bodies, educators, and employers). In addition, via the use of automatic functions called smart contracts verification could be automated based on a set of parameters/attributes set by the issuer [6]. Secure and instant online certificate verification can enable the disintermediation of the process, bypassing third-party mediators and improving efficiency of dependent processes. Blockchain technology enables self-sovereignty and identity management as it introduces the ability to track transactions in a transparent and immutable manner, thus addressing the existing issues with trust and provenance management.

Due to the availability of existing and demonstrated methods, the risks introduced by this technology are low and mostly limited to scalability issues, since none of the existing demonstrators have yet been tested to provide the desired functionality for more than a few thousand users. However, the recent Covid-19 pandemic and the increasing needs from education technical solutions make this limitation even more relevant. Also, especially, in the EU, the GDPR (General Data Protection Regulation) has introduced some limitations that mainly concern a user's right to data deletion, or "the right to be forgotten" [7]. As blockchain is immutable (meaning that data cannot be deleted from the system) most approaches in the research bibliography bypass this challenge by keeping personal and transaction data off the ledger and using the blockchain to store the transaction hash [8][9][10]. As any other technology that is still in its infancy stage, other unknown risks that can expose blockchain to unexpected security issues might also emerge and therefore risk assessment is necessary for any technical solution based on blockchain.

B. Semantics

The Semantic Web is an idea proposed by World Wide Web inventor Tim Berners-Lee and is based on creating machine-readable relationships between data instead of only between the files, in which they are contained [11]. Semantics can be applied in various subject areas to model domain-specific terms and organise data into information and knowledge. This can limit overall complexity of the data from a machine's standpoint that can help overcome many challenges that stem from heterogeneous data sources, lack of data interoperability, and multilinguality. For example, in a higher education setting this means that degrees and other education certificates could be represented by knowledge on the learning outcomes and skills associated with said certificate. This could greatly improve student mobility and bypass procedures such as translation and verification. In addition, in recent years many initiatives have combined semantics with blockchain to overcome the issues of centralization and security that come with the semantic web. Verifiable semantic certificates (combining both blockchain and semantic technologies) could enable a learner-controlled and trustable educational ecosystem by promoting and enforcing semantic interoperability through domain-specific standards and ontologies (including a blockchain ontology). In fact, new approaches and applications can build on and extend existing ontologies such as the EthOn Ethereum Ontology for Blockchain [12] (which is still a valuable vocabulary independently of the Ethereum solution, thus is not limited to one platform), the JSON-LD-enabling Open Badges Vocabulary [13], and the SARO Skills and Recruitment Ontology [14] to model professional skills, skillsets, awarding bodies, certifiers and other relevant concepts.

The integration of semantics in blockchain, especially in an education or professional setting can revolutionise and disrupt the domain. Educational or professional certificates stored in a blockchain can potentially include annotations linking them to specific skills in a remote repository. At the same time, the same skills vocabularies can be used to represent skillsets that are routinely observed, through NLP (Natural Language Processing) and IE (Information Extraction), in relation to open positions in the job market (identified in published online job profiles). The use of the same vocabularies to describe both certification and skillsets required by the job market will enable a number of innovative scenarios. Standards-compliant semantic representations of educational achievements will collectively be exploited to suggest to employers, the best matching employee for a new position, and also suggest career development path to employees (including suitable courses and training programs).

On the other hand, the reliance on NLP, IE, and limited supervision may introduce a certain degree of automation errors that will to an extent or another impact the reliability of the most innovative applications, e.g., identification of ideal job candidates, suggestion of courses and career pathways. In addition, the need to securely access and obtain knowledge from various sources (including blockchain) iteratively to arrive at these smart suggestions can introduce scalability issues. Solving these solutions might require balancing a trade-off benefiting either time (quicker results) or broadness (more in-depth or precise results), thus also limiting the short-term innovation potential. However, the extra possibilities made available through those innovative technologies make them worthy of exploring.

C. Data Analytics and Decision Support

Data analytics allows applications to perform queries and data processing activities in a given set of data. The general goal is to build new knowledge out of data and thereby add value to it. New advancement in data science allow the development of tools that can perform freeform queries and data analytics on millions of rows of data thus expanding the potential use cases that can be derived from such technical solutions.

In the context of an education or professional setting, these analyses have the potential to enlarge the scope of possibilities. For instance, the ability to analyse the status of an employee and personal progress trends could then be used to predict future possible positions. Alternatively, by applying MCDSS (Multi-Criteria Decision Support Systems) on the analysed data, employees could make more informed recruitment decisions based on a given set of parameters. In the case of a student, the current courses and skills in their educational profile can be used to make suggestions on additional courses and other learning activities based on a desired career path. In this case, data analytics could be combined with domain-specific semantic vocabularies to make more accurate and informed suggestions based on emerging skills and labour market trends and requirements as it will make dataset combinations easier. The same principles could be applied by a HEI to update an education curriculum based on emerging topics and technologies. Another example could be a match for the HR predictive analysis based on historical data of competencies and by following a prediction model. When analysing large amounts of historical data, technical solutions can also leverage advancements in ML (Machine Learning) that allows the creation of prediction models that are constantly trained and improved by the incoming streams of historical and open data. In general, data analytics can provide several value-added services such as intelligent profiling, career counselling, recruitment, competency evaluation or even consulting and decision support. Technically, a large range of ready-to-use methods and algorithms that are able to perform a wide panel of analytics are already available and free to use. For instance, one could have access to clustering libraries and methods [15] or open-source ML tools [16].

On the other hand, when designing data analytics and DSS (Decision Support Systems) applications, the complexity of deploying the required solutions to perform the envisioned analyses has to be taken into account from the beginning, and more specifically at the time of the added-value services definition and description. In other words, the decision support that an application will provide must be defined before setting out the analytics component and algorithms. This means that changes in a system's added-value services might cause delays in development. In addition, Machine Learning methods can be resource-consuming and might lead to less accurate results when not run on large servers. Therefore, especially when dealing with historical data in order to provide prediction services, the resources needed can impact the quality of the output even when efficient and parsimonious methods are used. Finally, data analytics on the semantic layer rely on a sufficient amount of semantic or structured data. Therefore, it remains a risk that despite the analytics methods being robust and effective, they might not produce the desired result due to insufficient data (e.g., lack of training data in the right format).

D. Gamification

Gamification is an effective design strategy to insert game mechanics into existing contexts. Under the context of this publication, gamification can be applied in competency management to transform processes, like recruitment, that are normally stressful and boring into something that can be intriguing, motivating, enjoyable and engaging. Another benefit is the possibility to address the complex process of competency evaluation, which, by using different gamification techniques, can become simpler. Gamification is a great way for employees to receive constant, up to date, and automatic feedback that is useful to be applied in the competency retention process, where employees can see how they are doing compared to benchmarks they had set for themselves in the past, or compared to other individuals and teams in the organisation. In the learning process, increasing the levels of engagement will lead to an increase in recall and retention, so the learner is able to have a fun experience and still learn the subject in question. A gamification approach can be used as an effective and informal learning environment, to help learners practice real life situations and challenges in a safe environment. When gamification is executed correctly, it is a win-win situation for everyone involved. Working against personal benchmarks, being recognised for a job well-done, etc., gamification can be used to meet various needs within the organisation. Combined with the ability to view feedback at any given time, gamification allows everyone, and not only those at the top of the leaderboard, to enjoy the possibility of improving their performance.

Although gamification is a powerful business strategy that can provide useful information and yield positive returns, it has some risks and potential negative consequences involved. Having a poor design is a major risk and can waste money and time. Consequently, it is essential to thoroughly understand who the users are and what motivates them. Through regarding mechanisms such as rewarding and leaderboards, sometimes companies risk rewarding ineffective collaborators while punishing valuable ones, or adding a leaderboard to a useless task, which will not enhance the quality of the task itself. Additionally, competition between employees can be good for output but could lead to hostility or tension between individuals if it is not monitored correctly. Promising extraordinary rewards can set up unrealistic expectations. Although rewards can be used to strongly motivate an employee, it is important that the provided rewards are sustainable. Also, the demand for rewards can increase over time. If an employee becomes accustomed to a reward, they may lose motivation if new and better incentives are not added. There are several gamification frameworks that aid in this process to guarantee that the final solution is not only effective but also sustainable.

III. THE QUALICHAIN CONCEPT

QualiChain is a project that aspires to investigate the impact of disruptive technologies, i.e., 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 of the project lies in applying the aforementioned technologies for the design, implementation, piloting, and thorough evaluation of the QualiChain technological solution, namely a distributed platform that targets the storage, service, and verification of academic and employment qualifications [17]. Besides the verification of educational and professional certificates, QualiChain aims to build manifold tools that could potentially provide solutions to the major challenged of the fields of education and labour market. Actually, its services are structured across the following to pillars, i.e., baseline and value adding services. Baseline services are grounded upon blockchain and semantics and enable the archiving, storage, and verification of educational awards and qualifications. In fact, they enable also the equivalence verification of certificates as well as qualifications' portfolio management. Value adding services will build upon the baseline ones and will leverage the computational intelligence and gamification techniques to offer more advanced services, such career counselling, intelligent profiling, competency management, and recruitment and evaluation support.

IV. Related Tools and Frameworks

This section pertains the comparative analysis of the current state of practices regarding tools, methods, and frameworks, similar to QualiChain that are used in education, public administration, and commercial applications. All the presented tools and frameworks have already been released for use. Furthermore, they are not expected to include every projected function of QualiChain due to the fact that their scope is much more specific. A comparison on the state-of-play of the functionalities and technical capabilities included in such systems can facilitate the identification of innovative ideas or potential shortcoming of the existing solutions.

A. Comparison Criteria

The criteria used for this comparative analysis represent the high-level technical capabilities of the various modules of the QualiChain platform and are the following:

1. Target users: This part of the analysis will help understand whether all the potential stakeholders have been identified.
2. Blockchain usage/Data security: Identify the solutions that leverage blockchain or other data security methods.
3. Personalisation approach: This criterion will facilitate the comparison of approaches that make the tools more user-centric.
4. Use of Semantics/Data interoperability: Distil the tools that provide the capability for data analytics and in less innovative solutions other searchable interfaces as well as the available pool of data.
5. Gamification approach: Identify approaches that increase user engagement.
6. Qualification certification and Multilinguality: Identify tools that certify qualifications. Two important sub-criteria here further divide the tools into automatic and non-automatic and examine whether they are capable to translate degrees in multiple languages.
7. Recruitment & Competency Management: This criterion pertains to the solutions that offer to organisations the ability to perform various HR related tasks.
8. Open source/APIs (Application Programming Interfaces): Identify the openness of each tool and the potential to create synergies with QualiChain.

B. Selected Tools & Indicative Analysis Tables

The tools and frameworks analysed under the context of this publication were the following:

1. Qualification Check [18] (tool): This tool offers a global solution for qualification verifications and is supported by a team of multilingual education experts. It provides qualification validation so that the organisations are protected from the damaging effects of credentials fraud.
2. Recognition Finder [19] (tool and framework): This tool facilitates the recognition of foreign professional qualifications in Germany. It provides invaluable information about the legal foundations, the recognition procedures for individual occupations, and the available counselling services. The tool finds the competent authority that the user needs to contact for the respective occupation.
3. ECTS (European Credit Transfer & Accumulation) System [20] (credit and grading system): ECTS is a credit system designed to help students move between organisations of different countries. Credits are based on the learning achievements and workload of a course, and hence a student can transfer their ECTS credits from one university to another, so that they add up to contribute to an individual's degree programme or training.
4. UHR Recognition of foreign qualifications [21] (tool and framework): The Swedish Council for Higher Education evaluates foreign qualifications to support people that look for work in Sweden, wish to continue studying, or wish to employ someone with foreign qualifications. This tool includes an online application through which users can apply for an evaluation and recognition of qualifications; however, the validation is not performed automatically.
5. ServiceNow [22] (tool): The ServiceNow module offers an expansive portfolio of training offerings across Information Technology (IT), HR, Customer Service, and other departments that cover the Now Platform (HR and workflow organisation platform for enterprises). It also provides certifications upon mastering new features offered in the latest release of the platform, micro-certifications on a variety of subjects, and verification of certifications received through the ServiceNow platform.
6. Teacher Certification [23] (framework): This framework of the British Columbia provides a number of services, such as certification services, criminal record checks, and fee information, to UK (United Kingdom) Ministry-

certified educators. It includes complete instructions regarding certification offices, pertinent e-mail addresses, and the methodological steps that a teacher should follow to complete a certain task.

7. DegreeVerify [24] (tool): This tool provides immediate online verifications of college degrees and attendance. It provides prompt access to degree and attendance records and eliminates the complications and delays associated with manual processing by individual schools. It can also reduce the risk of making bad hiring decisions and ensure that only verified eligible student customers are eligible for receiving offers from prospective employers.
8. WES (World Education Services) Degree Equivalency Tool [25] (tool): This tool compares a user's education credentials to Canadian and US standards. It allows a user to select the country they have studied in and enter their credentials. Then the tool shows the degree equivalency. This tool estimates the degree equivalency instead of replacing an official evaluation.
9. HEDD (Higher Education Degree Datacheck) [26] (tool): HEDD is UK's official degree verification tool and is used by organisations, institutions, and universities to verify degrees. HEDD cannot be used by students or graduates to verify their own degrees, and hence the organisation using the tool's services needs to request a proof of consent from the individual.
10. NOKUT Recognition of foreign education in Norway [27] (framework): This framework helps institutions, organisations, and universities to validate foreign higher education degrees, vocational education, and training certifications. It includes an exhaustive list of regulated professions and industries and a list of recognition authorities that users of the system need to contact to get recognised in Norway.
11. Vitnemalsportalen Diploma registry [28] (tool): This registry is a Norwegian service that helps users to automatically collect results from higher education institutions in Norway and share them with potential employers, educational institutions, and other relevant recipients. All transmissions are encrypted and only the sender can decide who they want to share their data with.
12. e-CF 2.0 Profiling tool [29] (tool): This tool aims to bring to life the content of e-CF version 3.0 and provide linkage to the EU ICT Professional profiles. It helps users build their own job and education profiles and provides comparisons between users' created profiles and established ICT professional profiles to support skill gap identification. The tool also supports multiple languages.
13. CEPIS e-Competence Benchmark [30] (tool): This tool facilitates the evaluation of ICT professionals' skills, based on the e-CF. It compares ICT professionals' competences with those required for a range of European ICT professional profiles. This helps individuals to plan their career development and make more informed decisions about further education.
14. e-Competences assessment and certification assessment [31] (tool): This tool allows users to create their own professional profile, find the best matching ICT profiles, and choose the certificates that could help them achieve their goals. It also provides users with the following three functionalities; a self-assessment tool, a comparison of e-competence related certificates, and an e-competence demand and supply calculator.
15. IT Staffing Nederland [32] (tool): This tool is embedding the European Competence Framework in their recruiting and matching systems in order to achieve better transparency and quality. This tool takes advantage of semantics for translation of ICT texts into digital e-competences and provides transparency to better interpret job descriptions, vacancy texts, incoming CVs, and training materials.
16. Blockcerts [33] (tool): Blockcerts is an open standard for creating, issuing, viewing, and verifying blockchain-based certificates. These digital certificates are cryptographically signed, tamper-proof, shareable, and registered on a blockchain. The goal is to allow individuals to possess and share their own official records.
17. Diplome [34] (tool): Diplome is a blockchain-based credential evaluation service that generates a "certificate wallet", in which users can upload their qualifications. This tool facilitates the enrolment in foreign universities and helps individual enter the labour market in a foreign country. Diplome is a global ecosystem that can be used by authorities and institutions to securely and unchangeably register education/training documents, guaranteeing their transferability and authenticity.
18. LinkChain [35] (tool): LinkChain is a Blockchain-enabled Linked Data Platform that provides certificate equivalence verification, credential auditing and verification while supporting multi-lingual capabilities.
19. Blockchain for Education [36] (tool): This tool, which is part of a platform that is in development, enables learners to present their digital certificates and supports certification authorities in the management and archiving of digital certificates. It relies on blockchain to enable tamper-proof archiving of certificates and their correct allocation to the learners. The existing in-use tool relies on Open Badges and uses JSON/JSON-LD for metadata and as a basis for querying (verification purposes).

For the analysis of the tools and frameworks that are presented above, the following tables (Fig. 1) were used to describe the general functionality of each tool, the technologies implemented in it and the added value that they provide to users.

Tool/method name	Recognition Finder[95]		
Category (tool, ready product, theoretical framework etc.)	Tool and framework	**Current Version (alpha, beta, pre-release etc.)**	Released
Description			
Recognition Finder is a tool for the recognition of foreign professional qualifications in Germany. Moreover, those seeking advice only need a few clicks and this online tool will name the competent authority for their application. In addition, it presents important information about the legal foundations, the recognition procedures for individual occupations and available counselling services in a concise form. It should be noted that the Recognition Finder does not automatically verify the user's qualifications, but rather finds the competent authority that the user needs to contact for the respective occupation.			
Implemented Technologies & Functionalities			
• Recognition check allows users to see whether their professional qualifications can be recognised in Germany • The portal is available in German and English, as well as Arabic, French, Greek, Italian, Polish, Romanian, Russian, Spanish and Turkish. • For mobile use, there is also the "Recognition in Germany" app, which offers the information in seven languages: German, English, Arabic, Dari, Farsi, Pashto, and Tigrinya. • The database currently contains more than 1,500 different contact addresses for the recognition procedures of occupations within the remit of the states and the federal government.			
Added Value			
• In the "Recognition Finder", the user can enter his or her profession and use the occupational profile displayed to determine the German vocational certificate that matches the qualifications acquired abroad. • Just a few clicks are sufficient to get the address where an application for an assessment of equivalence can be submitted. • All the information that is important for submitting an application is summarised – for example the documents required for an application.			

Figure 1. Analysis table.

Name	Current Version	Target Users	Blockchain/ Transaction Records/ Level of Security	Personalisation	Semantics/Interoperability, Data Analytics/ Searchable data	Gamification	Qualification Certification/ Multilinguality	Recruitment & Competency management	Open Source/ APIs
Qualification Check	Released	Businesses, government agencies, education providers, professional bodies, regulators, HR teams, recruitment firms	No Blockchain Full audit trail and detail record for each verification	No	No	No	Intuitive, automated qualification verification, worldwide education verification, electronic transcripts/ degree certificates to outside bodies/ Multilinguality	No	QCheck API allows integrated systems to query details
Recognition Finder	Released	Students, job seekers	No	No	No	No	Allows users to see whether their professional qualifications can be recognised in Germany, not automatic, finds the competent authority/ 11 available languages	No	No

Figure 2. Comparison table.

Following the previous analysis, a comparison table was created that analyses each tool according to the criteria described in Section IV.A. An indicative section of the comparison table is shown in Fig. 2. The full table is not presented in this body of work in its entirety, due to space limitations. The main objective of this table was to help draw the conclusions that will be presented in Section V.

V. Analysis of Results

This section will conclude on the approaches that were analysed and the potential position of QualiChain in the domains of Qualification Certification and Human Resource Management. The conclusions will be based on the eight criteria that were defined for the comparative matrix as well as the overall added value of the presented tools.

The target users are actually the only criterion where no significant differences among the various approaches can be noted. Since the tools presented are tailored for stakeholders of the domain of education, the domain the job market/HR management or a combination of both, there is no doubt that the target users are like those of QualiChain. Identified target users include students, job seekers, employers, private and public organisations, government agencies, education providers, regulators, HR teams and recruitment firms. This gives credence to QualiChain's approach for stakeholder identification and proves that the list of QualiChain stakeholders is exhaustive and complete.

Concerning other criteria, the analysis revealed that only 4 out of the 19 tools (Blockcerts, Diplome, LinkChain, Blockchain for Education) leverage Blockchain ledgers and decentralised standards for the purposes of record keeping, issuing and verification of certifications. While blockchains are harder to implement than more traditional databases, their capabilities for secure distribution of certificates, security, data privacy, and immutability are considered to be of paramount importance for the minimisation of fraud around educational and other certificates. In addition, considering the approaches that did not use blockchain, only 2 (Qualification Check, DegreeVerify) keep records of transactions and 1 (Vitnemalsportalen) provides any level of security by adding digital signatures on documents.

Regarding semantics and data interoperability, of all the tools that were presented, only 4 took them into account. In particular, IT Staffing Nederland applies semantic software that translates ICT texts into digital e-competencies while Diplome applies other standards of interoperability on the data. On the other hand, Blockchain for Education, offers JSON-LD support, which can provide the required verification methodology. Furthermore, LinkChain is projected to be fully semantic and support public and private RDF. Moreover, 4 solutions had minor data analytics capabilities, mainly to match a student's/job seeker's profile with the skills required for a given position. Finally, 6 out of the 19 approaches provided some data structure coupled with searchable registries for the user's convenience. However, except for LinkChain the rest of the approaches do not provide any automatic capabilities for analysis.

The level of personalisation that each tool provides was also used as a criterion. The results here are quite positive given that 8 approaches provide some level of personalisation. For instance, ECTS makes learning more user-centred by using credits as currency. Additionally, WES offers digital badges used to display verified credentials on social media, such as LinkedIn. Moreover, tools powered by the European e-Competence Framework, enable users to develop their profiles based on preferred orientation and competence gap analyses. Finally, the approaches that leverage the blockchain technology, i.e., Blockcerts, Diplome, and LinkChain, provide users with a valid and verifiable certificate/qualifications wallet.

Concerning gamification, there are no tools that can provide a clear solution. There are a few tools that provide some degree of informal gamification with credits and digital badges. However, the overall conclusion is that the community does not really consider it to be that important for the developed tools. Given that most of the tools are free of charge and offer solutions of low technical capabilities that are realistically applied in Niche markets, it makes sense that gamification is not a priority.

The main criteria used for the analysis revolve around the two main high-level functionalities that QualiChain will aims to provide, i.e., Qualification Certification and Recruitment/ Competency Management. One clear division between the various tools concerns the level of automation that they provide. Only 4 out of the 19 solutions help users navigate through the various procedures that they will have to follow in order to get certified in a given country or domain, instead of automatically validating their qualifications.

All the other solutions provide various levels of automation and will be assessed according to the actual added value that they offer to the entire end-to-end procedure of either Qualification Certification or Recruitment/ Competency Management. Starting from Recruitment/ Competency Management, no tools were found that offer holistic solutions in a pan-European level. In particular, while the majority of solutions offer solid functionalities that can help the HR teams of organisations make strategic decisions, tools like NOKUT (Norway) mainly apply to a specific country and other tools (i.e., e-CF 2.0 profiling tool, CEPIS e-Competence benchmark, e-Competences assessment and certification assessment and IT staffing Nederland) can be applied only for ICT positions and organisations. On the other hand, platforms like LinkChain have the potential to support external analytics and serve as a data backend for qualification analysis, opportunity identification, competency development and evaluation, etc.

On the contrary, regarding the domain of Qualification Certification, there are a number of solutions that provide added value in every step of the process. Tools such as Qualification Check, ECTS, Blockcerts, Diplome, LinkChain, and Blockchain for Education are considered to be holistic solutions that automatically handle every step of the process. In fact, some of these tools have already been adopted by multiple countries. However, there are still solutions that are country specific (i.e., Vitnemalsportalen, DegreeVerify), do not offer the full range of functionalities for every type of user (HEDD) or offer micro-accreditations for expertise in specific platforms and tools (ServiceNow). Moreover, only five of the presented approaches support Multilinguality and only three of them, namely NOKUT, Diplome, LinkChain, offer functionalities for both Qualification Certification and Recruitment/Competency Management. According to QualiChain, having both services seamlessly operate in a single platform has the potential to further connect high-level education with the job market. This will help each domain learn from the other and also help students, job seekers, but also organisation to make more informed decisions. Finally, the fact that 8 out of the 19 tools provide APIs that allow them to connect with other systems can potentially help QualiChain synergise with them.

All in all, most of the tools that were analysed are either commercial applications or country/domain-specific and are usually focused on specific functionalities that are useful in some steps of the processes required by students, job seekers, educational institutions and organisations of all types. This gives credence to QualiChain's holistic approach and proves that there is indeed a vacuum on the market of the domains tackled by the project. In fact, not only does QualiChain aim to fill a void in the market (that is made even more apparent from the Covid-19 pandemic) but also to advance the state-of-the-art by developing a holistic platform that provides open semantic interoperability and data privacy building on and extending the research in blockchain, semantics, data analytics and gamification.

VI. Reflections on the Covid-19 Pandemic

The Covid-19 pandemic disrupted many facets of everyday life, especially those that require the physical presence of people for their completion. Higher Education institutions managed to adjust to the new conditions by taking advantage of online communication tools for teaching courses, organising exams, and communicating with students for various issues. Several members of the team had first-hand experience on this change, as they are university professors. While such tools allowed universities to continue their academic activities, they also uncovered a number of challenges. For example, during exams, students were requested to identify themselves via webcam and by also providing a form of identification to the persons responsible for this process. Given that this had to be done for every student individually, it required from students to be present for a longer time during the exam, and a greater administrative effort from the school, leading to some general dissatisfaction. Furthermore, there were some data protection issues stemming from some of the online communication platforms that were brought forth. Moreover, universities had to face challenges regarding the issuance and verification of degrees and other forms of qualifications such as letters of recommendation. During the quarantine period of the pandemic, university administrative bodies operated in a very limited capacity. Despite this fact, students required their services for various reasons such as issuance of their degree or a letter of recommendation from professors so that they could keep pursuing professional opportunities. The lack of dedicated ICT infrastructures and the fact that degrees and other forms of qualification still require time consuming processes and are still largely produced/published in paper form delayed students a great deal. The same is true for employers and recruiters concerning the verification of educational credentials during recruitment processes.

On another note, during the pandemic, students and lifelong learners started taking more online courses as an addition to the knowledge received from the school as well as due to the increased opportunities presented to them by various open universities that operate online. While such courses do provide official qualifications after completion of a course, students in this case end up possessing multiple heterogeneous qualifications in a fragmented form. What they are missing is the capacity to showcase such qualifications in a professional profile by also providing proof of their authenticity.

It is obvious from the above that the Covid-19 pandemic made more apparent some of the issues and challenges mentioned in the previous sub-chapters. Given that we are now facing a new reality in everyday life and great uncertainty concerning the end of it, new innovative solutions must be generated to address the challenges that arise from this situation. Blockchain is a technology that is ideally situated right now as far as its level of maturity and the solutions that it can bring regarding the verification of identities, degrees, and other forms of qualifications. In fact, by also enhancing identity management systems with blockchain, people can have every form of identity gathered and validated in a single digital wallet that they can use to access online services taking advantage of the SSI (Self-Sovereign Identity) paradigm. Under the same logic, verification of degrees can become a one-time process that generates a digital degree and proof of the verification process that students and graduates can then share with other universities, employers, etc. If a prospective employer wishes to review the authenticity of a degree, they will be able to do so via the hash of the respective block and blockchain's algorithmic processes for validation of documents. The same is true for online and other forms of micro-accreditations that students receive from open universities and other online courses by implementing smart badge endorsement. In fact, by reengineering most forms of qualifications as smart badges, students and job seekers will possess a personal profile of verified credentials and qualifications making them easier to manage and share. Finally, it is hoped that digitising the aforementioned processes will make it easier to build added-value services on top of them bringing forth a new age in qualification validation.

VII. Potential Advancements for QualiChain

A key insight, which informs multiple aspects of QualiChain, is that the value of innovation in the education and employment sphere resides in network effects. An innovation may be ground-breaking in its own right, but if it does not play well with everything else taking place in the same domain, it does not add any value. The stereotypical example is perhaps the invention of the telephone – until there were two telephones, working to a common standard, the invention was valueless. Education and employment involve a highly diverse range of stakeholders, with different (if often complementary) interests and desires, and with different information needs. To add value in this area, an innovation must fit into the network of stakeholders and their interactions and contribute across perspectives. Most of the solutions identified in this publication are commercial or country/domain-specific and focus on specific steps of the relevant processes. The vision of QualiChain spans across education and employment and aims explicitly to address issues from multiple stakeholder perspectives in order to maximise the value added across the domain. The technical philosophy is centred on standards and interoperability – working along with existing and emerging technologies and approaches, both to increase adoption and also to deliver the radical vision of the project in an effective and sustainable way.

Blockchain, semantics, data analytics and DSS, and gamification are the four core technologies/concepts that have been identified as potentially ground-breaking in the education and employment sector. As such, the potential advancements of QualiChain for each of the aforementioned will be presented in the following sub-sections

A. Blockchain

Educational credentials and achievements, job applications, professional development records, and so on, can each contain various forms of personal information. While it is important to honestly share details that are relevant, e.g., in an application, it is also important that personal data is protected so that it is only used when necessary and by the smallest audience necessary. There are established practices for privacy and data protection in the non-blockchain case. When it comes to blockchain applications, the best practice is still emerging. QualiChain will go beyond the SotA (State of the Art) by making sure that users have control of their data directly in a personal data store, with self-sovereign distributed identifiers generated and used as needed. Blockchain records will ensure that user-held data can be proven to be genuine and unmodified without any need for the user to relinquish control. Existing solutions do not provide this combination of security and control while maintaining verifiability.

Furthermore, existing solutions using blockchains to guarantee immutability of data tend to be application-specific. In order to implement the semantic approach to QualiChain, it will be more efficient to extend existing work among the consortium into a general-purpose platform for Linked Data and blockchains supporting the private or public storage and sharing of Linked Data with secure provenance and verifiability, coupled with self-sovereign identifiers. This represents a significant advance on the SotA, with applications beyond education and employment, contributing to the development of a decentralised trust layer for the Web in general. The increased possibilities this makes available have the potential, in the longer term, to feed back to education and employment in the form of a wider range of both verifiable and non-verifiable datasets across diverse domains, which can be integrated with, e.g., qualifications, to derive further network effects and new unforeseen services for learners, educators, employers and recruiters.

Finally, regarding the legal and ethical compliance of the project with the GDPR, QualiChain has already performed a comprehensive analysis of the European legal and ethical landscape and has produced the necessary forms for informed consent/assent and risk assessment. In fact, QualiChain aims to generate a roadmap that can extend beyond the domain of education to help developers of blockchain solutions more easily navigate the legal landscape and achieve GDPR compliance. As such, QualiChain's outputs advancing the SotA are the following:

- Personal datastore-based blockchain system for credentials
- Self-sovereign identities in qualifications and Human Resources
- Recommendations for data protection best practice for blockchain applications

B. Semantics

The design of the Semantic Web and Linked Data is built around the assumption that data sources operate independently and organically, and that data integration and communication is best handled in a lightweight manner by encouraging the use of common vocabularies and providing the ability to relate post-hoc different vocabularies and schemas.

QualiChain will make use of semantic technologies throughout, and will, wherever possible, make use of existing standard ontologies and vocabularies to maximise interoperability with existing systems. Ontologies developed for the project will be designed with reuse in mind and will be shared and promoted in order to encourage this. Where QualiChain needs to work with existing non-semantic systems, standard mechanisms for mapping to other data models will be used and will themselves be open for reuse outside of the project. The overall goal is to ensure that integrating QualiChain with other platforms is as straightforward as possible, and to encourage and support the adoption of semantic interoperability standards in general, in order to achieve significant network effects. As such, QualiChain's outputs advancing the SotA are the following:

- Ontologies for blockchain and verification
- Ontologies for skills, competencies, and qualifications
- Ontologies for recruitment and Human Resources
- A general-purpose Semantic Blockchain platform

C. Data Analytics and Decision Support

Data analytics consist of the next abstraction level after the previously presented semantic layer. In the QualiChain solution, data crawling techniques will be employed to draw data from job posting websites so that they can be analysed in conjunction with the data already existing in QualiChain (user profiles, skill level of employees in a given domain etc.). The results of the analyses will then be used to feed the decision support systems assisting the project's end-users with their use-cases. In fact, the Data Analytics and Decision Support value adding services of QualiChain have the main goal to provide sophisticated tools for data visualisation and analysis as well as evaluation and selection among alternatives. Although they constitute general purpose services, their emphasis is primarily in covering the needs of the QualiChain pilot applications.

To provide decision support, QualiChain will make use of various MCDSS and algorithms to develop a general-purpose tool, utilised by several services that will help the decision maker choose among different options taking into account all the criteria that are meaningful for the final choice. This is feasible since multi-criteria decision-support methods quantify the benefit from every decision for every single criterion and combine them. Furthermore, the tool will provide the means to weight the criteria when there are many decision makers with different opinions about the importance of each criterion (e.g., different stakeholders have different goals, thus they have also different opinions about the importance of each criterion). As multi-criteria decision-making is a broad scientific field, there are plenty of methods proposed. However, most of them stem from two ideas, the Multi Criteria Utility Theory and the Outranking Relations Theory.

The Multi Criteria Utility Theory takes into account all the available criteria and calculates a total evaluation score for each alternative. The MAUT (Multi-Attribute Utility Theory) is one of the multiple methods classified as a multi-criteria utility method [37]. On the other hand, Outranking methods build a preference relation, usually called an outranking relation, among alternatives evaluated on several attributes. In most outranking methods, such as Electre and Promethee, the outranking relation is built through the execution of a series of pairwise comparisons of the alternatives [38]. QualiChain's DSS component will leverage algorithms from both theories and give users the ability to choose the ones that suit the purposes of their analyses. Based on the above, QualiChain's outputs advancing the SotA in this field are the following:

- Development of a multi-purpose DSS tool that can be extended and tailored to specific use cases
- Combination of various algorithms (MAUT [39], Topsis [40], Electre I [41] and Promethee II [42]) to cater to every multi-criteria decision support problem
- Add value to existing datasets by discovering new patterns
- Provide decision support in multi-parameter problems with multiple decision makers.

D. Gamification

As noted in the analysis part of the publication, there is very little in the way of gamification in the domain targeted by QualiChain's gamification plans. There is thus, significant potential for advancement by the project. In particular, approaches to gamification in professional development contexts require careful consideration and piloting, in order to ensure the goal of increasing motivation and engagement among target stakeholders, and to determine how best to employ gamification techniques in this area. To achieve this objective, QualiChain will build a gamification solution that can be used in each of the steps of a competency management system such as:

- in competency acquisition through the development of engagement activities, quizzes around company challenges, related questions, and behavioural puzzles, gamification will personalise and add a fun element to the recruitment process

- competency evaluation processes through the analysis of candidates' actual behaviour and capabilities such as time management, creative and innovative thinking or problem-solving, skills will be assessed
- in competency retention processes by creating mechanisms of collaboration and competition with a transparent point system within the company community, employees will continue to be motivated and focused
- in competency development process through the measurement of the employee on-the-job performance, by providing simulated work environments as training.

It is also intended to exploit the enhanced user engagement and motivation features of gamification techniques for bringing the QualiChain blockchain-based approach of storing education certificates into the mainstream and promoting the concept of lifelong learning. Gamification strategies will be used as a motivational tool to help employees reach tangible goals, by using game elements such as scores, competitions, badges, awards, and levels to motivate and maintain the employees in an encouraging and enjoyable system. The first steps to start developing the QualiChain gamification approach are underway via questionnaires, interviews, and focus groups with the respective pilot partners to distil business metrics that are intended to be fulfilled, each scenarios main actors (users, citizens, etc.), and the different existing mechanisms that appeal to the core drives of human behaviour.

VIII. Conclusion and Future Work

This publication aimed to perform a comprehensive state-of-play analysis on current approaches, technologies and applications that are employed in higher education and the labour market to facilitate qualifications' certification and management as well as recruitment and competency management processes. In addition, four core technologies, namely blockchain, semantics, analytics and decision support, and gamification have been identified by the research bibliography as potential game changers in these domains. It can be surmised from the bibliographic research that most existing solutions heavily underutilise the aforementioned technologies, oftentimes lacking the technical expertise and the means to develop and implement innovative solutions that leverage emerging technologies in addition to traditional ICT techniques. Furthermore, it seems that there is a disconnect between higher education and the labour market in most solutions as they cater to only one of the two domains, and as a result, most applications address only a specific part of the overall process flow. On the other hand, QualiChain, the project that is the main focus of the publication, views higher education and labour market processes as interdependent and aims to develop a solution that addresses current challenges in a holistic way. For that reason, QualiChain will develop various value-adding solutions that cater to the needs of multiple stakeholders on top of a robust infrastructure that is based on blockchain and semantics. The projected platform will leverage the data security offered by blockchain and data interoperability offered by semantics with the computational intelligence found in analytics and decision support to offer an all-around solution that can cover every step of the process. At the same time, gamification mechanics will be employed to increase user engagement. QualiChain aims to advance the current state-of-the-art in the aforementioned technologies and become a central point in showcasing their usefulness to develop innovative solutions. All in all, it is considered that QualiChain's technical solution will fill a large vacuum in the current market, also covering the increasing needs for remote verification, recruiting and competency management that are the result of the social distancing that was employed in a global level as a result of the recent Covid-19 pandemic.

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Digital Transformation of Education Credential Processes and Life Cycles — A Framework of Research Questions Based on the Main Challenges

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***Abstract*—This article describes the challenges that arise in the using and managing education credentials, and from the switch from analogue paper-based education credentials to digital education credentials. We analyse the available literature and notice that this transformation—from paper to digital for education credentials—has not been the focus of research so far. Using an approach based on the use cases and identified challenges, we propose a general methodology to capture qualitative descriptions and measurable quantitative results that estimate the effectiveness of a digital credential management system in solving these challenges. This methodology is applied to the European Union Horizon 2020 project QualiChain use case, where five pilots have been selected to study a broad field of digital credential workflows and credential management. It can form the basis of a future framework that will capture the whole life cycle of educational credentials, from creation, storage, management, access control, till it expires or is retracted.**

Keywords–Credentials; Education credentials; Digitisation; Challenges in digitisation; Digital Badges.

I. Introduction

Education and academic credentials are an essential part of our modern life. Pupils finalise schools with a set of marks certified on their final school report. Then, based on these results, they can apply for acceptance at higher education institutes or apprenticeship. Students and employees continue to collect credentials at university, at work, or via other education ways. Even today, when digitisation has entered into almost every part of our lives, education credentials are still often printed and written on paper. A transformation to digital workflows seems desirable to take advantage of the additional possibilities of digital certificates. However, such a transition is not without challenges. In [1], we first looked at these challenges and presented a proposal for a framework to evaluate credential management systems that support digital credentials transformation. This article now builds on and extends [1] by adding to the initial reasoning and providing an overview of related works.

Paper-based credentials show several problems in practice. For example, when applying for a job position, the handling of paper based credentials is tiresome for the applicant and even more so for the company that offers the position. Indeed, most companies nowadays require scans of the paper credentials, and will only check the validity of the originals once the candidate for the position has been selected, to avoid the manual labour involved. Additionally, surveys show that lying about education and employment credentials is a common problem. According to a survey by CareerBuilder [2], 58% of employers have caught a lie on a resume. Similar findings arise from another recent survey by StatisticBrain [3], which reports that over half of resumes and job applications (53%) contain falsifications and over three quarters (78%) are misleading. Digitisation of education credentials has the potential to make credential handling both easier and more secure. Nevertheless, it is important to ask the correct questions to be able to investigate how well a solution performs in the implementation and management of digital education credentials.

Everhart et al. define in [4] important key terms and concepts regarding digital badges, that we believe can be extended to credentials in general:

- *Authentication*: Certifies that a credential is authentic, i.e., has been awarded according to the standards referred to by the credential.
- *Authorisation*: The issuer of a credential has the power to issue the credential. This power can be certified by a trusted third party, usually the government where the issuer is based, or a well trusted public organisation.
- *Endorsement*: Other parties can endorse a credential, i.e., signing the credential, confirming its validity and thus adding trust to the content of the credential.
- *Validation*: Validation refers to the value a credential holds in the education ecosystem, i.e., how do the consumers of the credential interpret its value?
- *Verification*: Verification tests if the credential is genuine and has not been falsified.

As Room notes in [5], setting the standards in education, and thus, defining each credential's value, is a social policy issue and decided on a political level. Technology cannot be used solely to solve this problem. However, the combination of easily accessible background information as open data about the educational standards references in a credential, together with semantic information in digital credentials that make the access to this information accessible and immediate, can significantly increase the transparency in this field. This also has the potential to facilitate the labour intense practice of cross-country credential equivalence estimations, up to the point where this could be done automatically, once the background information supplies enough detail.

Looking at frameworks to measure digitisation in the economy, it appears that credentials have not been in focus so far. In [6], Kotarba gives an overview of standard digital economy metrics like the Digital Density Index (DDI) by Oxford Economics and Accenture, the Digital Economy and Society Index (DESI) by the EU commission, and Digital Society Metrics as part of OECD's digital economy measurement system. None of them refer to credential management as far as we can see.

The main contribution in this article is to present the main challenges encountered in education credential management and usage, and the changes from analogue to digital credential workflows. We propose specific questions that will allow a qualitative and quantitative assessment of the performance of a credential management system and infrastructure regarding these challenges (given in Table I). Finally, we introduce the use case of the EU Horizon 2020 project QualiChain [7], where these research questions will be evaluated with the help of the participants in the project's pilots.

The article is organised as follows: Section II presents different challenges encountered while analysing the reports and questionnaires provided by the QualiChain pilots. In Section III, we propose a set of questions for every challenge presented in the previous section. In Section IV, we offer the use case of QualiChain. In Section V, we give an overview of relevant related work. The article closes with Section VI, where our conclusions and future work are outlined.

II. Challenges in Education Credential Management

How can a solution offering the issuing, management, and verification of digital education credentials be evaluated? Two ways appear natural to approach this question: One can either start looking at it from the user perspective—where the users are the issuers, the holders, and the consumers of the credentials—or follow the switch from the well-established handling of paper-based credentials to digital credential management and look at all the challenges that appear. Both ways are of equal validity and should arrive at the same results. Based on the results acquired in [8], we noted that the overlap in requirements between credential issuers, credential holders, and credential consumers is substantial and that it seems more adequate for the investigation of the digital transformation of the education credential process and life cycles to follow the process of changing from an analogue to a digital setting. We, therefore, propose to segment the questions of interest into three subtopics:

- Challenges of paper-based credentials;
- Challenges of transition to digital credentials; and
- Challenges of digital credentials.

In the following sections, we deduce and present these difficulties and propose ways how to measure the performance of a presented solution for the implementation and management of digital education credentials. Figure 1 gives an overview of the complex of challenges.

A. Challenges of Paper-Based Credentials

Paper-based credentials are the state of the art and have a history dating back to medieval times. Their use over centuries makes it evident that, before digitisation, they were widely seen as the best solution. However, the developments in the last decades and the move to digital workflows increased the pressure on analogue, paper-based credentials and led to growing problems, especially in fraud prevention.

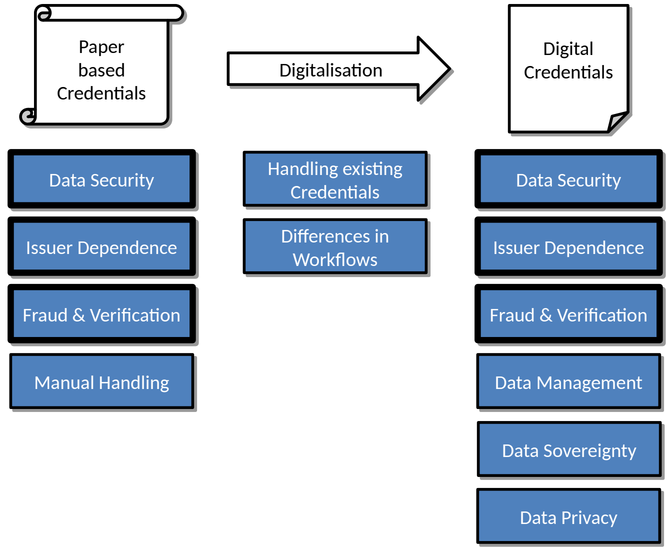

Figure 1. Challenges in the digital transformation of education credential processes and life cycles. Paper based credentials, the digitisation process itself, and digital credentials each are sources of specific areas of problems that are presented as darkly coloured boxes. It can be seen that both digital and paper based forms share a set of common challenges (thick outline).

1) Fraud and Verification: Advances in digital printing make it continuously more difficult to protect paper-based credentials against fraud. As already mentioned, a survey by CareerBuilder [2] reports that 58% of employers have caught a lie on a resume and 33% of them have seen an increase in resume embellishments and fabrications like embellished skill sets (57%), heightened responsibilities (55%), dates of employment (42%), job titles (34%), academic degrees (33%), companies worked for (26%) and awards (18%). A different survey [3] states that over half of resumes and job applications (53%) contain falsifications, and over three quarters (78%) are misleading. Most issuers do not have the capabilities to use advanced falsification protection in their paper credentials, compared to what is done, for example, for paper-based money. Without a general standard, it would also be impossible for a non-expert to decide if the credential in front of him/her has the correct characteristics. There are over 3,000 higher education establishments in the European Union alone [9]. Instead, institutions and states commonly register necessary credentials and allow interested individuals to inquire about a presented credential's validity. The UK, for example, offers the Higher Education Datacheck service [10]. The use of this service is chargeable, and the process can take up to seven days [11]. The process is also highly manual and time-consuming.

2) Dependence on Issuer: The problems with fraud make it challenging to issue education credentials for anyone else other than official education establishments. This leads to the issue that learners will be unable to furnish sufficient and incontestable proof over several types of qualifications gained outside this established system. In the job market, written recommendation statements (also easily to falsifiable) or contact persons of reference are used to compensate for this. These methods are also manual and time costs for the people involved. The challenge to correctly identify the issuer of such statements is related to this problem. Additionally, this can be why direct access to contacts for reference is often preferred. In this case, the authenticity of the reference can be checked by other means, like contact over official phone numbers, personal knowledge, or email addresses.

3) Handling: Paper-based credentials are easy to handle and store for the bearer. Still, in situations where many credentials have to be collected, screened, and analysed, the high manual handling costs make their use expensive. This leads to a time consuming and costly labour intense recruitment process. For staffing private and most public sector organisations, it can be challenging to efficiently handle competency management in large organisational structures. This observation is supported by the outcomes of our questionnaire collection at the QualiChain pilots.

4) Data Security: Paper-based documents have successfully been archived over many decades using high-quality, acid-free paper, storage in low humidity and room temperature in pest-free environments. Additionally, data protection can be enforced by physical access restrictions that are commonly available and do not require specialised information technology (IT) skills. However, most users of paper-based credentials outside of official archives and libraries lack the means of long-term storage, which makes paper-based credentials vulnerable to loss and damage. This is made more severe by the impossibility to create identical copies of paper-based credentials. In this context, it is interesting to note that digitisation in libraries often captures more than just the works' content. Further, digitisation is not seen as a substitute for archiving the works, but as an additional effort to make them readily available and keep at least part of the contained information safe from physical decay [12].

B. Challenges of Transition to Digital Credentials

Any solution that asks users to move from a well-established analogue paper-based workflow to a digital workflow will face challenges in this transition. Furthermore, how well the solution solves these issues will determine how well the users will receive it. In the following points, we present the problems we encountered mentioned in our data collection.

1) Digitisation of Existing Credentials: Analogue credentials are put into existence using written text, images, drawings, and security characteristics in various forms. To retain all this information in digital form is difficult. To efficiently work with the content of the credential, it is necessary to convert the unstructured text, e.g., gained by a scan of the document, into structured data that has been semantically enriched.

2) Interaction Between Analogue and Digital Workflows: While workflows for both digital and analogue paper-based credentials exist, it is desirable to cater to both types. The users' transition is seamless and can import paper-based credentials to take advantage of the added possibilities of digital workflows. These transitions will often mean making manual adjustments possible in a digital workflow or temporarily creating digital twins of paper-based credentials to incorporate them into pure digital workflows. This can also mean that digital credentials are printed out, to be included in paper-based credential workflows.

C. Challenges of Digital Credentials

Digital representations of credentials have their own challenges, that may be quite different from the paper-based ones.

1) Private Data Protection: Digital data can easily be copied, and creating identical copies of digital data is part of IT workflow. For example, if a digital credential is sent from the issuer over a secure channel to the credential holder, its actual data is copied multiple times in the process. First, the credential is copied from the data storage at the issuer to the network stack of the issuers system. Then, it duplicated into a transport format, over various relays in the communication system, and into the network stack of the receiver, unpacked. Finally, the receiving application's memory stores the last copy. This characteristic of digital data makes it also easy to leak private data in the process. In paper-based credentials, simple physical access control is often enough. Contrary, access control has to be secured digitally for digital credentials.

2) Data Security: Digital data ultimately is stored in physical form, and this storage will degenerate over time. It is, therefore, important to be able to copy the digital credential to new physical storage, and to continuously monitor the quality of the storage before the degradation leads to damaged data. In libraries, the "lots of copies keep stuff safe" (LOCKS) model has been successfully implemented for electronic publications, based on the idea that independent copies of the same data in physical and geographical independent data stores, ensure high data security and availability [13].

3) Data Management: Differently to paper-based credentials, a digital credential can only be perceived by a user if content or metadata is rendered in a perceivable form (usually visual). Management systems need to ensure that users know what is stored and what is transmitted if requested. This requirement is also demanded in the EU General Data Protection Regulation (see Section II-C4 for more details.) Digital credentials also have the unique possibility to easily collect and visualise each credential's context and relations to other skills and achievements. Beattie [14] argues that by making these connections and context apparent to the user, learning can shift from collecting credentials and thus increasing the "height" of the credential collection towards increased understanding and amplification if the "depth" of knowledge. Beattie [14] also sees it as an essential means of the learners' motivation, based on experience in role-playing games design. Elkordy also reports increasing motivation in [15]. Buchem in [16] gives an example where the depth of a credential is codified by three levels: *basic*, meaning "what everyone needs to know", *expertise*, meaning "what you not only know but also can do" and *master*, meaning "what only a few people know and can do."

4) Data Sovereignty: The ease of copying of digital data allows for the storage of digital credentials physically far from the users, e.g., in the cloud. However, this also means that the actual data then is outside the physical oversight of the user. The term "data sovereignty" [17] has been coined in recent years to describe "the idea that users, being citizens or companies, have control over their data" [18]. Improved data sovereignty for the user is also at the base of recent legislative developments like the General Data Protection Regulation (GDPR) of the European Union [19]. According GDPR, data subjects have the rights:

TABLE I. PROPOSED RESEARCH QUESTIONS TO EVALUATE THE PERFORMANCE OF A DIGITAL EDUCATION CREDENTIAL MANAGEMENT SYSTEM IN SOLVING THE CHALLENGES EXPERIENCED BY THE USER.

Challenge	Question	Units
Fraud protection and verification	How is the system protected against fraud?	qualitative
	What are the costs of a successful attack against the fraud protection?	time, money
Issuer dependence	What are the requirements for an issuer of digital credentials?	qualitative
	How much does issuing a credential cost?	time, money
Handling	Describe the workflow of a credential in the system.	qualitative
	How much does handling of a credential in the workflow cost?	time, money
Data security	How is the credential stored in the system?	qualitative
	Is the credential data format public and open?	yes/no
	How many independent copies of the credential are stored in the system at any time?	number
	How is the credential secured against accidental loss or data change?	qualitative
	How is the credential secured against unauthorised, but intentional, loss or change of data?	qualitative
Digitisation of existing credentials	How can existing analogue credentials be included into the digital workflow?	qualitative
	Is the content of the analogue credential converted to structured data to the same level of detail as digital credentials?	yes/no
Interaction between analogue and digital workflows	How can the system interact at the same time with digital and analogue credentials	qualitative
	How much increases the effort in the workflow, if digital and analogue credentials are mixed?	time, money
Private data protection	How is the private data stored in the system protected against unauthorised access?	qualitative
	What are the costs of a successful attack against the private data protection?	time, money
Data management	How is the data managed from the user perspective?	qualitative
	Can the user tell at any time of the workflow, what data exactly he/she is working with?	yes/no
	Can the user tell at any time of the workflow, who is able to access the data in question?	yes/no
Data sovereignty	How is data sovereignty enforced in the system?	qualitative
	Can the holder of the credential decide at any time of the workflow, who is able to access the data in question?	yes/no
	How much does it cost the user to store the data under his/her exclusive physical access?	time, money
	What are the costs of a successful attack against the access protection (access, denial of service, data change)?	time, money
	If there are other possibilities of storage, how convenient are they to the user?	time money
	What are the costs of a successful attack against these other storage possibilities (access, denial of service, data change)?	time, money

1) Obtain information about the processing of personal data;
2) Access to their personal data;
3) Potentially collect incorrect and incomplete personal data;
4) Request that personal data be erased when it is no longer needed or if processing it is unlawful;
5) Receive personal data in a machine-readable format and send it to another controller ("data portability"); and
6) Request that decisions based on automated processing are made by natural persons, not only by computers.

Education credentials certainly are personal data in the sense of GDPR. To provide the previously mentioned rights 1–4 to the holder of the credential, a management system must be able to provide access to the credential on request, and to remove or replace credentials if required. Credentials need to be available in portable formats (right 5), and the processes where the credentials are used to make decisions must be transparent (right 6).

III. PROPOSED RESEARCH QUESTIONS

In this section, we collect the questions whose answers will be utilised to validate the effectiveness of a system devised to achieve the challenges presented in the previous Section II. Each given topic translates into a set of questions. We start each topic with a question asking for a qualitative description of how the proposed solution approaches a relevant challenge. Then, we go into detail by adding quantitative questions that will enable us to measure the effect that the proposed solution has on each challenge in a given use case. Lastly, a digital credential solution is compared to the status quo of non-digital workflows using this mixed qualitative and quantitative approach. Table I presents our research questions; they are grouped according to the challenges presented in Section II. The challenge *data security* affects both digital and paper-based credentials in very similar ways, so we were able to combine all relevant questions into one field.

IV. USE CASE

The EU Horizon 2020 research and innovation action QualiChain "targets the creation, piloting and evaluation of a decentralised platform for storing, sharing and verifying education and employment qualifications and focuses on the assessment of the potential of blockchain technology, algorithmic techniques and computational intelligence for disrupting the domain of public education, as well as its interfaces with private education, the labour market, public sector administrative procedures and the wider socio-economic developments."[20] The fundamental idea of the project is to build an open source based distributed platform, supporting the storage, sharing and verification of education credentials. This platform will allow for the implementation of additional services, which will fulfil the needs of the participating actors, such as data analytics and decision support systems. QualiChain hosts five pilot projects distributed over Europe (for details please see [21]), where the system is tested in four real-world scenarios:

- Lifelong learning;
- Smart curriculum design;
- Staffing the public sector; and
- Providing HR consultancy and competency management services.

We provided online questionnaires to support the participants in the pilots in the definition of the use cases, challenges and possible research questions, as well as to define key performance indicators. These questionnaires were filled in and discussed with the people involved in the pilots in early 2019. The process is discussed in detail in [8] and not repeated here for the sake of brevity.

V. Related Work

In this section, we present relevant related work, segregated into literature that looks at the impact of digital education credentials, open badges infrastructure, and examples of transformation from analogue to digital credentials.

A. *Impact of Digital Education Credentials*

The articles in the collection edited by Ifenthaler et al. [22] offer a deep introduction into the topic of digital badges and micro-credentials. Digital badges are a special form of education credentials, usually following the open badges standard [23], that are often meant to be displayed prominently by their owner. Ellis et al. [24] write "Traditional badges are often graphic representations of what it is that the badge represents. For example, a scout merit badge has a symbolic graphic of what the topic of the badge is." Digital badges follow this tradition by incorporating images that represent the achievements certified by the badge. Micro-credentials are credentials that certify only a small and easy to define achievement of the learner—thus the name micro.

In [25], Willis et al. remark that open digital badges can bring transparency into awarding of credentials in education and raise question about the roles of instructors, badge providers and learning management systems. They note that digital credentials empower individual learners to "to take control of determining how their learning experiences can be validated and shared." They assume easy scaling for digital credentials, but also warn of issues of trust, confidence, excessive data collection, data protection and ethics. In [24], Ellis et al. also press the point that digital badges will face the risk of loosing their value in the education system if no commonly accepted way can be found to audit and evaluate them. Coleman et al. describe in [26] design principles for digital badges. They argue that creativity please an important role in learning and can be supported in badge design and badge management. They propose to use the principles of *transmedia story telling* [27], a "Curated Learning Journey", to create an experience for the learner that allows the learner to "participate in the learning process in an organic way."

Lockley et al.[28] note that "badges can be agnostic as to the education provider. They enable digital credentials to be issued outside higher education providers"; thus, removing the dependence on the traditional issuers of education credentials. They also note that micro-credentials allow learners more flexibility in their education process. More flexible and shorter education pathways empower education processes and provide a unique opportunity not supported in traditional certification methods. Lockley et al. [28] devise credential badges as "*lingua franca* for learners, educators and employers"; Willis et al. [25] refer to badges as "a currency to demonstrate marketable skills and abilities, at least in theory." Grant in [29] shares the point of view of badges being a currency in credential markets and the reputation economy.

Gander in [30] is proposing to evaluate the implicit and explicit promises and expectations of digital credentials, concentrating on micro-credentials. He notes that explicit promises are rarely expressed, while the implicit promises are that micro-credentials will meet the following properties:

- Follow established standards of evidence for skills and knowledge achievements;
- Are related to other digital micro-credentials;
- Offer authentication of experience;
- Promise individualisation highlighting each individual's developmental history, special interests, and talents;
- Enable longevity of the digital information; and
- Facilitate use and continued availability.

Gander further suggests to capture as much data as possible about these implicit expectations in the application of micro-credentials. As a result, the analysis of their impact is conducted by comparing the evaluation in regular intervals over time. The article also presents a case study of an institute situated in the US, which created a series of 17 micro-credentials and reports the start of the data collection. Aberdour in [31] argues that a transformation of workplace learning is necessary for organisations to stay agile, resilient, and effective. A digital badge program is shown as a way to establish a learning culture in a work place.

The main point of focus in the literature cited so far, is on the social impact of digital credentials and their effect on the transformation of the education system in itself. Though, we think that this is an important field of research, in our work, we decided to not go down this route. Instead, we look at the management of education credentials, ignoring the changes it may have on the education system itself. We note, however, that there is an overlap because of fundamental properties of digital badges, that drive these reported changes in education. This is especially true for the possibility to issue digital (micro-) credentials without being an official recognised learning institute, i.e., what we describe as the issuer dependence of credentials.

B. *Open Badges Infrastructure*

Dimitrijević et al. [32] present a framework of scenarios to define requirements for Open Badges platforms. The scenarios with the extracted requirements are:

- *Offering badges*: Education provider must be able to issue digital badges, i.e., creation of badges and badges templates, use of badge metadata, documentation, alignment to existing learning standards and publication of badges.
- *Badge discovery*: Learners must be able to search and find chances for badges, i.e., search for badge opportunities, review and comparison, selection of a badge opportunity.
- *Applying for badges*: Learners must be able to request badges, i.e., registration for badge chances, application for badges.
- *Awarding badges*: The process of awarding badges contains multiple requirements. They include the support

for **i)** automated assessment of an achievement and self-assessment; **ii)** multiple assessors and peer assessors; **iii)** evidence of achievements; **iv)** automated and manual badge awarding; and **v)** digital signing of badges, information of badge applicant of decision, and issuing of badges.

- *Management of and reflection over collected badges*: Learners must be able to collect and manage their badges, i.e., collection of badges, import of badges, organisation of badges, overview dashboards, and visualisation of badges and data.
- *Displaying and sharing badges*: display tailoring, tailoring of social media posts and display, support for personal badge stores, support for web display, and permissions management.
- (*Re*)*viewing a badge earner's achievements*: Other people than the learner must also be able to consume and review badges, e.g., a recruiter. Functional requirements are: User-based search, badge-based search, (re)view of the overall badge earner's experience, (re)view of individual badges, and evidence validation.

Based on these use cases and requirements, Dimitrijević et al. [32] then evaluate selected badging platforms, namely *BadgeList*, *BadgeOS*, *Credly*, *ForAllRubrics*, *Open Badge Factory + Open Badge*, *Passport* and *Peer 2 Peer University (P2PU)*. They report in their article that all inspected platforms cover the most basic functional requirements. The requirements of the detailed scenarios however are much less likely to be fulfilled. Few platforms fulfil all requirements of the "Offering badges" scenario. Half of the platforms support searching for opportunities from the "Badge discovery" scenario, but none of them allow comparisons of the opportunities. Regarding "Applying for badges", all platforms allow learners to support evidence by various means for the application. Also, the basic functional requirements of the "Awarding badges" scenario are in general well supported, but requirements related to assessment are rarely fulfilled. The authors also report that they were not able to verify the claim that is was possible to digitally sign badges on the platforms. All platforms, however, allowed the users to manage their badges gained at the same platforms, while few allowed to import badges from other places. The "Displaying and sharing" scenario in general was found to be well supported, while the "Reviewing achievements" scenario presented a mixed picture: all platforms were found to provide an overview of the achievements of the learner, but very few also allowed user-based or badge-based searches. For our investigation we followed the same basic approach as presented by Dimitrijević et al. [32], i.e., to define the relevant scenarios and then derive the functional requirements for it. This method is a very natural way to approach an evaluation. It also allows for including users in the field in the analysis, as the given scenarios translate directly into their use cases, requirements and experiences.

On a side note, in [16], Buchem presents design patterns that can be useful in the design a digital credential management solution. In the "Digital badges as parts of a digital portfolio" pattern, he describes the use of a grid system that describes the necessary skill sets for certain topics, activities and levels, resembling an easy to understand board game.

C. Examples of Transformation From Analogue to Digital Education Credentials

In [33], Glover describes the case of the Sheffield Business School at Sheffield Hallam University. They switched from paper based education credentials to digital Open Badges in 2014 for a selected program for students wishing to represent their peers in discussions with teaching staff and university management. An anonymous survey was then executed to capture the participating students' impressions of the badges in comparison to the previous paper certificates. Glover selected the following hypotheses:

- *H1*: Students see badges as a way to differentiate themselves from peers.
- *H2*: Badges motivate some students to complete existing or undertake additional work.
- *H3*: Students want badges that represent all aspects of their studies, including both formal and semi-formal learning.

Out of 89 students participating in the programme, 46 responded in the survey. The results confirmed H1 and H3, but not H2. It is interesting to note for the transformation to digital credentials, that participants reported overall positive or neutral reactions by their peers when sharing the digital badge and all sharing students stated that they might or would share the digital badges again. Glover also writes that "Several respondents explicitly contrasted the digital badges with an equivalent paper certificate, asserting that, as the certificate is a tangible artefact and is a widely recognised method of representing experience and learning, it would carry much more credibility than a digital badge. However, despite their scepticism around the value of digital badges, most of the respondents qualified these remarks with statements such as '... unless they are recognised by employers ...', suggesting that the utility of digital badges is directly linked to their wider acceptance." Glover, therefore, recommends that the concept of badges and their purpose is to be clearly explained, in order to maximise the perceived value of badges. He also remarks that the open nature of digital badges means that they can be created and issued by anyone, and for any purpose. He assumes that this creates a credibility problem for digital badges and recommends that organisations should implement quality control over the creation and issuing of badges to ensure that badges represent standardised levels of achievement, similar to processes already in place for academic programmes at education providers such as universities.

VI. Conclusion and Future Work

In this article, we discussed the main challenges in education credential management. We showed that the transformation from analogue to digital in education credentials had not received intense attention from the scientific community. Based on the available literature and information collected from participants in the EU QualiChain project pilots, we developed a methodology to qualitatively and quantitatively measure a system's effectiveness in addressing education credential management's challenges and the transformation from paper-based credentials to digital credentials. We will apply this methodology to the use cases of the Horizon 2020 EU Project QualiChain, which covers a wide area of applications of education credentials. Applying this methodology will allow us an in-depth evaluation of the project's performance.

Based on the experience gathered in this process, we plan to extend this work in the future to a full framework for the evaluation of the performance of education credential management solutions. This framework should capture the whole life cycle of education credentials from creation and issue over storage, management, and access control, towards credential expiring or retraction. We expect that this novel framework will provide transparency in the way how education credentials are managed, as well as the possibility to tracking down all the decisions done during the whole life cycle.

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Digitalization and Evolving IT Sourcing Strategies in the German Automotive Industry

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Abstract – **Digitalization and major changes in core business products and processes are now sweeping through the global automotive industry, and many automotive companies are confronted with the challenge of formulating and implementing a company-wide digital transformation strategy. Digitalization is associated with significant and extremely rapid change, and, in some cases, even the replacement of established business models. This transformation is part of what is often termed Industry 4.0 and, in large companies, where the provision of information technology (IT) has hitherto been outsourced, the introduction of these new technologies may be the catalyst for a major re-think of IT sourcing strategy. This may entail bringing previously outsourced activities back in-house – a process known as backsourcing - to regain ownership and control, in order to be more flexible and respond more effectively to rapidly changing demands. This study reviews the extant literature on the motivation for backsourcing, and then examines the potential impact of digitalization on IT sourcing in the German automotive industry. A conceptual framework for subsequent research is put forward, using a knowledge-based view of the firm. In addition, following initial feedback from an online survey, an initial model for analyzing change in IT sourcing strategy is proposed. The model is being developed through more in-depth interviews to provide operational guidance for IT management and strategists in the German automotive industry.**

Keywords – IT sourcing strategy; backsourcing; digitalization; digital transformation; German automotive industry; conceptual framework; operational model.

I. Introduction

The backsourcing process in the German automotive industry has been the focus of recent research [1], as companies continually assess their IT sourcing strategy in the light of the implications of digitalization and other industry trends [2]. Over the past two decades, many different forms of IT outsourcing have emerged, all associated with expectations that the company can better concentrate on its core business, focus on innovation, reduce costs and increase the effectiveness of IT services [3]. Now, however, this assumption is being challenged in the German automotive industry, as changes in the external technology environment - digitalization and new automation technologies – are demanding a reassessment of IT sourcing options.

When IT outsourcing agreements expire, or the activity is reviewed, the decision has to be made as to whether to continue the agreement, to switch to another vendor, or to bring management and control of the hitherto outsourced activity back in-house – thereby backsourcing the IT provision [4] [5]. The German automotive industry is the most affected of all industries by digitalization in the German economy [6], and the aim of this paper is to assess current understanding of IT backsourcing and determine what impact digitalization may have in the German automotive industry regarding current and future IT sourcing strategies. The study explores a relatively unknown field, and will contribute to both research and practice, providing new knowledge for researchers and operational guidance for practitioners.

This article has six sections. Following this Introduction, Section II looks at the main concepts under study, briefly discusses relevant background issues and sets out three main research questions. Section III then outlines the research methodology, which is based on a systematic literature review, but which is now being complemented by an online survey and interview analysis with industry experts. Section IV analyses the existing literature to address the three research questions and makes an initial attempt to establish a conceptual framework and provisional operational model. Section V then reports on the preliminary findings from the online survey. Finally, Section VI provides a summary of the ground covered in the paper and makes some concluding comments on the significance of evolving IT sourcing strategies in an industry sector undergoing unprecedented change.

II. Background and Research Questions

The term sourcing is a generic term that combines several different sub-concepts, models or strategies besides the two fundamental directions of insourcing and outsourcing. Theoretical and empirical studies to explain insourcing and outsourcing decisions also refer to the terminology of vertical integration. Vertical integration is generally defined as the degree to which a firm intends to source services externally or carry out the activity in-house. This leads to make-or-buy decisions which reflect the strategic intent and purposeful design of in-house service competencies and depth [7] [8]. A large body of research provides an overview of what can be the subject of a make-or-buy decision and the criteria that should be taken into account (Figure 1).

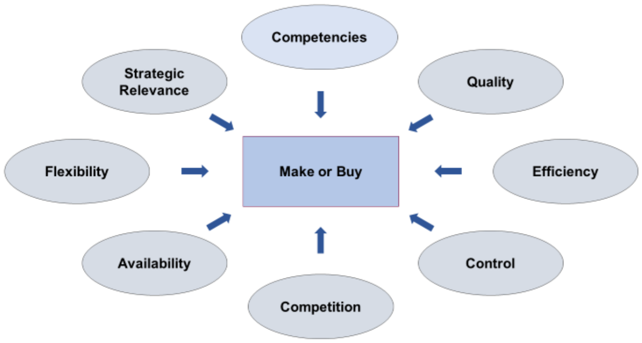

Figure 1. IT sourcing and criteria for make-or-buy decisions

Many different forms of IT outsourcing have emerged in recent decades, which can be combined in many ways and lead to a high degree of complexity, there being many possible dimensions to the outsourcing process (Figure 2).

Whilst backsourcing involves *bringing* previously outsourced activities back in-house, insourcing is sometimes used as a general term for *performing* activities in-house. Terms, such as backshoring, reshoring, onshoring or relocating, are sometimes used synonymously with backsourcing. However, Nujen et al. [9] underlined that these terms imply a change in location, and backsourcing is the only term that indicates a change in ownership. A distinction can also be made between total and selective sourcing. Lacity and Hirschheim [10] defined total outsourcing as being when more than 80% of IT budgets are outsourced to an external provider. Similarly, total insourcing occurs when more than 80% of the IT budget remains within the company. Finally, selective sourcing suggests an allocation of between 20% and 80% of the IT budget to a particular sourcing strategy, and selective outsourcing has been the most popular and the most successful outsourcing strategy [11]. This study applies the same definitions to backsourcing, which may involve just a single IT service - such as a datacenter or a bundle of applications - or complete backsourcing, where a company rebuilds the previously outsourced IT organization.

There is some overlap in the literature between the terms “digitization”, “digitalization” and “digital transformation”. Digitization is a more technical interpretation and refers to the conversion of information from an analog to a digital storage medium [12]. It also equates to the transfer of tasks to the computer, which were previously performed by humans. Thus, digitization also refers to a special form of automation. The focus is on digital technologies, for which the acronym “SMACIT” (social, mobile, analytics, cloud, and Internet of Things) is sometimes used [13]. This has been widened by some authors to encompass Big Data, artificial intelligence, digital twin, 3-D-Printing, augmented and virtual reality, and

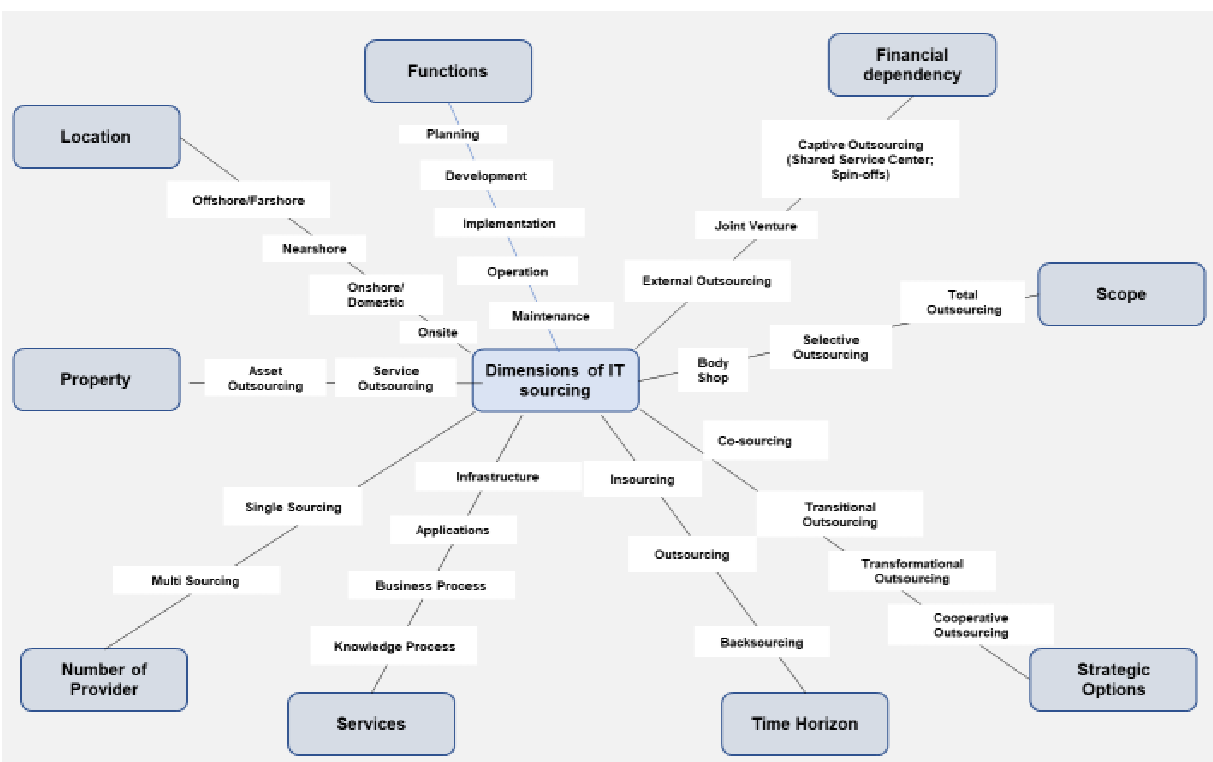

Figure 2. The potential dimensions of IT sourcing. Based on Krcmar [7] and Von Jouanne-Diedrich, Zarnekow and Brenner [8].

robotics. Many of the technologies mentioned are not new or revolutionary on their own. Rather, their innovative potential stems from their significantly enhanced efficiencies, their intensive networking possibilities and their increasingly widespread use [14].

The term digitalization is more broadly defined and is intended to express the fact that digitalization now affects all economic and social areas [12]. Riedl et al. [15] define digitalization as "the process of introducing digital technologies, which essentially deal with changes caused by information technologies". Koch, Ahlemann and Urbach [16] define four conditions for this. First, the technologies used do not have to be new - rather the newness is created in the context of business and value creation models. Second, digitalization is data-driven, and is based on an increased generation, processing and analysis of often new types of data. Third, digitalization means that the character of the value added or the business model changes significantly as a result. Fourth, there needs to be an association with a clear strategic dimension, as companies expect competitive advantages from it.

Digital transformation is a result of digitalization and refers to how the deployment of digital technologies can lead to new, disruptive business and value creation models [17]. For Singh and Hess [18], this requires a company-wide digital transformation strategy to guide a company through the transformation process. However, there is no uniform definition of this term to date. Vial [19] reviewed 282 digital transformation related academic publications and found 23 different definitions. Based on the existing definitions, he developed a conceptual definition of digital transformation as "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies" [19].

Industry 4.0 can be viewed as part of digitalization, encompassing the entry of complex digital technologies and architectures into manufacturing processes. A generally accepted definition has not yet been established in the literature, but the definition of Roth [20] is used in the context of this research. "Industry 4.0 comprises the networking of all human and machine actors along the entire value chain as well as the digitalization and real-time evaluation of all relevant information with the aim of making processes and value creation more transparent and efficient in order to optimize customer benefits with intelligent processes and services." Industry 4.0 is also sometimes called the "fourth industrial revolution" or Industrial Internet of Things (IIoT), where the focus is on the strong integration of Internet-based information and communication technology (cyber-physical systems) into industrial processes [20].

Industry 4.0 has its roots in the concept of the Smart Factory and this is viewed as the starting point and main purpose of Industry 4.0 [21]. People, machines and products to be manufactured are connected in a network. The aim of this network is to achieve the overall optimization of quality, lead-time and utilization of resources. It is considered a decisive innovation that all data are available in real time, providing a permanently up-to-date, virtual image of reality, which allows complex manufacturing processes to be better controlled [21]. The Smart Factory represents an adaptable system in which flexible production lines automatically adjust their processes to different types of products and changing conditions [22].

In recent years, digitalization has become one of the most important topics in social, scientific and economic life [12]. Digital technologies are regarded as major technical changes or breakthroughs and the associated digital transformation is seen as a driver for significant and extremely rapid change, in some cases even leading to the replacement of established business models [23]. The term "transformation" reflects the variety and complexity of the measures that may need to be taken when companies are confronted with these new and disruptive technologies [18]. Some companies may see this as requiring a company-wide digital transformation strategy, which can encompass all business areas as well as products, processes and organizational structures.

If pre-existing IT strategy is aligned with the business, IT can be seen as an enabler for digital transformation [24]. Companies may review their IT sourcing strategies and governance models and consider alternatives for existing outsourcing arrangements [25]. This in turn may lead to a move towards IT backsourcing. Many companies have already established innovation labs, digital factories or technology accelerators in recent years, in order to keep up with the increased demands of digitalization [26]. Volkswagen, for example, strengthened its IT department with 1,000 new IT employees from various disciplines [27]. At Daimler, too, there are signs of a part move away from the IT sourcing strategy that has been pursued for years, aimed at increasing its own contribution to IT from 25% to 35% [28].

The significance of digitalization as a factor in the backsourcing of IT provisions has received little attention in the scientific literature so far. In contrast to insourcing and outsourcing, IT backsourcing generally lacks scientific studies [29]. The literature that does exist deals mainly with the reasons and decision-making processes for IT backsourcing in relation to contract problems that have led to failure [30]. Internal or external organizational changes are only explained using individual examples of high profile / large-scale events, which have received press attention but cannot support generalization [31].

The German automotive industry consists of the Original Equipment Manufacturers (OEMs) and a three-tier supplier network. The industry is facing serious external organizational changes, which are leading to four megatrends in the automotive industry: Connectivity, Autonomous Driving, Shared & Services, Electric [32], for which the acronym C.A.S.E. is often used.

Each of the C.A.S.E. elements has the power to radically change the industry and undermine existing business models. The challenge is to combine them in a way that delivers a comprehensive and seamless package to the customer. Digitalization and Industry 4.0, and the associated connection of the physical with the digital world, as well as the networking of the entire value chain, are the drivers of this change [33] (Figure 3).

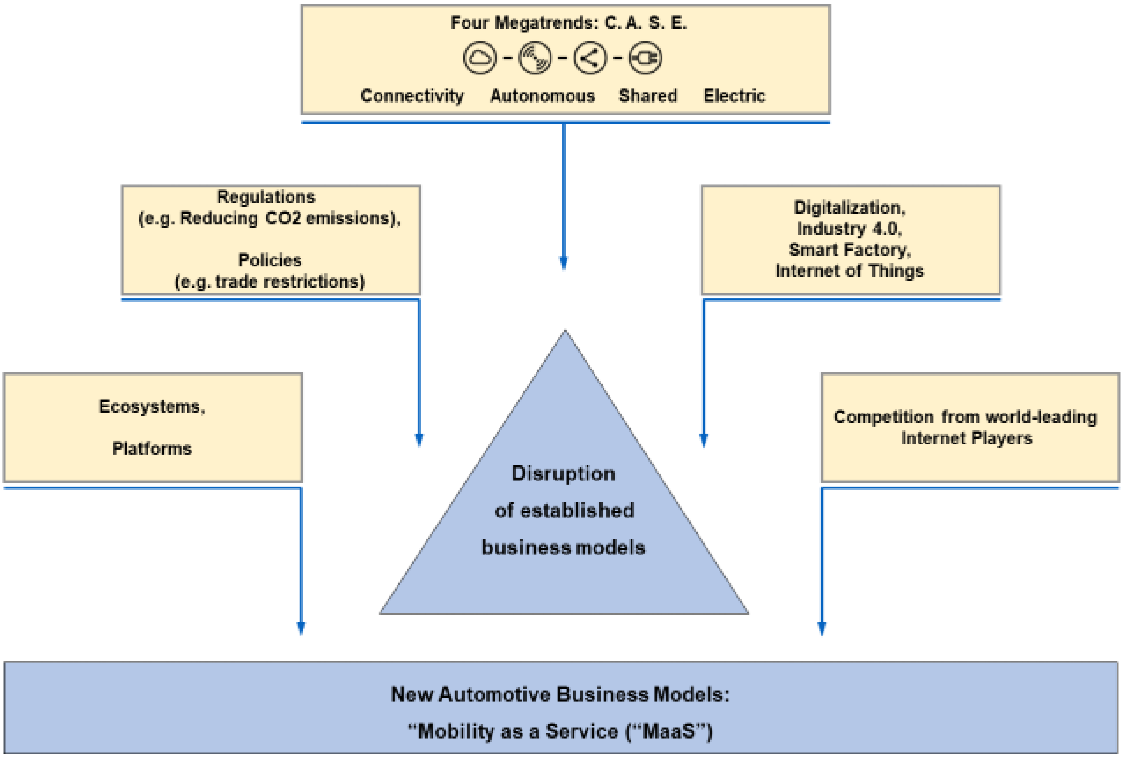

Figure 3. External environmental changes in the German automotive industry. Based on Automobil-Produktion [32] and Daimler Annual Report [33]

Digitalization and digital transformation affect all areas of a company. The aim of the study is to analyze to what extent digitalization has influenced the German automotive industry's move towards IT backsourcing, and provide new insights concerning decision-making relating to overall IT sourcing strategy. The current study addresses three Research Questions (RQs):

RQ 1: What does the extant literature reveal regarding current thinking on the rationale for IT backsourcing?

RQ 2: To what extent has digitalization influenced the German automotive industry's strategy regarding IT backsourcing and what are its potential benefits?

RQ 3: How can an operational model be developed to aid practitioners in the German automotive industry in the reassessment of their IT sourcing strategy?

This article presents initial findings from the study that are now being pursued through in-depth interviews with industry practitioners. In general, current evidence for IT backsourcing, as presented in the existing literature, brings only partial answers to the research questions of this study.

III. Research Methodology

To date, a systematic literature review has been undertaken. The search for existing and relevant literature was carried out in three stages. As the selection of search terms (keywords) has a significant impact on the search results [34], an initial exploratory search was undertaken in April 2019 in order to ascertain key terminologies and concepts used in the literature. A combination of keywords was used in the search string when identifying relevant literature.

A second systematic search was carried out in May 2019 using complex combinations of keywords, and a third search was undertaken in July/August 2019, after reformulating the research questions. Keyword searches were conducted in the Science Direct, IEEExplore, Business Source Complete (EBSCO), AIS Electronic Library and Google Scholar databases, restricting the publication dates to be within the year 2008 and after, because the topic of digitalization was not a current issue before 2008.

A practical screening was performed [35], and after deleting duplications and separating all non-relevant ones, 22 publications were selected. Backward and forward searches based on references and authors were performed to uncover seminal publications on the subject of IT backsourcing [36]. The backward search showed no further results. The forward search resulted in five more articles from Sage journals, SpringerLink, Emerald insight and Researchgate. Of the 27 articles in total, 13 are peer reviewed. Practice-oriented publications such as the frequently published magazines MIT-Technology report, CIO magazine or reports from the Association of German Automobile Manufacturers (VDA) as well as from international IT consulting and supplier organizations were also reviewed.

The research project is now being extended to encompass an online survey and exploratory interviews with senior management in the German automotive industry, and with other industry practitioners and consultants as the primary source for data collection. This will allow interaction with decision-makers in a complex and dynamic situation, taking account of many context-relevant factors that support an assessment of the "situation as a whole". Data collection and analysis is based on the selection of a single case study, taking the German automotive industry as whole as the main unit of analysis and the different companies in this industry as embedded sub-units of analysis. The case study entails a double-phase research design, beginning with an online survey to identify important themes, followed by the main stage of data collection with in-depth semi-structured interviews. The purposive sampling for both the survey and the interviews is representative of the German automotive industry, including IT executives and practitioners from 6 German OEM's and 22 German first-tier suppliers which belong to the Top 100 world-wide automotive supplier of the year 2019. The first responses from the survey and first interviews with industry experts have confirmed the practicability of these methods for data generation. The early results from the survey are reported in section V below.

IV. Findings From the Literature Review

RQ1: What does the current literature reveal regarding current thinking on the rational for IT backsourcing?

The reasons for individual backsourcing decisions are a focus in both the academic and practitioner literature. The practitioner literature highlights cost savings, quality improvements, and increase in control and flexibility as the three most important reasons [37]. The academic literature looks at a broader picture and distinguishes between the three important categories: contract problems, internal organizational changes and external environmental changes, to which individual reasons are assigned [2]. Contract problems emerges as the main reason for backsourcing until now (Table I).

As regards contract problems, one of the main motivators for backsourcing is dissatisfaction with the quality of services provided by the vendor. Moe et al. [38] state a lack of communication between client and vendor, the inability to provide the necessary knowledge and skilled resources, a high turnover of employees on the vendor side and cultural problems such as different understandings of responsiveness and punctuality. Gorla and Lau [39] have analyzed how negative experiences in outsourcing affect future outsourcing decisions. They conclude that competence and coordination problems with the vendor have a stronger influence on backsourcing and future outsourcing decisions than unexpected costs. According to Kotlarsky and Bognar [40] low service quality is typically linked to poor responsiveness or a lack of professionalism on the vendor's side. The relationship between client and vendor, as well as trust, also plays a significant role in either changing vendors or taking backsourcing into account [41]. The gap between expected and actual cost reductions through outsourcing is another important driver for backsourcing. As Kotlarsky and Bognar [40] point out, cost savings through outsourcing tend to be overestimated and hidden costs such as transition costs, rising wages in the outsourcing destination country or staff turnover are not sufficiently taken into account. Another critical factor is losing control over the vendor's activities or over certain functions [8]. This can be risky if security or intellectual capital is involved, or if it turns out that outsourced systems have a strategic value.

Kotlarsky and Bognar [40] stated that a knowledge mismatch is one reason for loss of control if the vendor knows more about the systems than the client does, or the vendor only barely understands the client's business. Another possible reason for backsourcing is when the IT outsourcing company fails to adopt the latest technologies, thereby not delivering best value to the customer [42]. Losing control also leads to limited flexibility for the client compared to in-house operations [43]. Benaroch et al. [44] contend that in times of increased demand uncertainty, there is a tendency among clients towards backsourcing or insourcing decisions, as opposed to vendors' view that these situations would be motivators for outsourcing. They also claim that companies would prefer the flexibility of contracts in increased demand uncertainty, e.g., the possibility to pay a lump sum as a penalty to ease backsourcing. However, without the flexibility built into the original outsourcing contract, the probability of backsourcing is limited.

The most recent studies show, however, that contract problems and the resulting operational difficulties are no longer major drivers of backsourcing. Könning, Westner and Strahringer [31] analyzed over 1,000 sourcing deals in Austria, Switzerland and Germany between 2006 and 2017 and show that the companies are able to manage a large number of IT vendors. They also mention that companies use international sourcing consultancies (e.g., ISG, Accenture, BCG, Deloitte, KPMH, PwC) to design tenders and contracts, support the transition process, the provision of global delivery models and advise on the processes for the constant monitoring of the various vendors and services. A review of the German automotive industry shows that, on the one hand, the depth of service in the in-house provision of IT services is generally between 20% and 30% of the overall IT budget [28], while at the same time companies have employed thousands of IT employees worldwide [45]. These IT organizations have also developed and implemented comprehensive process models to minimize contractual and operational risks in outsourcing [46]. However, Solli-Saether and Gottschalk [47] refer to the Sourcing Circle and the stages-of-growth model to determine whether a formerly in-house function has a higher degree of maturity when it comes back after years of outsourcing. They argue that the outsourcing phase is not a waste of time, "it is not a return to the beginning, but something that has been altered" [47].

The literature on internal organizational factors for IT backsourcing focuses on the discussion of strategic reorientation in the company, the intensive debate about the value of IT and internal power-political behaviour, which are more subjective and therefore more difficult to assess [48]. In this context, the role of IT and the sourcing strategy of IT are repeatedly reassessed. According to Butler [48], the proper alignment between business and IT strategies requires the re-positioning of the IT function from a commodity to a key strategic asset, and this may lead to appropriate backsourcing decisions. He also points out that not all IT functions are core business or non-core business, but the challenge is to categorize IT functions as either commodity or strategic in order to adjust the IT sourcing strategy. Qu, Oh and Pinsonneault [49] also emphasize that companies should make more efforts to assess the strategic value of IT, rather than considering IT as a non-core activity. Benaroch et al. [50] add that strategic considerations play an important role in transaction- and information-intensive processes with volatile demand and that backsourcing increases the capabilities for innovation and competitive advantages.

Thakur-Wernz [51] combined the two theoretical lenses - Transaction Cost Economics (TCE) and Resource Based View (RBV) - and concluded that companies decide backsourcing for two reasons: short-run total costs and internal capabilities. She contradicts earlier research, which assumes that costs and capabilities play a complementary role and are intertwined, especially in the long run. Based on a backsourcing topology, however, Thakur Wernz [51] claims that costs and capabilities are independent of each other, especially in the short-term. The reason for this assumption is that companies would not be in a position to change or expand their capabilities at short notice. She concludes that companies are less likely to undertake backsourcing when the total short-term costs of backsourcing are higher, and more likely to go for backsourcing when internal reintegration capabilities are higher.

Oshri et al. [52] stated that dissatisfaction with an outsourcing agreement is an even stronger driver for backsourcing decisions than cost considerations. They used the behavioral theory as a lens, which is based on realistic assumptions about human cognition and relationships. The theory suggests that decision making in companies is characterized by the limited rationality and organizational politics of decision makers. The assumption is that problem-driven managers tend to make irrational decisions rather than based on a systematic assessment of long-term opportunities and risks. The transition from outsourcing and especially from offshoring to backsourcing means a radical change of strategy with significant economic consequences. Those responsible would do well to first consider a detailed feasibility study.

Qu et al. [49] postulate, from the knowledge-based view, that IT backsourcing would create value and competitive advantage. Best practice processes require the integration of IT and business knowledge and this interaction increases the alignment between IT and business objectives. Shared knowledge and smooth coordination between IT and business is not a commodity, which can be bought on the market. This in-house knowledge only evolves over many years and is part of the corporate culture.

External environmental changes such as economic cycles with volatile demand, financial crises, changes in the structure of the industry that redefine the overall business strategy of the company are identified by some authors as the catalyst for backsourcing [52]-[54]. Regarding mergers and acquisitions, several authors cited the example of how JP Morgan Chase terminated its large-scale outsourcing contracts after the merger with Bank One or Bank of Scotland merged with or Halifax Building Society because the mergers gave rise to new internal capabilities to provide in-house IT services more effectively. In addition, changes on the vendor side are triggers for backsourcing, when the vendor redefines its business strategies or its organizational structure, which is often the result of mergers and acquisitions between vendors. German companies have been affected by the wave of concentration on the vendor side, which can also be assumed as a reason for backsourcing.

TABLE I. SUMMARY OF REASONS FOR IT BACKSOURCING BASED ON LITERATURE REVIEW

Contract Problems: Outsourcing agreement did not meet expectations
• Higher than expected costs • Poor service quality • Poor transition planning • Loss of control over the core business • Loss of flexibility • No benefits from outsourcing • Disagreement with vendor • Loss of know-how • Incompetence of the vendor (e.g., missing innovations on the vendor side hinders the client's business success)
Internal Organizational Changes
• New or changed executive management • Structural changes in the company (e.g., new business line, new corporate entity) • New business strategies • Recognition of IT as business enabler • New/changed importance of outsourced activities • Changes in IT strategy due to mergers and acquisitions • Power and politics
External Environmental Changes
• Changes in the environment of the company • Economic cycles • Bandwagon effect • Changes in vendor organization • Technology changes ("break-through" technologies)

Thakur-Wernz [51] refers to the bandwagon effect mentioned by Lacity and Hirschheim [10]. Outsourcing was widespread, many companies did it and therefore more companies followed suit. There was significant increased risk that the outsourcing decision was not adequately researched and assessed, and backsourcing is the correction of outsourcing failures. Ironically, the bandwagon effect could now also happen with backsourcing. Finally, and most significantly for this study, Wong [43] and Von Bary [55] state that new and disruptive technologies, lead to a repositioning of the value of IT and trigger backsourcing decisions.

RQ2: To what extent has digitalization influenced the German automotive industry's strategy regarding IT backsourcing and what are its potential benefits?

Germany is the second largest outsourcing market in the western world [56] but is under-represented in the academic literature, although online sources provide evidence of a number of failures in large outsourcing deals in German industry. In addition, digital technologies are regarded as major technological changes, and the associated digital transformation is seen as potentially leading in some cases to the replacement of established business models. The German automotive industry as a manufacturing industry and the most important German industrial sector is particularly affected by these changes. New digital business models are becoming the starting point for the future competitiveness of the German automotive industry on the world market [57]. According to Veltri et al. [2] and others, external environmental changes are seen as motivators for IT backsourcing because the core competencies of a company need to be redefined. These dependencies and effects have not yet been specifically investigated by researchers using the example of an entire industry in Germany.

Researchers have applied various theories, such as TCE, RBV or Knowledge-Based View (KBV), to explain and demonstrate the benefits of IT backsourcing. However, there is some debate as to whether these theories are useful in evaluating IT backsourcing decisions, and in providing practical guidance. According to Wernerfelt [58] and Barney [59], the RBV considers an organization from the inside and the central thesis of the RBV is that companies generate sustainable competitive advantage by introducing strategies that exploit their internal strengths. However, in the KBV concept, it is argued that competitive advantages are achieved not only on the basis of physical or financial resources, but also through knowledge-based capabilities [60]. Teece, Pisano and Shuen [61] published the theory of Dynamic Capabilities (DC) in 1997, which extends the internal view to the market and defined the DC as "the firm’s ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments” (p. 516).

According to Teece, Pisano and Shuen [61] markets can be divided into moderate and highly dynamic markets. Moderate dynamic markets are characterized by continuous changes. These are relatively easy to predict. Moderate markets are transparent and stable. Resources, organizations and processes are generally based on existing skills, knowledge and abilities. Highly dynamic markets, on the other hand, are characterized by rapid changes, have unstable structures and the resources of a company are based less on existing skills than on situation-specific knowledge, skills and abilities that can be quickly developed and newly created. The static approach of the RBV is not suitable for this field of operation [62]. The RBV would only apply to firms in predictable environments.

Since the German automotive industry is in a highly dynamic market because of the digital transformation, the theories applied to answer the question of whether IT backsourcing contributes to a sustainable competitive advantage or not should be extended to include the DC approach. A review of the existing literature shows that there is no analysis and evaluation with the DC theory on IT backsourcing.

Previous research on IT backsourcing has concerned IT technology and IT systems in general. In the context of the strategic alignment between business and IT, there is a need to examine which outsourced IT functions, technologies or applications are brought back in-house, particularly against the background of digital transformation, in order to achieve sustainable competitive advantage. There is clearly a link to the core production process as many manufacturing companies have outsourced parts of their production, especially to offshore locations such as China. It is to be expected that digitalization and Industry 4.0 will lead to backsourcing of production to some extent [63]. The new technologies provide opportunities for production to be more flexibly and cost-effectively re-located in the home country for two reasons: firstly, because the cost advantages that originally resulted in offshoring can be neutralized, and secondly, the application of Industry 4.0 technologies can then increase flexibility in the production process. This would also have implications on outsourced IT services for manufacturing processes. Backsourcing does not necessarily mean that the affected functions and capacities are locally returned to the headquarters of the mother organization. The German automotive industry has worldwide access to resources and know-how and has the opportunity to network resources and knowledge with modern forms of agile cooperation [27].

RQ3: How can an operational model be developed to aid practitioners in the German automotive industry in the reassessment of their IT sourcing strategy?

The existing literature partly shows in individual case studies the challenges of knowledge transfer during outsourcing, and provides overviews of the requirements for knowledge re-integration during backsourcing or switching vendors. An overall framework that offers guidance to practitioners involved in backsourcing in the German automotive industry is missing.

The proposed conceptual framework (Figure 4) represents the theoretical basis for answering the research questions in this study. It uses the theory of dynamic capabilities to investigate the value of IT backsourcing. The concept of dynamic capabilities can be divided into the ability to identify and shape opportunities and threats, the ability to seize opportunities and the ability to maintain competitiveness by improving, combining, protecting and reconfiguring the assets of the business [64]. Sensing, seizing, reconfiguring and transforming are the main components of dynamic capabilities. This theory is combined with the knowledge-based view of the firm, since it is assumed that digital transformation requires significant change in the knowledge-base of the company to increase its innovative capacity [65]. However, in combining these theoretical perspectives, three main dimensions of change relating to the new digital technologies, the change in processes relating to IT

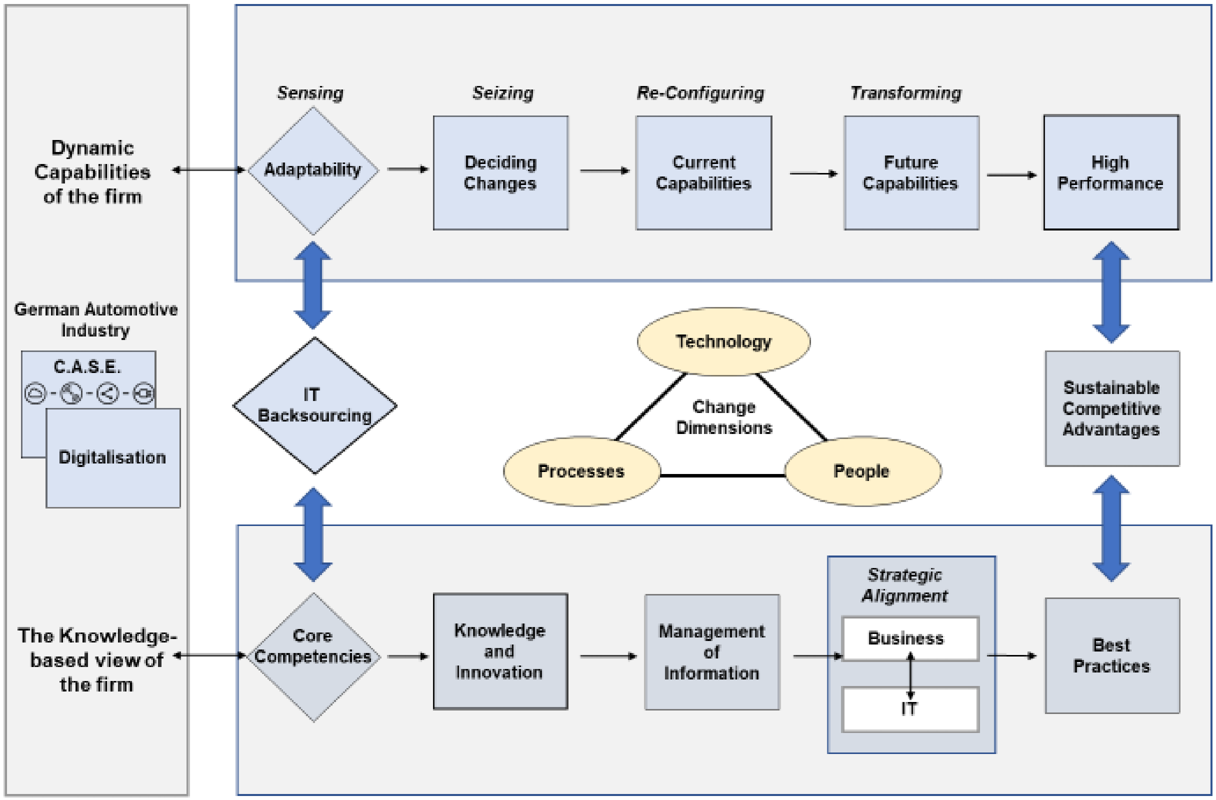

Figure 4. Theoretical conceptual framework

backsourcing, and the necessary enhancement of people skills and capabilities, will be used to identify critical success factors (CSFs) to achieve competitive advantage from the adoption of appropriate IT sourcing strategies. This aligns with other studies of change and innovation relating to the introduction of new technologies into organizations [66]. IT backsourcing may thus be viewed as a strategic decision of a company to respond to the rapidly changing external environment and provide a source of sustainable competitive advantage. This is especially the case when this enables important innovation, increases flexibility to respond very effectively to new business requirements, introduces emerging technologies to achieve new capabilities and facilitates the rapid placement of new digital business models, products or services in the marketplace.

The knowledge-based view has received a great deal of interest in the literature because it recognizes the fundamental economic changes that have resulted from the accumulation and availability of knowledge over the last two decades [67]. The transition from production to service in most developed economies is based on the manipulation of information and not on the use of physical products [68]. Knowledge has become one of the most important assets for creating a sustainable competitive advantage [69], and this trend becomes even more pronounced with digitalization. A central element of digitalization and of Industry 4.0 is the generation of huge amounts of data with cyber-physical systems and the storage and linking with technologies such as Big Data. However, data itself are of little value. The data from many different sources are only transformed into valuable information through comprehensive analysis and correlations. What matters is the management and the intelligent exploitation of this information to evolve new business models and processes.

The conceptual framework and underlying philosophy of the study is therefore based on the authors' belief that the digital transformation of a company is an eminently knowledge-based issue. The theory of the knowledge-based view of the firm assumes that a company exists because it has advantages in the market through the generation of knowledge and innovations [70]. In addition to the dynamic capabilities, in responding to changes in the external environment, knowledge is also a key resource for achieving sustainable competitive advantage.

Based upon the conceptual framework, research findings to date indicate that an operational model (Figure 5) may be of value in supporting practitioners in German automotive companies in adjusting their IT sourcing strategy. Based on the preliminary findings from the first expert interviews, this model involves a three-way classification of sourcing status: insourced, outsourced, or value-added sourced. In this context, backsourcing is viewed as a process that changes the status of all or part of the IT provision from being outsourced to being insourced. Value-added sourcing reflects the fact that

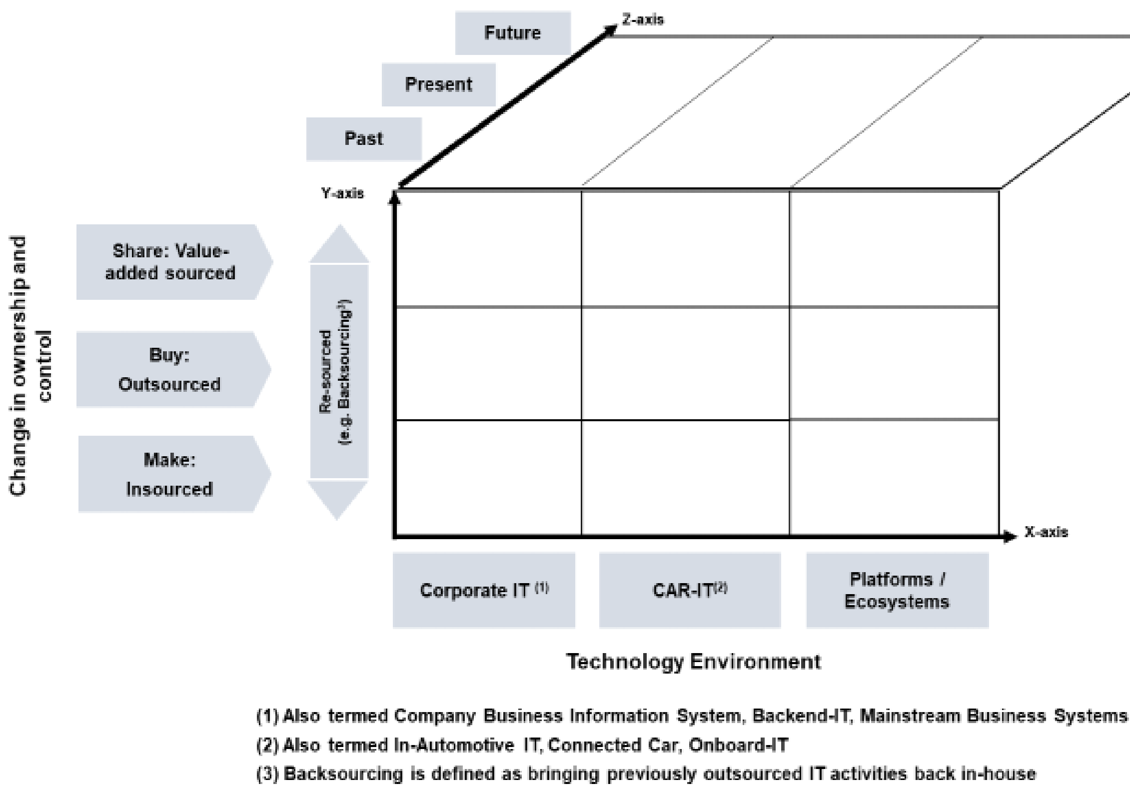

Figure 5. Provisional operational model

the classic make-or-buy decision is now becoming a make-or-buy-or share decision. Joint ventures constitute an alternative to external and internal sourcing of the IT provision to provide mutual benefit from complementary competencies [71].

Significantly, this model encompasses *all* IT technology environments in the automotive industry, including not just standard "Corporate IT" (mainstream business systems), but also "Car-IT" and digital "Platforms and Ecosystems" [72]. These sourcing classifications will be applied and analysed in past, present and future scenarios to understand how and why IT sourcing strategies are evolving. In addition to developing CSFs for the realignment of IT sourcing, the resultant model will provide operational guidance for managing this transition, and be of value to IT and company strategists in the German automotive industry, and in other car manufacturers undergoing parallel changes.

Interview findings will help determine to what extent digitization and the C.A.S.E. trends are encouraging backsourcing and changes in overall IT sourcing strategy. Any such correlations and conclusions will also take account of other influencing entrepreneurial factors. In this context, "digital entrepreneurship" [73] emerges as a significant new competence in making IT sourcing decisions. The impact of digitalization and the complexity of the C.A.S.E. change agenda will require high investment in new competencies and knowledge to develop sustainable competitive advantages in the long term. Digitalization leads to extremely rapid change, in some cases even the replacement of established business models, and the German automotive industry will have to demonstrate appropriate capabilities to change and adapt. The industry must have the dynamic capabilities to react flexibly to the accelerating changes in the external environment the internal capabilities, in terms of resources and knowledge, to drive and support the necessary innovation. This can provide the basis for the development of company-wide digital transformation strategies, encompassing possible re-positioning in the marketplace, reworking of sourcing agreements, and implementation of necessary change in terms of technologies, processes and people competencies.

V. Initial Report on Survey Results

Preliminary results come from the online survey, drawing on the findings from the extant literature discussed above, and incorporating the experience of practitioners from the German automotive industry to identify key issues and trends. The survey comprises twenty-four statements and a five-point Likert scale (ranging from Strongly Agree to Strongly Disagree), statements being clustered into three main areas of IT sourcing related business activity. The first cluster concerns digital transformation strategy, which provides the business and management framework for decision-making and action in the different technology environments. Secondly, there are statements regarding digital entrepreneurship, which provide the culture and mindset for organizational changes. The third cluster of statements focuses on the justification of IT backsourcing and evolving IT sourcing strategies. The initial report on survey results helps develop responses to RQ2 and RQ3. RQ1 is, in the main, addressed by the findings from the literature review.

Survey respondents from the German automotive industry confirm that the so-called "megatrends" (C.A.S.E.) and Industry 4.0 have been triggered by the emergence of digital technologies. These technologies are partly considered revolutionary and disruptive and partly only evolutionary. The evolutionary perception is more prevalent among companies that have had the financial resources to constantly invest in state-of-the-art IT technologies. The companies surveyed also indicate that a digital transformation strategy has been developed, but that its execution requires more than the traditionally existing IT strengths of the companies. There is a generally agreed view that, amongst the digital technologies, artificial intelligence combined with self-learning algorithms are gaining industrial relevance and constitute an increasingly significant competitive factor. The survey also indicates that the shortage of skilled experts has been the biggest hurdle for digitalization and has led to a "battle for talent".

The survey results also emphasize that the deployment of digital technologies must be supported by digital entrepreneurship. Some companies argue that digitalization is not necessarily a new phenomenon, but rather an organizational challenge alongside the mainstream economic and strategic questions. Digital entrepreneurship requires investment in cultural change, enabling the company to be more agile, more experimental, risk-taking to an acceptable degree, supportive of continuous learning, and adaptive and tolerant of new forms of collaboration. This provides a sound basis to generate value from technology. Additionally, the advent of digital technologies and associated transformation strategies is leading to a significant redefinition of core competencies in IT that where lost in the past due to the high degree of outsourcing. There is consensus that a clear strategic goal is to have the key IT capabilities and related resources for digital technology deployment in-house in the long run. Thus, IT sourcing management must take on new roles and competencies as changes in the sourcing strategy are driven by the search for highly specialized talent and the closing of digital skill gaps. Digital technologies have made IT sourcing a much more complex and multi-layered process. Significantly, companies claim that IT sourcing strategies are a proven source of sustained competitive advantage, but they also report a lack of validation to prove success.

The majority of respondents took the view that the introduction of digital technologies leads to a higher degree of vertical integration and thus an increased provision of IT services in-house. Digitalization encourages bringing IT services back in-house in order to strengthen core competencies, become more agile and respond more effectively to rapidly changing demands. However, these first survey results show different perceptions about further outsourcing. There is some agreement that due to the trend towards standardization of IT infrastructure components and services, an almost complete outsourcing of IT infrastructure services is expected in the future. This is in line with the agreement that cloud sourcing will become the digital backbone for standardized infrastructure. The responses partly underline a trend that further outsourcing of commodities (e.g., infrastructure) will create flexibility to focus resources on strategically important technology areas, such as software engineering. This initial analysis of survey responses has highlighted a number of key perspectives, which will be developed and tested through the further collection and analysis of data within the case study.

VI. Conclusions and Future Work

Many companies in the automotive sector are currently under pressure to review their IT sourcing strategies to reflect the anticipated implications of digital transformation, industry 4.0 and the megatrends that are sweeping through the industry - changes in Connectivity, Autonomous Driving, Shared and Electric. This is part cause/part effect of the moves towards sustainability in the automotive industry and in society in general [74]. In this context, the literature review indicated that there are three main motivations for IT backsourcing - unsolvable contractual problems, internal organizational changes and external environmental changes, and digitalization is a significant component of the last-named category. Digitalization has the potential for new, disruptive business and value models, and requires companies to shape their digital transformation process, within which an evolving IT sourcing strategy will play a significant part.

Future work will use the conceptual framework and provisional operational model to identify critical success factors and key actions for the successful adoption of new IT sourcing strategies. IT backsourcing will undoubtedly play its part, arguably creating better conditions for the interaction between IT and business, and for sharing and integrating IT and business knowledge, which can underpin the adoption of best practice [49]. The protection of mission-critical knowledge, intellectual property and security issues are taking on a new significance in the context of digitalization and supplier partnerships involved in value-added sourcing.

The contribution of this research to theory has several aspects. First, it will provide an informed view on whether digitalization is encouraging IT backsourcing – currently a gap in the extant literature. Second, it will explore and explain how companies in the German automotive industry justify decisions for IT backsourcing within the framework of a company-wide digital transformation strategy. This will allow key issues regarding IT backsourcing to surface - for example, the need to develop dynamic capabilities and redefine core competencies in order to achieve sustainable competitive advantages in the so-called digital age. Research results will also establish the methods used by companies to forge a strategic link between digitalization and IT backsourcing and to determine the resulting value.

In terms of contribution to practice, the project aims to provide decision makers in the German automotive industry with operational guidance to assess the different options for IT sourcing as part of a digital transformation strategy. The study will provide illustrative examples of the practices, procedures and organizational change needed for new IT sourcing strategies. It will provide an insight into how the German automotive industry is being forced to fundamentally reinvent itself to survive. The traditional core competencies of the industry revolve around car-production, and the industry is still heavily invested (including labour) in end-of-life business models, technologies and products. Value is generated exclusively through physical materiality. In the future, software will account for a large share of automotive value creation. Car manufacturers will need to develop their own operating systems for networking their vehicles. Additionally, the world-leading internet platform players are currently all pushing into the automotive and mobility area for new data-driven business models. As an alternative to pure insourcing and outsourcing, the industry needs gap-closing sourcing concepts with IT tech players, such as alliances, where mission critical resources and competencies are shared in a partnership. Thus, especially for Car IT and the creation of shared platforms and ecosystems, the traditional make-or-buy will become a make-or-buy-or-share decision for IT sourcing. The operational model developed through this research will support automotive industry practitioners in developing new strategies to navigate this rapidly evolving technology and business landscape.

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Identifying Functional Requirements for the Design of Business Rules Management Solutions

A Functional Architecture for the Elicitation, Design and Specification of Business Decisions and Business Logic

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***Abstract*—Functional architectures are created to be used as a standard by their respective industry. Organizations use reference functional architectures to guide their development or as a means to become compliant. However, a reference functional architecture to manage business decisions and business logic does not yet exist. One research field that focuses on the management of business decisions and business logic is Business Rules Management (BRM). In this paper, we re-address and - present our earlier work** [1] **that focuses on the construction of a functional architecture that other organizations could utilize to design BRM solutions. Yet, we extended our previous research with more detailed discussion of the related literature, running cases, and results, which provides a grounded basis from which further research on functional architectures for the design of BRM solutions can be conducted. To do so, we utilized three thematic coding rounds to analyze 536 functional requirements for BRM solutions, resulting in 18 functional categories and mapped the functional categories to the BRM capabilities. The results form a first basis for the construction of a reference functional architecture for BRM capabilities, also identifying multiple directions for future research.**

Keywords-Business Rules Management; Functional Architecture; Functional Requirements.

I. INTRODUCTION

Decisions are amongst the most important assets of an organization [2], and business decisions and business logic are an important part of an organization's daily activities. Therefore, the performance of an organization depends on the ability to manage its business decisions and business logic [3].

To structure the process of managing business decisions and business logic, Business Rules Management (BRM) could be utilized. BRM comprises a systematic and controlled approach to support the elicitation, design, specification, verification, validation, deployment, execution, governance, and monitoring of business decisions and business logic [4]–[7], see Fig. 1.

Considering the BRM research domain, a predominant focus towards technically-oriented research can be identified. For example, Nelson et al. [8] state: "*studies provide beginnings of a business rules research program, but collectively the research often overlooks major steps in BRM and fails to focus on business rules specific challenges and the larger context that rules play in organizations.*" Moreover, Kovacic [9] argues about the current research directions in the BRM research field, stating: "*With so much emphasis towards the technological aspects, we can lose sight of the management of information systems considerations.*"

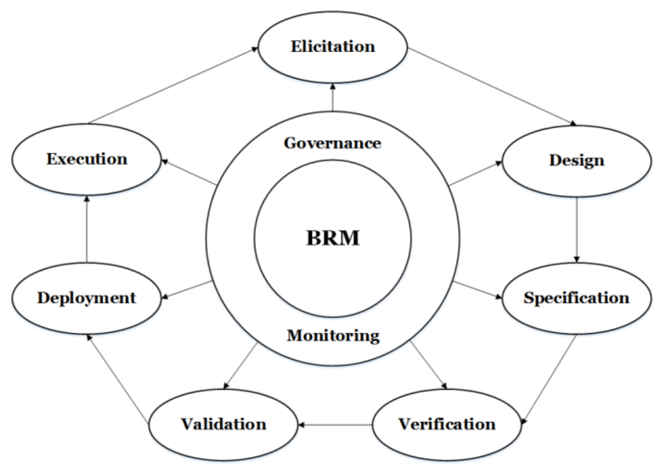

Figure 1. BRM capability overview [4]–[7].

Therefore, we identify that there is an imbalance when comparing technical-oriented research to the management of information systems and BRM artefacts used in BRM processes. In addition, in the work of Arnott and Pervan [10] featuring a thorough literature review, a conclusion is drawn stating that the field has lost its connection with industry some time ago and research input with practical relevance is scarce. Arnott and Pervan revisited the knowledge base in 2014 and concluded that a transition is taking place towards a more practical-oriented approach, whilst a strong connection between theory and practice is still lacking [11], which is also concluded in the work of Zoet [12]. Therefore, research conducted in the area of BRM should also ground practical usability, while taking into account the theory as part of the existing academic knowledge base on BRM.

In this study, we revisit an extended version of our dataset containing functional requirements from seven large Dutch governmental institutions intending to derive a functional architecture that other organizations could utilize to design BRM solutions. In an earlier study [13] we identified that some research has been conducted on BRM-related functional architectures. For example, Schlosser, Baghi, Otto and Oesterle [6] propose three architectural perspectives that could guide organizations designing BRM solutions, however, do so at a high-level of abstraction. Our previous study, in which we analyzed a set of 750 BRM-related functional requirements, resulted in a functional framework in which we identified several themes per BRM capability [13]. This study seeks to extend the understanding of functional requirements, in the context of BRM, by exploring the required functionalities for Business Rules Management Systems (BRMSs). This paper focuses on the first three BRM capabilities, being elicitation, design, and specification. The goal of this research is to derive a functional architecture focused on the Elicitation, Design, and Specification capabilities that organizations could utilize to design BRM solutions. To do so, we aim to answer the following research question: “Which functional requirement categories should be taken into account when designing a BRM functional architecture for the elicitation, design and specification capabilities?”

The remainder of this paper is structured as follows: In Section II, we provide insights into the elicitation, design and specification BRM capabilities, as well as the value of functional architectures in the domain of BRM. In Section III, the research method that was utilized to collect and analyze the data required to construct the functional architectures is described.

In Section IV, the manner in which the data is collected, as well as analyzed is presented. In Section V, the functional architectures are presented and elaborated in the results section. In Section VI, we discuss the conclusions of our research and provide discussion about our research method and results. Section VII presents possible directions for future research.

II. BACKGROUND AND RELATED WORK

Organizations are increasingly looking for ways to automate products and services. Doing so, organizations need to ensure that these products and services take into account all legal sources that influence the organization doing business, i.e., law, regulations, internal policies or international conventions [14]. To do so, business decisions and underlying business logic are implemented. Business decisions and business logic are an important part of an organization’s daily activities. A business decision is defined as: “A conclusion that a business arrives at through business logic and which the business is interested in managing” [15]. Moreover, business logic is defined as: “a collection of business rules, business decision tables, or executable analytic models to make individual business decisions” [16]. A business rule is [14] “a statement that defines or constrains some aspect of the business intending to assert business structure or to control the behavior of the business.” In theory and practice, business decisions and business logic comprise several different concepts, such as derivation structures, decision tables, business vocabularies, fact type models and rule requirements [17], [18]. However, as our focus in this paper is not to define these different concepts that are utilized in a variety of ways by organizations, we adhere to these concepts as artifacts in a general sense. Smit, Zoet, and Berkhout [19] created a metamodel depicting these concepts, as shown in Fig. 2.

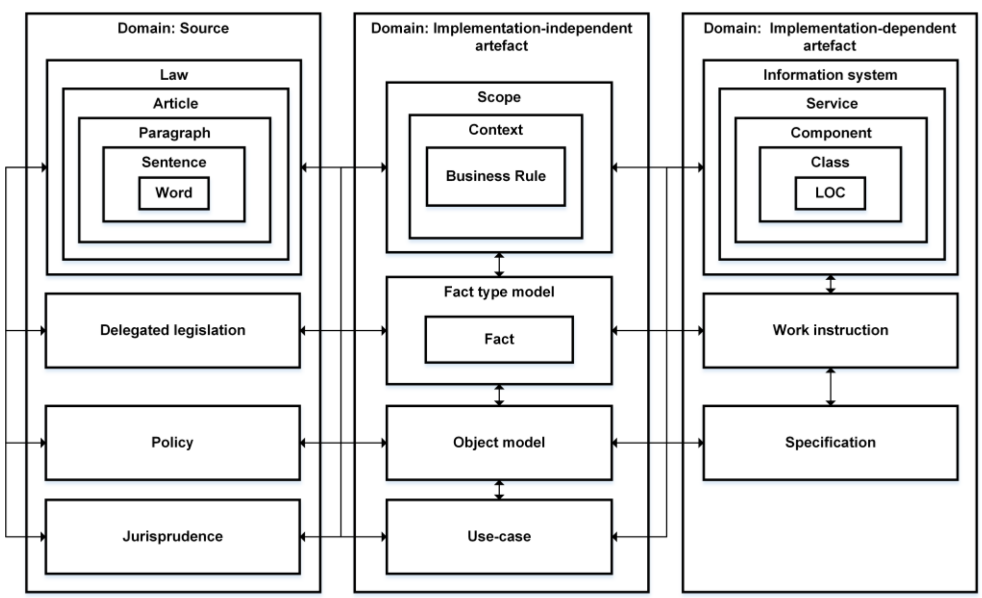

Figure 2. Metamodel of a business decision with underlying business decisions and business logic [19]

Example artefacts (i.e., sources, contexts and business rules) used to define and implement business decisions and business logic are depicted in Fig. 3.

See, for a detailed description of each of the concepts to design, specify, and execute business decisions and business logic, the work of Smit and Zoet [18]. When individual artefacts are affected in the functional category, the artefact is specified with a label, e.g., '*derivation structure*'. However, when it concerns the collection of all artefacts, the general term 'artefact' is used in this paper.

The previous section already mentioned the specific focus of this study on the elicitation, design and specification BRM capabilities. Based on the definition of [16], a capability is defined as: "*An ability that an organization, person, or system, possesses.*" A detailed explanation of each capability can be found in [7], [18]. However, to ground our research, a summary of the elicitation, design, specification, verification, deployment, execution, governance and monitoring capabilities is provided here.

The purpose of the elicitation capability is twofold. First, the purpose is to determine the knowledge that needs to be captured from various legal sources to realize the value proposition of the business rules [20]. Different types of legal sources from which knowledge can be derived are, for example, laws, regulations, policies, internal documentation, guidance documents, parliament documents, official disclosures, implementation instructions, and experts. Depending on the type of knowledge source(s), for example, documentation versus experts, different methods, processes, techniques and tools to extract the knowledge are applied [21]. The second purpose is to conduct an impact analysis is if a business rule architecture is already in place. When all relevant knowledge is captured, the business decisions need to be designed in the design capability. The purpose of the design capability is to establish a business rules architecture, which contains the business decisions and how the business decisions are derived to deliver the value proposition [17]. After the business rule architecture is designed, the contents of the business decisions need to be specified in the specification capability. The purpose of the specification capability is to write the business logic and create the fact types needed to define or constrain some particular aspect of the business. After the business logic is created, it is verified and validated in the verification and validation capabilities, respectively.

The capabilities described are implemented by organizations in different ways. One common approach is to implement information systems that are tailored to one or a combination of the elicitation, design and specification capabilities. Such information systems are often referred to as Business Rules Management Systems (BRMS) [20], [21]. Looking at the architecture of Information systems, decomposition can be achieved by the creation of several different architectural views or perspectives, i.e., technical, functional, information, data, process, components, service or classes [22]. Analysis of the BRM body of knowledge shows that the functional perspective, also referred to as the functional architecture, has received little attention [6], [8], [9] compared to the technical perspectives. The functional architecture perspective is equally important compared to the other perspectives as it guides, especially business stakeholders, with the exact functionality an information system offers to execute a capability. Developing a functional architecture for BRM capabilities is therefore also in line with the lack of research in the BRM domain that is practically oriented [10]–[12]. In this paper we adhere to the following definition of a functional architecture: a functional architecture comprises a modular decomposition of the functionality of an information system [23].

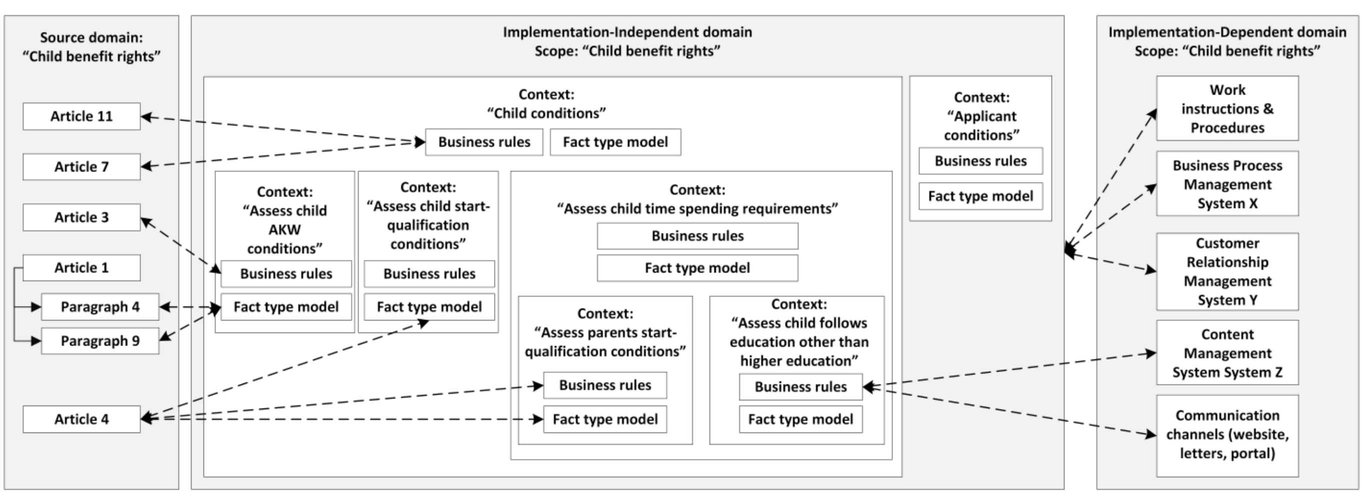

Figure 3. Example of a business decision with underlying business decisions and business logic

Functional Architecture of software products, which comprises: a modular decomposition of the product functionality; a simple notation for easy comprehension by non-specialists; and applicability in any line of business, offering a uniform method for modeling the functionalities of software products [23]. Functional architecture perspectives are, for example, utilized in practice by integrating them in standard operating models [23], [24]. Examples of such models are the eTOM business process framework [25], the Insurance Application Architecture (IAA) [26] and the Banking Industry Architecture Network (BIAN) [27]. Functional architectures for BRM can be established using both inductive, as well as deductive reasoning. The current body of knowledge does not contain detailed contributions to help the construction of a functional architecture for the BRM capabilities. Therefore, the approach in this paper follows an inductive approach to construct a BRM functional architecture from the BRM-related requirements that are collected. In this paper, we solely focus on functional requirements with regards to BRM systems as a functional requirement emphasizes what is required, and not how. This is in line with the notion of a capability, which also focuses on what (value) an organization can deliver, but not how the value is delivered. The functional requirements are often created by subject-matter experts, which are also the stakeholders and end-users of the BRMS that is being designed or developed. This strengthens the validity of the resulting functional architecture.

In literature and practice, several methods exist to formulate functional requirements, i.e., personas, wireframing, use cases, mockups, and user stories [28]. User stories are increasingly being adopted and are comprehensible by, i.e., both developers and customers and support participatory design by all stakeholders as they are all able to design the behavior of the system. In addition to user stories, the agile community [29] also utilize epics and themes. An epic is a large user story while a theme is a collection of user stories. Making use of user stories enables empirical-focused design by enabling the designers to make decisions by studying prospective users in typical situations [29]. The organizations analyzed all defined their functional requirements employing user stories. Therefore, in our study, the unit of analysis is a user story.

III. RESEARCH METHOD

This research aims at creating a functional architecture containing the BRM capabilities: Elicitation, Design, and Specification. Therefore, qualitative research is selected as our research methodology. Case study research is chosen as the most suitable strategy for this research.

By selecting case study research, the researchers were able to gather functional requirements for the BRM capabilities Elicitation, Design, and Specification in the Dutch public sector. Our study utilizes a holistic case study approach, more on this in the work of Yin [30]. This case study approach features one context, BRM solutions requirements phase, and four cases containing in this context. The BRM solution-related set of functional requirements of the participating organizations is set as the unit of analysis. The data collection consisted of secondary data, which is a form of third-degree data collection. According to [31], when data, such as requirements are studied, third-degree data collection is the best fit. The coding of the functional architecture consists of three rounds of coding according to Strauss and Corbin's process of open coding, axial coding, and selective coding [32].

IV. DATA COLLECTION AND ANALYSIS

The data collection for this study occurred for eleven months, between November 2016 and September 2017. The selection of the participants is based on the group of individuals, organizations, information technology, or community which best represents the studied phenomenon [32]. Related to this study, the studied phenomenon is represented by organizations, and individuals within these organizations, which deal with the selection of BRM solution-related requirements. Organizations dealing with these BRM solution-related requirements are often financial and government institutions because of the large-transaction, knowledge-intensive, digital products and services they deliver. Therefore, several Dutch executive governmental agencies were invited to provide requirements for this study. Executive governmental agencies are responsible for the execution of a variety of services like the screening of immigrants, handling student loans, tax returns etc. thereby serving approximately 17 million citizens and organizations in the Netherlands. The participating governmental agencies are comparable in terms of business processes. The participating seven governmental agencies requested that their data is handled anonymously. Therefore, from this moment on, the organizations are labelled as A, B, C, D, E, F, and G, as shown in Table I. The participating organizations were invited to gather and send all their BRM solutions-related requirement documentation to the researchers by filling in a form and sending it via e-mail. Organization G did not submit any functional requirements specific to elicitation, design, and specification capabilities. The requirements Organization G submitted where all non-functional requirements. Each organization defined their BRM solution-related requirements with a team existing of an enterprise architect, business rules architect, business rules analyst, legal or policy expert. Additional support was provided by a procurement officer, BRM project manager, business consultant, IT architect and external advisors.

Based on the data received, the researchers analysed and structured the functional requirements. The data analysis consisted of three rounds of thematic coding, according to Strauss and Corbin's process of 1) open coding, 2) axial coding, and 3) selective coding [32]. During the coding rounds, two researchers coded separately from each other thereby increasing the inter-reliability in the coding [33].

TABLE I. EXAMPLES OF CODED FUNCTIONAL REQUIREMENTS

ID	Role	Feature	Outcome	Organization	Organization reference	Category
5	Rule Analyst	I want an overview of all relevant sources	So that I can scope the project	A	5.3	Create Overview
13	Rule Analyst	I want to be able to include a source in the analysis environment	So that the source is in the system ready for analysis	B	PR13_UR_A_1	Import Sources
70	Technical Operations employee	I want to be able to make use of uniform options when drawing up the control elements	So that I can work uniformly	C	BLIKZT-1871	Change control
100	unknown	I want to be able to model graphically	So I can draft DRDs	D	1	Define Artefacts
328	Administrator	I want to be able to adjust the weekdays, holidays and periods that are excluded	unknown	E	BR1-W3	Define Artefacts
68	unknown	I want derivation rules to be hierarchically arranged in structures.	unknown	F	23(.1)	Filter Artefacts

The first round of coding is the open coding round. The open coding round identifies the functional requirements from the secondary data together with the meta-data of the functional requirements. To ensure optimal analysis the researchers numbered each requirement with a unique ID. Additionally, for each requirement the responsible role (i.e., manager or business rule analyst) was added, the feature (what does the owner or role wants with the functionality), the feature outcome (the benefit of the functionality), organization and an organization ID (to ensure the traceability of the functional requirement towards the case organization documents). During this round of coding, two situations occurred: 1) The functional requirements could be documented explicitly by registering the organization name and organization ID, as shown in Table I) the functional requirements were stated implicitly as nested requirements or plain text.

The second round of coding is the axial coding round. Axial coding refines and differentiates concepts that are already available and code them into categories [34]. The axial coding round was utilized to structure the functional requirements over the BRM capabilities Elicitation, Design and Specification proposed by [6], [17]. Therefore, the coding scheme in this round is as follows: Elicitation, Design, and Specification. For example, the first two requirements in Table I are coded into the Elicitation capability.

The third and thereby last round of coding is selective coding. The purpose of the selective coding round is the identification of functional categories [34]. This round of coding is focused on the identification of categories within the set of functional requirements distributed over the BRM capabilities in the axial coding round. Our earlier work on functional requirement themes for BRM capabilities is also taken into account in this coding round, which resulted in eleven functional themes [13]. These were (Elicitation) 1) Import Sources, 2) Annotate Sources, 3) Generate Overviews, 4) Perform Impact-Analysis, (Design) 5) Create Business Decisions, 6) Create Relationships, 7) Create Overviews, 8) Reuse Business Decisions, (Specification) 9) Define Business Logic, 10) Add Meta-Data, and 11) Create Relationships. These themes could influence the functional architecture that is being constructed in this paper.

Additionally, the coded categories in the three capabilities are checked for possible overlap. An example of this is the category ‘’impact analysis’’ which exists in the Elicitation, Design, and Specification capability.

V. RESULTS

In this section, the results of our data collection and analysis are presented and elaborated. Per coding round, as described in the previous section, descriptive results are provided. This is followed by the presentation of the functional architecture and the elaboration of the functional categories it comprises.

For the construction of the functional architecture, to the knowledge of the authors, no explicit practices or specific guidelines exist. However, to theoretically ground the construction of the functional architecture, several definitions are analyzed that comprise one or multiple characteristics that compose a functional architecture. This leads us to the following criteria [22], [34], [35]: 1) a functional architecture represents a high-level view of the major functions from a usage perspective, 2) a functional architecture specifies the interactions of functions internally between each other and externally with other products, 3) the functionalities presented represent arrangements of requirements, 4) the functional architecture should be expressed in easy to understand diagrams, 5) the functional architecture should be constructed with the input of relevant stakeholders, such as product managers, architects, and managers.

The open coding resulted in the registration of 536 functional requirements, originating from seven organizations, see Table II.

Subsequently, the second round of coding consisted of assigning the functional requirements to either the elicitation, design or specification BRM capability as described in the previous section. The results of this process are presented in Table II. In the second coding round, no differences were identified between both researchers.

The third round of coding resulted in the identification of 18 functional requirement categories, see Fig. 4. For each functional requirement category, we report on its number, functionality and possible overlap with functionality categories as part of the other BRM capabilities.

TABLE II. BREAKDOWN OF FUNCTIONAL REQUIREMENTS PER BRM CAPABILITY

Organization/ Capability	**Elicitation**		**Design**		**Specification**		**Total**
A	0	0.0%	8	1.6%	122	22.7%	130
B	1	0.1%	4	0.8%	47	8.7%	52
C	12	2.2%	52	9.7%	62	11.5%	126
D	20	3.7%	25	4.6%	22	4.2%	67
E	42	7.8%	14	2.7%	67	12.5%	123
F	1	0.1%	7	1.4%	30	5.7%	38
G	0	0%	0	0%	0	0%	0

Fig 4. shows some functional requirement categories without any business logic (decision, context, business rule, fact type, fact value, or derivation structure), this is because these categories simply do not include any business logic. In the third coding round, 14 differences were identified in the coding and were resolved by the third researcher. Lastly, to better understand the artefacts described in this section, we refer to Section II in this paper, as well as the work of Smit and Zoet [7].

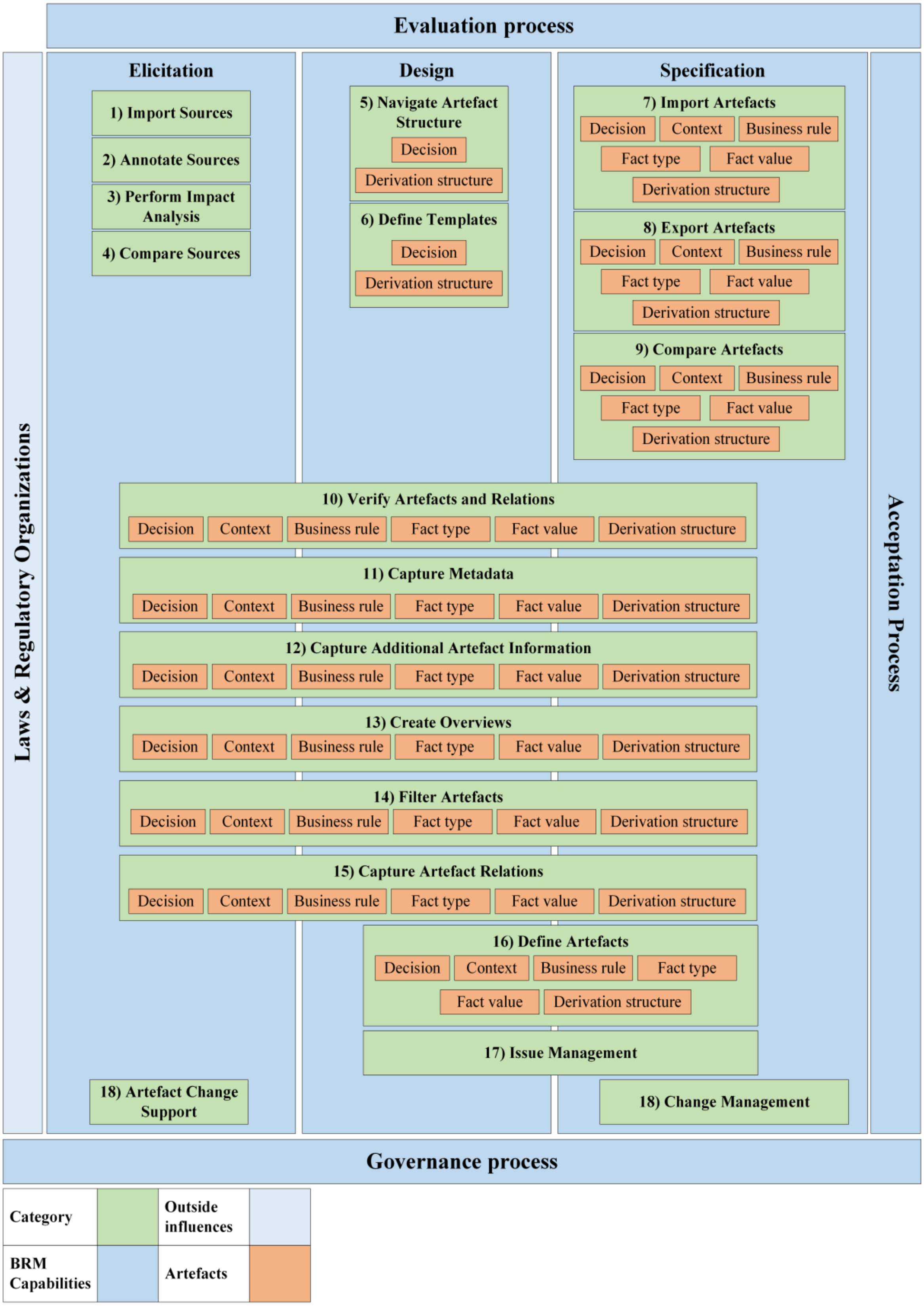

Figure 4. BRM Functional Architecture for the Elicitation, Design and Specification capabilities

A. Elicitation

With regards to the elicitation capability, four functional categories were identified: 1) Import Sources, 2) Annotate Sources, 3) Perform Impact Analysis, and 4) Compare Sources, as shown in Fig. 4.

1) Import Sources - The knowledge needed to create business decisions and business logic is elicitated from a variety of different sources, i.e., laws, regulations, policies, internal documentation, guidance documents, parliament documents, implementation instructions, and official disclosures [13].

This functionality encompasses the import of a source, which must be supported in both manual and automated style. As these sources come in different formats or type of documents, the functionality should support as many as possible extensions that can be imported, i.e., MS Office document types, PDF, XML, other open-source word processors, or HTML. Also, in some source types, tables and figures or other representations are important to take into account. Therefore, functional support for importing media as part of sources is deemed important.

Examples of BRM solution-related requirements which led to the coding of the category *Import Sources* were: *"I want to be able to include a source in the analysis environment"* and *"I want to read data from ISO Standards"*

2) Annotate Sources – Concerns the manual annotation of sources used to create business decisions and business logic, i.e., derivation structures, terms, or roles. As organizations all differ significantly from each other in terms of what concepts to annotate in sources, i.e., fact types, sentences or sections, functional support to ensure organizations can modify the concepts to annotate should be taken into account. This also includes the support for definition and use of templates for analysts to use during the annotation process.

Examples of BRM solution-related requirements which led to the coding of the category *Annotate Sources* were:*"* I *want to be able to annotate a part of the source that is relevant to be elaborated in the rule base"* and *"I want to indicate, per annotated part of the source, why it is relevant or not"*

3) Compare Sources – Encompasses the functional support to compare two or more sources. This is required by analysts that are tasked to review the changes to legal sources that affect the already implemented business decisions and business logic. Comparison of sources must be supported in an automated way in which the machine recognizes and labels Create, Update, and Delete modification types. Similar to the import source functionality, functional support for multiple document types is essential as these documents need to be compared exactly as published by their source. Functional support for automatic comparison of sources enables the reduction of human error and could boost efficiency because of the decrease in manual comparison.

Examples of BRM solution-related requirements which led to the coding of the category *Compare Sources* were: *"I want to be able to compare two different versions of the same source"* and *"I want to be able to do the comparison of two different versions of the same source automatically"*

4) Perform Impact Analysis – Allows the user to determine the impact of modified sources with regards to already implemented business decisions and business logic. This functionality should enable the selection of artefacts to review its dependencies with other artefacts, which, on the one hand, encompasses the support for manual impact analysis. On the other hand, functional support for an automatic impact assessment that enables a user to input scenario variables to calculate the impact should be present as well. Automatic impact assessment is regarded as it allows for higher efficiency and less human error. The results of an impact analysis are often used for communication with stakeholders and to determine a course of action. Therefore, there must be functional support for exporting (part of) the impact assessment results in the format and with the variables that the organization requires.

Examples of BRM solution-related requirements which led to the coding of the category *Perform Impact Analysis* were: *"I want to be able to generate an impact report"* and *"I want to be able to merge the result of the impact analysis with regard to a term change with output of earlier executed impact analysis tasks"*

B. Design

With regards to the design capability, two functional categories were identified: 5) Navigate Artefact Structure and 6) Define templates, as shown in Fig. 4.

5) Navigate Artefact Structure – The roles responsible for creating or modifying business decisions and business logic need to be able to search and navigate efficiently and effectively to be able to do so. This could be achieved in several ways, depending on the requirements of the organizations, however, the navigation should support the selection of all possible artefacts to view during navigation through business decisions and business logic. While doing so, maintaining a proper level of abstraction is important, modifying the level of abstraction by minimizing or maximizing artefacts is deemed important. Lastly, functional support to navigate by selecting an artefact type or the relationship between artefacts should be taken into account as well.

Examples of BRM solution-related requirements which led to the coding of the category *Navigate Artefact Structure* were: *"I want the system to support me in navigating through the decision model using a drill-down functionality from the top layer, decisions, down to the bottom layer, base data and sources"* and *"I want every node in the decision model to have the ability to access information about all of the rulebase components related to that node."*

6) Define templates – To promote consistency when structuring artefacts, organizations must be able to define and manage templates. Utilization of templates ensures that artefacts are structured consistently. Templates can be required by the machine that is responsible for executing the templates, being business decisions and underlying business logic. Organizations must be able to modify templates to match their context, on top of being able to use standard templates (usually included by the vendor of the software).

An example of a BRM solution-related requirement which led to the coding of the category *Define templates* were: *"I want to be able to adjust the preconfigured structure of business rules, so that we can improve the adoption of the structure as well as ensure that it complies with our organization-defined rule structure."*

C. Specification

With regards to the specification capability, three functional categories were identified: 7) Import Artefact, 8) Export Artefact, and 9) Compare Artefacts, as shown in Fig. 4.

7) Import Artefact – Similar to the import of sources, import of artefacts is useful as it enables roles to efficiently create or modify artefacts without having to manually insert one of many variables required to do so. Because organizations organize their elicitation and design capabilities different, either supported by information systems or by using word processors, this category requires functional support for different formats or type of documents, see also functional category one. Additionally, when importing artefacts, a role must be able to select what artefacts, type of artefacts and relationships to import. According to the data, a translation of annotation and artefacts between the elicitation and specification capabilities may be required. This means that a role must be able to translate annotations automatically into artefacts utilized in the specification capability. Lastly, because more artefacts are shared nowadays, also between colleague government institutions, import of artefacts from external data sources must be supported.

Examples of BRM solution-related requirements which led to the coding of the category *Import Artefact* were: *"I want to be able to configure the automatic import of business rule artefacts using a meta model."* and *"I want to be able to re-import adaptations and / or additions that have been made in the analysis environment, while keeping existing connections."*

8) Export Artefact – At some point during or after the specification of business decisions and business logic, a user must be able to export artefacts, which can have several reasons. Usually, this is for either the testing/acceptation, communication or documentation of the business decisions and underlying business logic. Each reason requires different file formats, thus the user must be able to select the type of document that must be exported. Additionally, the representation of the contents in the export is an important factor, depending on the reason for the export. A user must be able to select the representational notation in which the contents are presented in the exported document, i.e., decision tables [36], structured English (controlled natural language) [37] or The Decision Model (model-based) [17]. Similar to importing artefacts, a user must be able to modify whether all artefacts within a given scope or a selection of artefacts or artefact types are exported.

Examples of BRM solution-related requirements which led to the coding of the category *Export Artefact* were: *"I want to be able to indicate which part of the Applicable Rules* [type of rules this particular organization utilizes] *I want to export."* and *"I want to be able to export applicable rules* [via a platform that is developed by this organization,which serves multiple other applications in the organization by providing the possibility to send artefacts across]*."*

9) Compare Artefacts – The comparison of artefacts is different from the comparison of sources as it focuses on artefacts that are internally created, modified or implemented. Comparison of artefacts must be supported in an automated way in which the machine recognizes and labels Create, Update, and Delete modification types. While comparing artefacts, presentation of meta-data of the artefacts is important, as well as it allows for quick identification and reduces human error.

Examples of BRM solution-related requirements which led to the coding of the category *Compare Artefacts* were: *"I want an automated analysis of differences between artefact versions"* and *"I want the difference analysis to include at least the version number, the date and time when a change was made on the version, and who made the change on the version."*

D. Overlapping functional categories

Regarding any functional categories that coverall three capabilities, six functional categories were identified: 10) Verify Artefact and Relations, 11) Capture Artefact Meta-data, 12) Capture Additional Artefact Information, 13) Create Overviews, 14) Filter Artefacts, and 15) Capture Artefact Relationships, as shown in Fig. 4.

10) Verify Artefact and Relations – During the execution of processes along with the elicitation, design and specification capabilities, a multitude of artefacts are created, updated or deleted. The capability following the specification capability is verification, which ensures all business decisions and underlying business logic is syntactically and semantically correct. However, there is no fixed sequentially of the processes conducted as part of the specification or verification capabilities, mainly because this is dependent on how verification is executed, as well as the tooling that is used. Verification can be performed using four techniques: 1) manual detection, 2) manual preventions, 3) automatic detection, and 4) automatic prevention [38]. The data shows that a user must be able to request verification or an artefact or a relationship between artefacts while using a system, as well as being supported by a system that interrupts a user when a syntax or semantic error is detected. Therefore, functional support for a combination of automatic detection (initiated by a user) and automatic prevention must be taken into account.

Examples of BRM solution-related requirements which led to the coding of the category *Verify Artefact and Relations* were:*" I want the system to support the rule author by only providing the relationship types the rule author may use* [e.g. is only authorized to use] *in the context of that particular artefact."* and *"I want the system, in relations that lead to a rule base outside the scope of the decision, to indicate that it is outside the scope of the decision."*

11) Capture Artefact Meta-data – This functional category focuses on all data captured to support the governance capability, which consists of three sub-capabilities: 1) traceability management, 2) version management, and 3) validity management. More meta-data captured in the elicitation, design and specification capabilities result in more efficient and effective governance during the entire lifecycle of a business decision and its underlying business logic. For example, development status is more efficiently determined when all artefacts under a business decision that is being designed and specified are accompanied by a status and/or version number, which is required for proper version management. For validity management, this means that a user must be able to capture and store variables that represent the validity status of the artefact as provided by the source. For traceability management, this means that a user must be able to capture and store variables that focus on coupling artefacts with each other in a specific format. Additionally, the organization must be able to modify the functionality to capture meta-data as the requirements with regards to governance are different for each organization.

Examples of BRM solution-related requirements which led to the coding of the category *Capture Artefact Meta-data* were: *"I want to add a character of the enforcement object* [which are details regarding the object that should be monitored for enforcement of the applicable rules by organizations responsible for the enforcement of the rules in practice]*"* and *"I want to determine what properties the elements have in the meta-model."*

12) Capture Additional Artefact Information – Additional to capturing meta-data required for the governance capability, the data shows a demand for functional support for capturing additional artefact information that is not required to be able to execute or govern the business decision and underlying business logic. Additional artefact information is required, mainly, due to two reasons. First, it enables more effective communication among stakeholders that are responsible for (parts of) the artefacts being created or modified. Second, it enables communication with end-users or clients actually using the business decision, i.e., a governmental portal in which citizens apply for child benefits. The variables allowed to be additionally captured with regards to an artefact depends on the organization and its context. Examples of additional artefact information that were identified in the data are: explanations, motivation/rationale, notes, design or specification decisions per person or role, help text or appendices. Also, a user must be able to capture additional artefact information in each of the, usually, several abstraction levels, i.e., fact-level, decision logic-level, and decision requirements-level [7].

Examples of BRM solution-related requirements which led to the coding of *Capture Additional Artefact Information* were: *"I want to add a description of the violation"* and *"I want to add a violation class."*

13) Create Overviews – In most organizations large amounts of artefacts are utilized to implement business decisions and underlying business logic. These amounts can pose challenges when searching or reporting certain artefacts, artefact relationships or artefact types. A user must, therefore, be able to create overviews (also referred to as reports) per artefact or other units of analysis. One type of overview that is often identified in the data are meta-data overviews (i.e., generating an overview with all version numbers and validity periods of an artefact), which emphasize that there must be functional support to create overviews for meta-data as well. Additionally, similar to exporting artefacts, a user must be able to select the representational notation in which the contents of the overview are presented. Lastly, depending on the type of modification that has to be processed regarding an implemented business decision and its underlying business logic, users must be able to find and replace efficiently within such overviews.

Examples of BRM solution-related requirements which led to the coding of the category *Create Overviews* were: *"I want the defined rule to be shown in formal language"* and *"I want the defined rule to be shown as a reference."*

14) Filter Artefacts – Additional to searching certain artefacts, artefact relationships or artefact types, our data shows that filtering and sorting functionality is deemed important. Additionally, filtering or sorting is not only required for certain artefacts, artefact relationships or artefact types, but meta-data as well.

Examples of BRM solution-related requirements which led to the coding of the category *Filter Artefacts* were: *"I want norms to be arranged hierarchically in structures."* and *"I want data groups to be organized hierarchically into structures."*

15) Capture Artefact Relationships – Relationships between artefacts are essential to create decompositions, as well as to ground traceability. Therefore, a user must be able to capture relationships between artefacts, on all abstraction levels of business decisions and business logic. Additionally, organizations must be able to modify relationship types to match their context, on top of being able to use standard relationship types (usually included by the vendor of the software).

Examples of BRM solution-related requirements which led to the coding of the category *Capture Artefact Relationships* were: *"I want to be able to group business rules that can be linked to dynamic question and answer dialogs"* and *"I want to be able to copy the structuring of a text element from a previous version of this text element."*

E. Design and Specification capabilities

With regards to the overlapping functional categories that show overlap with the Design and Specification capabilities, two functional categories were identified: 16) Define Artefact and 17) Issue Management, as shown in Fig. 4.

16) Define Artefact – According to the data, artefacts that comprise a business decision and underlying business logic are created in the design and specification capabilities. All organizations utilize different stakeholders and tooling. Therefore, a user must be able to define artefacts in multiple representational notations, such as mentioned under functional category export artefact. Another measure to improve efficiency when defining artefacts is to re-use existing artefacts, while a user must be able to change all variables of the existing artefact. Because artefacts are often created or modified by more than one role, collaboration could improve when there is functional support for simultaneously working on artefacts. Additionally, transparent presentation to see which stakeholders have the responsibility and who is working on a (part of a) artefact, should be supported.

Examples of BRM solution-related requirements which led to the coding of the category *Define Artefact* were: *"I want the language to contain operators for specifying the granularity of characteristics of an artefact. This granularity is used in other functions and in determining the validity and content of a characteristic."* and *"I want the language to have functionalities to define fact patterns that abstract from time aspects."*

17) Issue Management – Collaboration between stakeholders during the development of business decisions and business logic poses several communication challenges. To mitigate this, functional support for issue management is required. Issue management should enable the registration of issues to be solved per artefact in each abstraction layer. Furthermore, all stakeholders must be able to maintain a to-do list, also with the goal to effectively balance the work between relevant stakeholders.

Examples of BRM solution-related requirements which led to the coding of the category *Issue Management* were: *"I want to be able to record that no reminder is sent to the person responsible for a given issue in the system"* and *"I want the system to remind those responsible about open issues."* With regards to the overlapping functional categories that show overlap with the elicitation and specification capabilities, one functional category was identified: 18) Artefact Change Support, as shown in Fig. 4.

18) Change Management – Changes to sources impacting business decisions and underlying business logic are inevitable, as well as errors that force the organization to modify artefacts throughout the elicitation and specification processes. While we argue that Change Management could be of importance as a functionality for the design capability, our data did not contain requirements aimed towards the need for artefact change support in the design processes. Examples of BRM solution-related requirements which led to the coding of the category *Change Management* were: *"I want the ability to change rules while it has no direct effect on the execution"* and *"I want to be able to subscribe to case law, which appears in my domain (s)."*

The required collaboration between stakeholders or individuals sharing role responsibilities to modify business decisions and underlying business logic often includes hierarchy. For example, based on experience level, some roles or individuals are allowed to process a modification but are disallowed to process the actual change. Functional support to approve changes is deemed important and should be considered. Similarly, roles or individuals tasked with reviewing changes made should be supported to roll-back these changes, for example, when errors are detected. Meta-data is an important factor to be considered when processing changes but requires additional labour to maintain manually for each change. Therefore, a user must be supported by automatically modifying the meta-data of the changed artefact or suggesting changes to the meta-data so that the user can approve them.

VI. CONCLUSIONS

The goal of this research is to derive a functional architecture that other organizations could utilize to design BRM solutions. To be able to do so, the following research question was addressed in this paper: "Which functional requirement categories should be taken into account when designing a BRM functional architecture for the elicitation, design and specification capabilities?" In order to answer this question, we utilized case study research and conducted three rounds of coding, involving 536 functional requirements specified by seven large Dutch governmental agencies. From a theoretical perspective, our study provides a fundament for future research towards (functional) architecture development in the BRM research field. This is needed as the current knowledge base lacks empirically grounded research into the functional application that facilitate the implementation of BRM capabilities at organizations. From a practical perspective, (governmental) organizations, can use the architectural views per BRM capability presented in this paper as guidance. Organizations that are innovating by applying automating products and services with business decisions and business logic are often searching for guardrails to design their BRM solutions. The results in this paper offer an empirically grounded functional view, based on a large collection of functional requirements, which could function as a guardrail.

VII. Discussion and Future research

In this study, the conclusions are solely drawn based on data collected from seven Dutch governmental institutions, which limits the generalizability of the results presented. The first limitation is the sampling, which prevents broad generalization towards other industries. Organizations dealing with BRM solution-related requirements are often government and financial institutions because of the large-transaction, knowledge-intensive, digital products and services they deliver. However, we argue that the goal of the functional architectures is to represent a guardrail to be used as a best practice, organizations active in industries other than the government, can utilize what fits best with their context. Also, the sample size is limited, and a broad generalization of the results can be achieved when larger sample sizes are used to collect and validate the data, as well as validate the functional architecture. Additionally, the amount of submitted functional requirements by the organizations were different. This this may be because an organization may be more mature or further in the purchasing process of a BRMS. Such experience also translates to the knowledge about and ability to draft these requirements. Future research should, therefore, focus on incorporating larger amounts of functional requirements, preferably from a mix of different industries to further validate the current set of functional requirement categories, as well as to compare between different industries with the goal to provide situational sets of functional requirements. This enables better contextualization of the functional architectures based on the industry and organization using the functional architectures. Furthermore, the data collection period stems from 2016 to 2017. Performing this study with a recent dataset would only lead to new requirements focused on specific new solutions in the field of BRM, and in turn would probably not induce changes to the identified main categories. Of course, this framework does profit from the inclusion of more recent data, which is therefore a grounded direction for future research.

To create a functional architecture covering all BRM capabilities mentioned in the introduction of this paper, more research is needed. This is necessary as business decisions and business logic are processed in and by several other BRM-related processes and stakeholders before being implemented. Furthermore, as can be derived from Table II, one organization submitted secondary data which comprised no functional requirements according to our coding but contained functional requirements for other BRM capabilities outside the scope of this paper. For transparency, we retained the organization in the data collection.

Another limitation is the lack of a mixed-method approach to construct the functional architectures. While literature analysis, case study research and secondary data analysis is combined during this research, future research should focus to further improve upon the validity and generalizability of the research results by executing a mixed-method approach. A mixed-method approach could be realized by additional empirical data collection through, e.g., interviews, focus groups and delphi-studies in which requirements are ranked and scored to search for importance in the framework, which is currently not present. Doing so also enables the inclusion of more data and wider validation of results due to the quantitative viewpoint of the mixed-method approach. Such an approach would also ensure a solid means to validate the functional architecture presented in this paper.

The final limitation is that of the appearance of new publications in this research field. BRM and BRMS have their practical relevancy but is not on the same level in their scientific counterparts. This could lead to researchers needing to build upon their own work. To the knowledge of the authors, the references utilized in this study are the most recently appeared contributions in the field of BRM and BRMS.

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Blockchain in Recruitment – Greek Public Sector Analysis and the QualiChain Solution

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Abstract - **A significant challenge for public sector human resources management in Greece is to optimize the civil personnel recruitment procedure regarding both process effectiveness and perspective employee quality while continuing to enforce, beyond any doubt, the principles of transparency, participation and accountability. Blockchain, perceived as a disruptive technology by design, has evolved beyond traditional payment solutions in the finance sector and offers a potential for transforming many sectors including human resources and recruitment. This paper analyses gaps of the current process of Greek public sector recruitment and describes the expected benefits of utilizing blockchain through a pilot case of QualiChain project.**

Keywords – Blockchain; Public sector recruitment; Qualification; Verification; Evaluation.

I. INTRODUCTION

Public sector organizations are expected [1] over time to fulfill mandates revolving around objectives such as qualitative and cost-effective service delivery as well as accountability in the management of various types of resources. To achieve that, effective assessment in recruitment of the most qualified personnel is of the essence. Carrying out this complex procedure with the use of multiple assessment tools and information collected from diverse sources is expected to provide a more comprehensive approach of the candidates being assessed and to further add value to the recruitment system overall. Securing access to the candidates' work and educational background as well as performance reviews in a credible way is argued that it will substantially improve the current recruitment process in view of the aforementioned mandates.

Blockchain technology is regarded as a game-changer in several sectors including the domain of Human Resources (HR) and recruitment, mainly because of its inherent characteristics of decentralization, transparency and immutability. There are currently numerous business and research, private and public sector endeavors to explore both the theoretical and practical implications (technical, political, socio-economic, legal and cultural) of the blockchain technology. Extending the work in [1], the first purpose of this paper is to present some of these initiatives.

The novel integration of technology and business flows that blockchains have brought, represents [2] both challenges and opportunities for enhancing digital services in civil service recruitment but, so far, Greek public sector has lagged behind other sectors in both research and exploration of this technology. So, this work further describes public sector recruitment in Greece, analyzing the current process and explaining the areas where blockchain could provide solutions through pilot cases of QualiChain project initiative for decentralizing academic and employment qualifications. In addition to that, QualiChain platform will implement other innovative features that could be deployed in the recruitment process, such as Multi Criteria Decision Methods (MCDM) and visualization tools, providing insight, flexibility and scientific foundation to existing evaluation procedures.

This paper continues in Section II with an analysis of the need and the advantages of blockchain in recruitment. Section III elaborates on public sector recruitment in Greece describes the current process, the challenges and the areas of necessary improvement. Section IV analyses the QualiChain case. The acknowledgement and conclusions close the article.

II. BLOCKCHAIN IN RECRUITMENT

Despite Bitcoin being the most well-known applied paradigm, the blockchain technology has evolved beyond traditional payment solutions in the finance sector and offers a potential for transforming many sectors including the public sector.

A 2018 OECD (Organisation for Economic Co-operation and Development) Working Paper [3] on Public Governance argues that blockchain technology has the potential to catalyze a major shift in public service delivery and internal government strategies and states that potential fields of application range from decentralized identity management to personally managed data storage for the health, insurance, and financial sectors, on to decentralized power on the basis of neighborhood energy trading solutions, and through to new voting procedures.

Conceptually, the blockchain is [4] a distributed database containing records of transactions that are shared among participating members. Each transaction is confirmed by the consensus of a majority of the members, making fraudulent transactions unable to pass collective confirmation. Once a record is created and accepted by the blockchain, it can never be altered or disappear.

A. *The need*

One of the sectors that should consider the above benefits that this technology delivers – such as trustworthy verification of counterparties' identity and documents without the involvement of a third-party – is [5] HR, by identifying problems and areas of inefficiency in existing operations that could be addressed through blockchain. The processes most appropriate for transformation through blockchain are likely to be those that are slow, labour-intensive and expensive due to the need for significant data collection and third-party verification, such as recruitment.

Moreover, repeatedly, in both research and grey literature, increasing amounts of fraud and corruption related to applicants' credentials have been reported, shaking not only the trust in the education system [6][7] but also in the entire recruitment process, as well as in the employees themselves. Falsified information is often related to references, diplomas/degrees, previous salary, certifications or work experience.

In a 2015 report (by Business Insider) 17 incidences were listed where high-level business people (even CEOs) lied about their credentials on their resume. A 2017 survey [8][9] claims that "over half of the curricula and job applications (53%) contain falsifications and over three quarters (78%) are misleading". According to different articles (HireRight's 2017 employment screening benchmark report, 2017 CareerBuilder US Survey), more that 75% of employers / HR managers have found a lie / misrepresentation on a resume or job application. It is also reported that 2 out of 5 HR managers initially spend less than a minute looking at a resume, while 19% spend less than 30 seconds so, the case is that sometimes HR professionals do not even check a candidate's qualifications so they do not take the necessary precautions to avoid a bad hire.

The estimated cost of a bad hire to a business or organization can be significant but the cost can be more than just financial because of the reputation impact an underqualified recruit could have on their operations.

Therefore, it is clear that one of the biggest gaps in the hiring process is verifying the applicant's credentials (both academic and work history) and that is why, in the current work we focus on this cumbersome HR task, i.e., recruitment, where Blockchain could have a major impact on both sides of the employment relationship, from recruitment process for the potential employer to the ability for people to maintain – and control access to – a comprehensive, trustworthy blockchain-based record of their education, skills, training and workplace performance.

The possible connection between applicants evaluation and blockchain has very recently been verified in a recent publication [10] where participants discussed their desire to utilize blockchain in checking performance appraisals of candidate employees to verify their performance potential and suitability for the advertised job stating that "it would be beneficial to know the employee's performance appraisal and misconduct in his previous jobs from the blockchain…it will be useful in achieving transparency, planning and accessing trusted data that can help with allocating employees for internal vacancies" or "we have a problem since in spite of the well-written CVs presented by the candidates during the recruitment phase, when they join work, they show poor performance…so if we can verify performance appraisals from the blockchain, it will make a big difference".

In public sector the problem is even more intense because the formal procedures of verifying credentials integrity and authenticity are stricter and more bureaucratic due to the need for non-digital (required paper form etc.) or non-real-time communication between public authorities. Moreover, when mistakes or oversights do happen in the selection, the administrative process of replacing the employee is definitely more time consuming than in private sector.

It should be noted that the general problem of documents verification is not a new one and several existing technologies can be used to tackle some of the aforementioned issues. For example, the digitization of academic certificates in combination with digital signatures and Public-Key-Infrastructure is a partial solution but with drawbacks (centralized nature of necessary Certificate Authorities, national central authority still needed for academic certificates). Another alternative is the use of interoperability (web services technologies, e.g., WSDL, SOAP) but either bilateral agreement among issuers and recruiters or a trusted third party in both national and international level is necessary. Taking into consideration other factors that add to the complexity of the problem such as diversity (geographical, administrative, technological) of academic (or professional) institutions, cybersecurity, scalability, transparency it is clear that blockchain pillars of immutability, decentralization and transparency, by design, provide a common viable solution worth exploring as shown in the following paragraphs.

B. Related Work

On one hand there are research originated projects [6][8] addressing the problem of qualifications such as:

- The combination of Blockcerts [11] with Open Badges [12] technologies. Open Badges are verifiable, portable, digital badges with embedded metadata about skills and achievements. Blockcerts consists of open-source libraries, tools, and mobile apps enabling a decentralised, standards-based, recipient-centric ecosystem, enabling trustless verification through Blockchain technology. Blockcerts uses Open Badges as certificates and Blockchain addresses as recipient identification.
- The European Blockchain Services Infrastructure (EBSI) [13] is a joint initiative from the European Commission and the European Blockchain Partnership (EBP) to deliver EU-wide cross-border public services using blockchain technology. One of the four use cases that have been selected for 2019 was centered on diplomas, aiming to give control back to citizens when managing their education credentials as well as significantly reducing verification costs and improving authenticity trust.
- University of Nicosia [14] decided to store the academic certificates, for all the students who successfully completed the course "Introduction to Digital Currencies", on the Bitcoin blockchain.

- Rooksby and Kristiyan [15] that have implemented a blockchain system based on Ethereum for use by a university to store student grades.
- EduCTX [16] proposed as a blockchain based global higher education credit platform based on the concept of the European Credit Transfer and Accumulation System (ECTS). It constitutes a globally trusted, decentralized higher education credit, and grading system that can offer a globally unified viewpoint for students and higher education institutions (HEIs), as well as for other potential stakeholders, such as companies, institutions, and organizations. The authors also present a prototype implementation of the environment, based on the open-source Ark Blockchain Platform as proof of concept.

On the other hand, several companies and startups have been quick to recognize the potential in blockchain and are exploring ways to leverage the technology in HR systems:

- APII is a career verification platform, putting employee background checks and resume verification on a secure blockchain. Their goal is to help speed up the background check process tagging the blockchain's distributed ledger capabilities to make sure that employees have accomplished what they claim to.
- Jobeum is using blockchain technology to create a 'LinkedIn-like recruitment tool'.
- Peoplewave wants to revolutionize the recruitment and background checks with verifiable data on the blockchain. It implements Wavebase platform, which is a blockchain solution using smart contract to tackle the problems of authenticating an employee, their performance, their history and information across multiple companies, roles and managers.
- Zinc is an automated reference checking tool, built with blockchain, where candidates are empowered to own and control their reference data that's reusable throughout their career.
- TrustLogicsTM is an award-winning technology solution, powered by distributed ledger technologies that enable professionals to build credible global profiles, facilitate pre-screening and allow private networking supported by artificial intelligence. Using blockchain, TrustLogic's goal is to root out the usual suspects that increase the cost of hiring: phony resumes, incomplete information, not enough verifiable data, and so on. Job-seekers can get their credentials verified, and employers will know they are drawing from a legitimate candidate base for better matches in the hiring process.
- Indorse leverages the blockchain to solve two persistent problems in HR: the lack of trust in skill verification, and users giving up their data for little or nothing in return. Techwise, Indorse.io is a Dapp built on Ethereum and is using the Inter Planetary File System (IPFS) as the storage mechanism.
- Aversafe leverages the accuracy, security and transparency of the blockchain to offer decentralized credential issuance and verification services on a global scale. Aversafe's digital certificates and verified work histories are recorded on the blockchain, a tamperproof distributed ledger, so that anyone can confirm their authenticity and origin.
- HireVibes is a low-cost recruiting tool that increases employee and peer referrals from a global network of recruiters. It can be viewed as a collaboration platform being built for the global talent community. It's powered by a native digital currency called HireVibes Tokens (HVT), which are utility tokens based on the EOS.IO blockchain. HVT is held by over 200,000 accounts and can be used to vote on community funds and proposals, pay for hires and send peer-to-peer.
- In 2019, a new consortium announced the building a global clearinghouse or database, called the Learning Credential Network (LCN) [17], which would use blockchain technology to store permanent, verifiable records of job seekers' skills and academic qualifications.
- In a more recent (2020) announcement by a cooperative non-profit entity, Velocity Foundation, the vision to harness distributed ledger technology to build the "Internet of Careers", is highlighted [18]. Velocity is a utility layer that globally connects career related data processors — HRIS (Human Resources Information Systems), contingent workforce management, freelancer platforms, student information systems and other vendors — and allows for interoperability, transparency and portability of trusted, verified data.

Of course, the lists above are not all inclusive but it is interesting to note that many other cases have been reported in literature or press these last few years that have no online presence any more or remain as stale references. Besides, so far, to the extent of our knowledge, most initiatives are oriented to academic institutions or private sector while no HR public sector authorities have any related ongoing projects.

III. PUBLIC SECTOR RECRUITMENT IN GREECE

In this section, we elaborate on public sector recruitment in Greece describing the legal framework, the current process, as well as challenges and potential areas of improvement.

A. Legal framework

The Supreme Council for Civil Personnel Selection (ASEP) is an independent authority that acts as the institutional guardian for the principles of transparency, publicity, objectivity and meritocracy regarding civil service staff hiring, in Greece. It is an independent body provided under the Greek constitution [19], entrusted with performing public administration recruitment processes for project agreements as well as fixed-term and short-term employment agreement positions at all levels.

Under the current legal framework, ASEP is entrusted with performing public administration recruitment processes in Greece, apart from certain exceptions provided by law. More specifically, certain Greek public entities are empowered by the said legislation to proceed with recruitment of personnel, either supervised by ASEP or not.

ASEP is supported by a high-end electronic information system managing the vast volume of applications, vacancies, news releases, results and most importantly candidates involved in ASEP selection processes records. Candidates are evaluated based on the score they achieve in written exams, the outcome of their interview and their qualifications overall. Some of the tools missing from ASEP's day-to-day business are functionalities that could relieve the public from the bureaucratic burden (such as achieving validation and confirmation of authenticity of university degrees) and further enhance qualitative and cost-effective service delivery and accountability (by way of, amongst others, simplifying the already complex recruitment process of Highly Qualified Civil Personnel).

B. Current Process

Vacancies in the civil sector are made public by ASEP through newsletters, its official website (www.asep.gr) and the press, in a non-personalized way whatsoever. Citizens can make queries via its website about announced vacancies, looking for those that better match their qualifications. Following announcement, citizens sign in to the ASEP Registry where they fill in their qualifications and submit an e-application regarding the announced vacancies. The e-application itself does not suffice as the candidates are further expected to print out their e-application and send it to ASEP along with the hardcopies of all supporting documents and certificates. Only recently, in 2020, a legislative modification attempts to alleviate the obligation for hardcopies, replacing them with digital/scanned documents, but its application is still in early stages and of course the full need for validation still exists. ASEP's Central Committee then issues and publishes interim results in the form of tables containing all necessary information, which may be appealed by those with vested interest. ASEP's Council Members in composition review the appeals and the interim results, issue and publish the final results.

Vacancies in the public sector addressed to highly qualified candidates, although announced and handled similarly with the rest (online application process, interim and final results and so forth), are significantly more complex to the extent that some stages are added in the recruitment process, just before the issue of the interim results, as represented in Fig. 1.

More specifically, in the first round of candidates' evaluation, some are rejected based on legal requirements (fee, online submission etc). This stage is executed by the respective organization department.

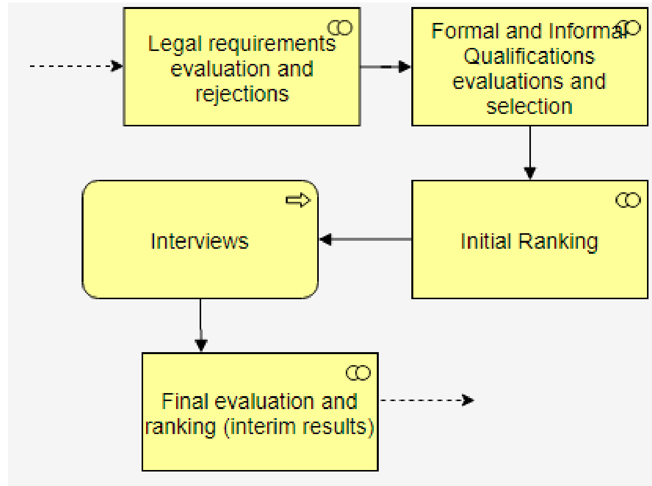

Figure 1. Specific steps for HQP.

Then, in the Second round of candidates' evaluation, some are rejected based on both formal and informal qualifications, e.g., experience and postgraduate degree minimum requirements as well as pertinence to specific vacancy needs. This stage is executed by an Evaluation Committee comprised mainly by Council Members and University Professors where one member (as an industry expert) provides a preliminary assessment.

In the Third round, an initial ranking, evaluating candidates' declared qualifications, is issued by ASEP's Evaluation Committee (for internal use only). This is based on an assessment methodology that varies each time, as law leaves it to the Committee's discretion to decide upon. The candidates ranking higher are then called for an interview.

Candidate Interviews take place in Next stage.

In the last round of candidates evaluation, the Committee, taking into account the interviews along with all previous stage results, issues and publishes interim results in the form of tables containing all necessary information (e.g., name, ID number, credits collected per qualification etc.).

Then the normal flow resumes where interim results may be appealed by those with vested interest. ASEP's Council Members, in composition, review the appeals and the interim results, issue and publish the final results.

Following the announcement of the final results in both scenarios as described herein above, the public entities who triggered the recruitment process proceed with hiring the prevailing candidates as per ASEP's results and validating their qualifications. In case of fraud detection, public entities may submit, within three years from the final results publication, a request to ASEP for replacement.

C. Current process challenges and areas of improvement

Qualifications' evaluation and validation by ASEP (initially by the Central Committee or the Evaluation Committee as per the case and later by the Members in composition) is a time-consuming process as it is performed in a non-automated way.

In the case of education credentials, a challenge [6] that slows down the connection between academia and the labour market is the fact that they are largely resisting the pull of technology often requiring paper documentation and time consuming manual processes for their verification, mainly related to

- the fact that higher education institutions (HEIs) keep student data in centralised databases and dedicated online systems
- the fact that, although administratively all HEIs are under the supervision of a common authority (Ministry of Education), no single point of reference exists so far for student degrees.
- the fact that while interoperability technology (i.e., web services) is mature enough to tackle the connection problem, only a small percentage for HEIs offer some kind of service and even then as isolated cases without achieving semantic interoperability neither among themselves nor with public labour market.

As a result, Qualifications' validation by the public entities who trigger the recruitment process and ultimately hire the prevailing candidates as per ASEP's results is also performed in a non-automated, almost non-deterministic, way, requiring communication by telephone, exchange of letters and, in certain cases, circulation of hardcopies, with all the cost that the stakeholders at issue incur with regard to time and money.

In fact, during formal and informal discussions with stakeholders in Greek public sector, it has been communicated that, the verification of authenticity and validity of a certificate, issued by a Greek HEI, has a time range of five to thirty days depending on the HEI's responsiveness. In the case of certificates issued by non-Greek HEIs where, sometimes the respective embassy intervention is necessary, the delay has, reportedly, been extended to five months in the past (although recently it has decreased down to three months). In the case of foreign language titles (i.e., issued by respective institutes) the estimated validation time is twenty days and may incur additional cost for the candidate.

On top of that, when the validation fails for any reason, the replacement process itself is also time-consuming and linked with both direct and indirect costs.

Regarding the evaluation of candidates, in the case of Highly Qualified Civil Personnel, as already described, every Evaluation Committee, before, during and after the interview process, may decide on different evaluation criteria and assessment methodology, for both formal and informal qualifications. Furthermore, coordination between different steps of this multi-stage procedure is through an excel based exchange of documents. However, as stated in the literature [20], personnel selection, depending on the recruiter's specific targets, the availability of means and the individual preferences of the decision makers (DMs), is a highly complex problem, whose multi-criteria nature makes MCDM methods ideal to cope with, given that they consider many criteria at the same time, with various weights and thresholds, having the potential to reflect at a very satisfactory degree the preferences of the DMs. As a result, in the current process, there is no common scientific ground onto which the DMs' assessment and the results from different evaluation processes can be based, compared and cross-evaluated even for vacancies with very similar requirements, even when the same applicants participate in more than one of these vacancies proclamations.

These are the gaps on both validation and evaluation procedures that the current work aspires to bridge within the QualiChain research project as explained below.

IV. THE QUALICHAIN CASE

QualiChain is a EU funded research project that targets the creation, piloting and evaluation of a decentralised platform for storing, sharing and verifying education and employment qualifications and focuses on the assessment of the potential of blockchain technology, algorithmic techniques and computational intelligence for disrupting the domain of public education, as well as its interfaces with private education, the labour market, public sector administrative procedures and the wider socio-economic developments.

A. Public Administration Recruitment Pilot and goals

As shown in Fig. 2, out of the four distinct key areas that QualiChain is targeting [21] for exploring the impact of decentralisation (i.e., lifelong learning, smart curriculum design, staffing the public sector, providing HR consultancy and competency management services), the Greek pilot, is under the "Public Sector Staffing" use case.

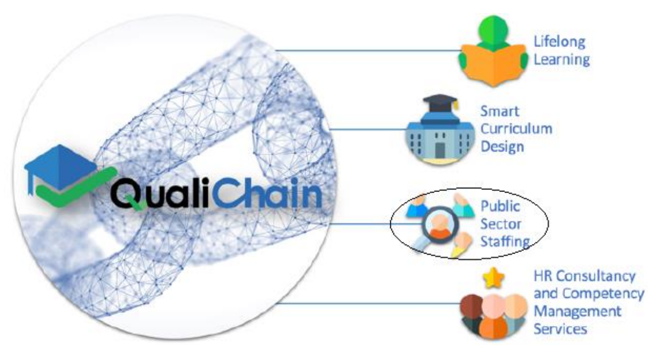

Figure 2. QualiChain key areas and ASEP pilot target.

Qualichain pilot goals in relation to public sector recruitment are the following:

- Demonstrate the QualiChain concept and technological solution, by piloting the combination of disruptive technologies involved in the context of staffing the public sector.
- Assess the impact, i.e., the benefits and risks of the QualiChain technological solution on the full spectrum of stakeholders towards which it is addressed in public administration.

B. Stakeholders

The stakeholders involved in the ASEP use case are the following:

1) ASEP Council Members and Employees:

As publishers, evaluators, validators, and decision makers with regard to the candidates' qualifications and the entire selection process in general.

2) Citizen/Candidate:

As the main participant of a selection process and the owner of qualifications.

3) Public Entity:

As "customer" of ASEP selection process and the future employer of the candidate.

4) Qualifications' issuing/accrediting institutions and their personnel:

As (indirect) providers of qualifications or on the receiving end of requests for verification, by public entities.

C. Expectations

The recruitment and competency management services of QualiChain will be exploited to enhance not just the check of the candidates' declared qualifications, but also their screening leading to a short list of those to be interviewed and ultimately to the identification of the best possible applicant for the role.

Specifically, this pilot has the following main expectations as illustrated in Fig. 3:

- To provide personalised candidate notifications for job vacancies by matching individual profiles with available jobs in the civil sector.
- To utilise the solution's Blockchain based digital ledger in order to validate (i.e., confirmation of authenticity) formal academic qualifications of individual candidates, thus freeing the public sector from the relevant bureaucratic burden. Of course, this functionality may extend in the future to other qualifications (professional qualifications, informal academic ones, etc). In any case, the expected benefit against the current system (as reported in Section III) is significant since the delays are anticipated to be reduced by orders of magnitude, i.e., from days/months to minutes.
- To improve efficiency of the selection process in terms of time, credibility and flexibility by utilizing value adding services provided by "Analytics and DSS" QualiChain component. To this end several multi-criteria decision making methods will be implemented, such as ELECTRE, TOPSIS, Promethee, so that appropriate qualitative (e.g., interview performance, cooperation/communication skills, experience pertinence) and quantitative criteria (e.g., months of experience, graduation degree) as well as other necessary parameters can been embedded in the form of a comprehensive evaluation management system.

D. Use case flow

The expectations above will be met through the execution of the Highly Qualified Civil Personnel recruitment process steps, in the context of the pilot, as illustrated in Fig. 4. The main steps are the following (note that the terms Citizen/Candidate are used interchangeably):

1) The issuing organization issues a qualification component (either an academic qualification or a work experience certificate) for a citizen.

2) The isssuing Organization, after obtaining the candidate's consent, uploads the qualification component in QualiChain and notifies Citizen.

3) Citizen signs up to QualiChain and fills in preferences for notification

4) ASEP announces positions/vacancies and required qualifications on QualiChain.

5) Citizen/Candidate gets notified of new vacancies via a Data Analytics Tool embedded in QualiChain.

6) Candidate signs up to ASEP's Registry (if not already registered), fills in his qualifications, uploads the relevant proof of qualifications declared (e.g., university degree) and applies for the vacancy he/she is interested in.

7) ASEP confirms the validity of the proof of qualification declared and potentially its metadata (e.g., year of graduation) and updates ASEP backend (marking the qualification so that this process does not have to be repeated).

8) ASEP uses QualiChain ´s MCDSS (Multi Criteria Decision Support System) to get an initial ranking of candidates.

9) Based on this initial ranking, ASEP proceeds to the stage of interviews.

10) ASEP uses QualiChain MCDSS to get the final ranking and ultimately the interim results.

E. Pilot Challenges

Several challenges have been identified from the beginning as follows:

- Friendliness and usability of user interface provided by Qualichain, given that it will be, mainly, used by ASEP'S Members and employees, of no technical background whatsoever.
- Pilot planning and integration with internal ASEP procedures.
- Technical limitations of Blockchain technology related to performance and scalability, such as Quality of Service or throughput. However, the estimated impact for the pilot is expected to be minimal since the cornerstones of ASEP use case are transparency and immutability, both of which are among the pillars (and more popular characteristics) [22] of Blockchain.
- Semantic interoperability between Greek terms used by ASEP information systems (e.g., institution

names, qualifications, certifications, job descriptions and so forth) and QualiChain terminology.

- Convincing field experts, committee members and ASEP decision makers that more precise, sufficient, detailed and complete justification of ASEP committees' decisions can be achieved using QualiChain DSS features.
- Compliance with Greek and EU regulation, e.g., General Data Protection Regulation (GDPR).

Beyond the scope of the Greek pilot, it is interesting to see whether the current stiff legal framework safeguarding personal data in the EU will ultimately adapt to the blockchain's nature, in order to make the most of the decentralization notion, as well as how interoperability and blockchain can co-exist or consolidate within an organization.

V. Conclusion

In order to achieve effective assessment in recruitment of the most qualified personnel in the public sector, methods and tools must be constantly developed and tested to educate and train everyone in line with new developments, in our case, with the blockchain technology, so that their benefits can be fully realized by all stakeholders.

Several solutions / proposals aspire to promote the use of blockchain in recruitment but are still in the research / proof of concept phase or are mainly focused on private sector.

By participating in QualiChain project, as a pilot for staffing the public sector, ASEP will have the opportunity to embed state of the art tools, not only to achieve validation (i.e., confirmation of authenticity), of university degrees, utilising blockchain technology to free the public sector from the relevant bureaucratic burden, but also to provide personalized information to citizens/potential candidates and explore ways to bring most value to the highly qualified personnel selected, enabling, effectively a breakthrough in contemporary recruitment processes in Greek civil service.

In the future, ASEP aspires to extend the capabilities of QualiChain to other qualifications as well as explore other components / concepts totally foreign to public sector recruitment operations such as gamification or artificial intelligence.

Acknowledgment

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Figure 3. Pilot expectations.

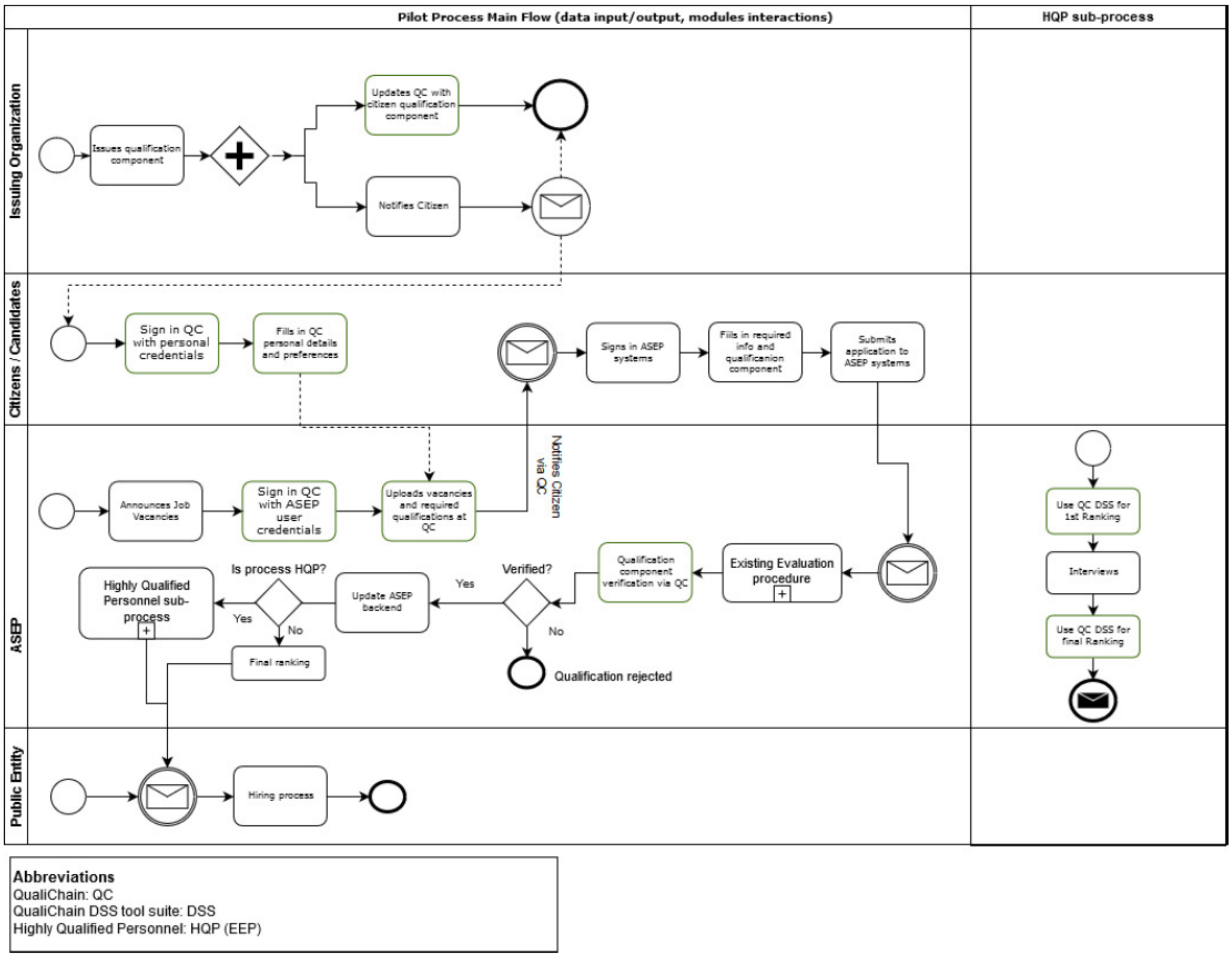

Figure 4. QualiChain ASEP pilot BPMN workflow.

Implications of COVID-19 Across eGovernment Services: An Australian Taxation and Social Services Comparative Case to the Health Environment

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Abstract— **COVID-19 has had a profound impact on people across the world and on the provision of government services. This has impacted how governments provide services to their citizens, in addition to the implications of digital first service provision which initially impacted how individuals interact with public sector entities. This research highlights the similar assistance requirements and concerns with different public sector digital services, while highlighting the differences across digital health and taxation and social services. Evidence for this research is presented through a case study on the Australian Taxation Office, data collection from the Services Australia and two digital health platforms, MyAgedCare and My Health Record. By understanding the different issues and assistance seeking requirements across the public sector digital services, particularly while responding to unpredictive and disruptive environments such as the ones triggered by COVID-19, digital service designers and policy makers can shape better services that meet the needs and expectations of users. A primary finding of this research highlights the need to maintain human interfaces for assistance-seeking, in order to maximise an individual's capacity to interact with the system successfully. General expectations and key concerns of users , particularly focusing on the current disruptions triggered by COVID-19 Pandemic are also discussed in light to advice policy-makers within the public sector digital environment.**

Keywords- Digital Health; Assistance Seeking; Digital Inclusiveness; Digital Ecosystem; Public Sector.

I. INTRODUCTION

The implications of the COVID-19 global pandemic have impacted the methods used by government organisations and public sector entities in provision of services. To reduce the risk of infection to both patients and staff, services have had to swiftly shift from predominantly face-to-face to digital formats. These services encompass the scope services and include healthcare, social services, taxation, and private sector services. COVID-19 combined with the shift of public sector services to digital first technologies have created additional barriers and complexities to the adoption of services in the mandatory and voluntary services space.

As public sector services adopt new technologies and start to identify the considerable benefits associated with utilising digital services, the availability and use of legacy systems will decrease [1] [2]. Public sector services are fundamental in a modern society and service availability is crucial. However, with the use of digital services in lieu of legacy systems, especially in the mandatory service space, users are becoming more and more limited in their choices [2]. Therefore, this paper argues that for governments to be truly inclusive, legacy systems must remain in place, to enable and provide access to all who require them.

The ongoing coronavirus (COVID-19) situation has led to a global health emergency and declared by the World Health Organisation as a pandemic on March 11th 2020 [3]. This situation has put previously unseen stress and unexpected impacts on the healthcare system across the world [4]. The current COVID-19 pandemic has created an opportunity for the extended use of digital technologies in the health sector. Digital health technologies and tools include telemedicine/telehealth, digital health records and mobile health technologies [5]. Although obvious benefits exist in the ability to provide services online, this opportunity does not come without complexities and difficulties for accessing and developing services (for both service users and developers). Especially as a result of the speed in which the transition to digital for many services from legacy was conducted.

This paper explores the responses across government organisations and public services to the global pandemic, through the application of findings from an Australian Taxation Office (ATO) case study, used to understand the barriers and opportunities affecting digital service provision in the public sector. Additional data was collected to develop a case study on social services in Australia, through exploration of the Australian service provider Services Australia. The findings from these two case studies have been used to start the discussion on the digital health environment, including the most common Australian digital health platforms known as My Health Record and MyAgedCare [6], both services which are displayed with similar digital formats. This paper does not argue against the use of digital approaches for service provision, however it questions the inclusiveness and equity of access of providing digital first services in mandatory service space (e.g., tax lodgement or aged care referrals). In addition this paper explores the responses to COVID-19 from the aforementioned government service providers in Australia, outlining how through a crisis government organisations responded quickly to an escalating situation.

The purpose of transitioning public sector services to digital platforms is clear, to provide easy access to government services, and to promote the transformation and delivery of modern and future proof digital services to those who need them [2] [7]. There are millions of Australians who utilise online government services through the central platform "myGov", as well as numerous state government online services [2]. The large numbers utilising the services demonstrate how Australian public sector digital services are well adopted within the community. However, there are still pockets of the community who are struggling to access necessary services [2].

In addition to the global pandemic, government organisations and their associated public services have been progressively responding to other changes in the environment. All Australian Public Sector Organisations were impacted by the introduction of the Australian Digital Continuity Policy 2020, mandating the use of digital first channels for every public sector service provided [8]. This policy put considerable pressure on both public sector organisations and service users. Through exploration of previous literature, a considerable gap was identified between what is known about digital service users and non-users, and those individuals who are required to use them. Therefore, the impact of shifting mandatory public sector services to a digital first platform is still largely unknown. As digital first service provision is the way forward for all public sector organisations (especially in Australia), a holistic view of users is needed. Research needs to support and assist users, improve services and inform policy to increase long-term voluntary compliance obligations in a mandatory service space. To support this view, this research is exploring the relevance of previous research based on a case study on the ATO, and comparing them to different services provided by the Australian Department of Health.

This paper will explore the barriers to digital adoption in the public sector space, specifically comparing mandatory and voluntary spaces. These comparisons will be based on understanding that ATO, Services Australia and MyAgedCare services are mandatory and My Health Record being voluntary. This research explores the common reported themes among digital barriers and proposes additional research to be undertaken to address the gaps. The themes will be derived from an ATO case study (conducted previously) and comparing to a pilot study undertaken on MyAgedCare. Additional research has explored the identified barriers to the use of My Health Record (a voluntary service), to understand the similarities across digital health and digital taxation, as well as mandatory and voluntary. Through the use of thematic analysis outlining the barriers to digital adoption, links between the ATO and Services Australia case study and the digital health platforms are introduced to demonstrate the similar issues across the different eGovernment services. Further analysis was conducted to understand the implications of shifting traditionally in-person services (including doctors consultations) to digital platforms or telephone, during COVID-19 have been used to further understand the implications of digital services in healthcare. This is not to imply that the use of digital technologies in healthcare are not valuable, cost effective or is capable of providing high quality services to meet the needs of users, however this research indicates that the complexities of patients and their healthcare requirements can be missed without face-to-face consultations. In face-to-face communication, all participants can not only hear, but see body language and facial expressions, which can aid understanding of meaning behind the spoken words. Digital technology which uses video as a form of face-to-face has positive aspects but can impact eye gaze with participants concentrating on the screen. Any barrier which impedes medical staff ability to understand non-verbal cues, has the potential to detrimentally impact provision of patient centred care.

By exploring the various barriers and their links to the User Centred Model (Figure 1) the analysis provides lessons learned applicable to both policy makers and digital services designers.

The structure of this paper is divided into six sections. Section one contains the introduction, section two outlines the literature reviewed, section three discusses the ATO, social services, My Health Record, Telehealth and MyAgedCare, the fourth section outlines the methods, the fifth section highlights the results of the study and the final section is the conclusion.

II. Literature Review

All government organisations and public sector services across the globe have been impacted by COVID-19, with varying responses. The most significant affect has been felt in healthcare sector [9], where demand for services remain high and additional services are required to deal with COVID-19. Within the public sector space, there have been significant impacts for financial support sectors (including taxation and social services) [10]. With a critical demand for financial support as a result of increased rates of unemployment, lockdowns temporary closing businesses and restrictions impacting the number of patrons and employees allowed on site [11].

A. *Digital Inclusion*

Inclusion is complex as it incorporates numerous concepts including; awareness, acceptance, respect and understanding, to provide equal participation opportunities [12][13]. An inclusive environment encourages people with different characteristics, backgrounds and ways of thinking, to work together to fulfil their potentials [12][13]. These environments require considering both internal and external stakeholder perspectives, and placing equal value on all perspectives regardless of where they originated [14]. Digital inclusiveness is also increasingly complex, as it involves multiple components within the specific digital ecosystem of an individual. Therefore, digital inclusion identifies the importance of access to information and communications technology and the resulting social and economic benefits for users [15]. An individual's level of digital inclusion is impacted by digital skills, connectivity and accessibility. Digital skills include the capacity to use technology to connect with the services (internet and computer), connectivity involves having internet access (the infrastructure) and accessibility is the user friendly digital services that assist in accessing the service [16]. Thus raising the question, does digital health have potential negative implications on levels of digital inclusiveness?

B. *Digital Divide*

One of the most significant issues towards the use of digital public sector services is the digital divide, whereby in Australia more than 2.5 million individuals are still not online [16] and the digital divide is largest in those older than 65 [16]. The digital divide is defined as the gap between individuals or groups with limited access to digital information and services, compared to those who have effective access [16]. With the shift of government services to online delivery methods, there is considerable potential for older Australian's to be disadvantaged from the greater use of emergent and dominant communication technologies [16], as digital services tend to leave older Australian's out [17]. An aging population is vulnerable and in some cases reluctant to use digital technology, raising concerns about ability to use technology, scams, privacy, self-diagnosis resulting from misunderstanding of information and the desire for face-to-face explanations [18]. Thus raising the question, how do digital health platforms affect service use?

The digital divide is an issue that effects lower income earners, individuals with poor access to the internet and/or those individuals who lack the skills to use technology, making it harder to access. Furthermore, lower levels of digital inclusion are associated with individuals who only access internet through mobile devices. Digital exclusion often exacerbates other forms of social exclusion; this includes unemployment, low education and poverty [19]. Therefore, the importance of digital inclusion is undeniable; all Australians require access to both technology and skills to ensure they can take part in every aspect of social and economic life. There are practical concerns for achieving equitable levels of access between different social groups and public services, as society is not homogenous, providing basic accesses to the community is not sufficient. Services provided to citizens by government need to align their design and application to the needs of the community, to encourage digital inclusiveness and begin to breakdown the digital divide.

C. *Barriers to eGovernment*

Previous research has explored the specific barriers to digital adoption within the eGovernment space. The European Commission, defines a barrier to eGovernment as the, characteristics within the contexts of legal, social, technological, or institutional which negatively impact the development of eGovernment [18, P.3]. This can be caused by users' lack of demand and the obstacles preventing engagement with services, or disincentives for the government to supply the eGovernment services or prevalence of obstacles preventing its supply [19]. This research identified barriers and compiled them into seven key categories; leadership failures, financial inhibitors, digital divide and choice, poor coordination, workplace and organisational inflexibility, lack of trust and poor technical design [19]. However, research suggests that regardless of the platform, the impact of stakeholders (internal and external) can negatively influence its use [20]. Therefore, successful eGovernment platforms depend on understanding the environments in which they operate [21]. These elements including stakeholder inclusiveness should be considered more in-depth, with their relationship to the multiple barriers preventing eGovernment/digital service adoption and their applicability across disciplines.

III. EGOVERNMENT SERVICES: ATO AND HEALTH

For this research, mandatory environments are classified as "Public Sector Organisations who must by legislation provide Digital Platforms for their services" [22][23]. Whereas mandatory interactions are defined as "Users who meet certain characteristics and must by legislation interact with the public sector service provider to meet these obligations" [22][23]. Therefore, users must engage with providers, but under the digital first mandate expectations around how they do so has changed. In contrast voluntary public sector services are similar to those provided by the private sector, in that an individual can decide whether they want to utilise the service or not.

A. *ATO*

The ATO was the first service provider to adopt digital first service provision, with the introduction of myTax for individuals, business portals, and tax agent portals. The ATO requires all individuals to interact annually with them to submit their tax return, all individuals who derive income within Australia. Since the digital first transition, the majority of services are digital and require an understanding of both taxation and computer systems. Taxpaying population is in Australia is over 16 million; of these 84% are individuals [23]. The ATO has high digital adoption rates of the MyTax platform, with 95% of individuals eligible to utilise the service [23], however there are still gaps within the population that need to be explored and understood.

In addition to the ATO's digital transformation and taxation responsibilities, they have been made responsible for the implementation of various COVID-19 financial responses [24]. Firstly, the Jobkeeper Payment, which was available to businesses who were also employers (or sole traders) in order to continue to pay their employees during financial hardship (including lockdowns, restrictions and decreased financial turnover) [24]. Second, the Cash Flow Boost payment, which was made to businesses who met certain characteristics to maintain cashflow during financial difficulties [24]. Thirdly, remissions of general interest charges for taxation debts incurred post January 23rd 2020 [23]. Finally, the deferral of business reporting requirements and payments as a result of COVID-19 [24]. The ATO was also responsible for additional financial support measures for individuals including early release superannuation ($10,000 payment from their retirement funds) [24]. The implementation and roll out of these measures required a rapid response, in many cases occurring over days or weeks. There is no doubt that the pandemic has driven innovative responses and overnight changes in how the ATO and day to day operations responded to disruption– leveraging on the capabilities of digital technologies.

Progressively the myTax platform became more inclusive, through annual and ongoing adaptions, and the progressive changes in the manner in which digital adoption and service provision has occurred [25] [26]. Each iteration incorporates the feedback from users to ensure ongoing viability of the platform, while also ensuring ongoing success [26]. The iterative approach of ongoing improvements has been a key component outlining the success of the myTax platform, which makes the platform a good case study on the creation of inclusive government services. This is not to say that the platform is 100% inclusive, there are still issues with accessibility, understanding and willingness to change that impact its use [27].

B. Social Services

Services Australia underwent digital transformation in 2016, shifting the majority of their services progressively to digital first platforms [28]. This was largely in response to the Digital Continuity Policy 2020. Services Australia is the overarching body of Centrelink, who is responsible for the provision of a number of social services including financial payments for multiple pensions (e.g., retirement, disability, carer and student) [29]. Therefore, they are responsible for the provision of financial support for some of the most vulnerable individuals in the community.

Social services in Australia were considerably impacted by the COVID-19 pandemic, specifically due to the increased need to access financial support, causing unprecedented site traffic [30]. This is largely the result of the increased unemployment rate in Australia, as a result of COVID-19 [31]. Similarly to the ATO, updates to the site and phone services were made in a matter of days. The impact of these recent events clearly highlights the need to evaluate and complement the existing digital ecosystem, setting out the plans (and supporting legislation) to address high volume systems' demand. There is an opportunity to further expand the scope to support a unified platform for the social service sector to speed data access and ensure privacy for users, during this accelerated process to digital transformation.

The responses to the digital transformation of social services has been mixed in Australia. With inconsistent levels of demand, access to the site can be limited and difficult at times [32]. The provided services can also be complex and difficult to understand, namely the wording, the documentation required and the process to obtain financial support [32]. As a result, there have been multiple iterations to the creation and development of the digital services, however there remains a high demand for legacy services and options moving forward [32].

C. Digital Health

Healthcare systems are becoming significantly more complex, with more professionals becoming involved in each individual patients care, and ever-changing healthcare needs of the population [33]. Healthcare is the product of a complex adaptive system, comprised of people, equipment, processes and institutions which all work together [34]. Healthcare systems operate at their best, by undertaking ongoing improvements. However, when the system fails to improve it negatively impacts the system [35]. Therefore, the research argues that through the application of a systems thinking lens, the complexity of the different interacting internal and external environments within organisations, health systems and society for example, can be better identified and understood. The systems complexity highlights both problems and opportunities and requires responsive organisations and systems capable of adjusting to changes. The ability of the system or components of the system to respond to changes, all depends on one's ability to understand influences [36]. Systems thinking can provide a holistic view and assist in identifying areas requiring revisiting [37].

D. Telehealth

Telehealth or telemedicine has had a transformative effect on healthcare delivery worldwide, especially as a result of the rapid shift in telemedicine adoption from both patients and providers during COVID-19 [38]. Research demonstrates that telemedicine is an important tool used by medical practitioners and their timely delivery of healthcare and support to patients during the COVID-19 pandemic [39]. Telemedicine (also referred to as telehealth) includes real-time audiovisual interactions between a patient and a healthcare provider [39]. Telemedicine allows providers and patients the opportunity to obtain healthcare regardless of geographic location and increases the number of interactions a health provider can have during the day [39].

Interestingly, research demonstrates how telemedicine visits typically include less information than video or in-person visits [39]. Furthermore, there are key barriers associated with the wider adoption including limited financial reimbursement for appointments, reduced comfort levels with telemedicine technologies for both patients and providers and geographic limitations to the use [38]. Digital and telehealth is dependent on available technology, reliable data and phone/mobile connections [39]. Comfort levels with using technology, levels of digital and health literacy are important factors impacting adoption and use [39]. An argument for maintaining in-person-care or face to face consultations.

Further research demonstrates that the rapid development and application of telemedicine have required doctors and healthcare providers to quickly learn how to facilitate appointments online, which include empathy and appropriate diagnosis techniques [38]. Research into the satisfaction of users and providers of telehealth has provided unclear results, especially when it comes to perceived quality of care [40]. Effective communication skills are vital for health care workers, particularly when access to non-verbal cues is either diminished or absent in the case of telephone calls. There are also times when specialist medical staff are reliant on the physical assessment skills of a health care worker available with the patient.

E. My Health Record

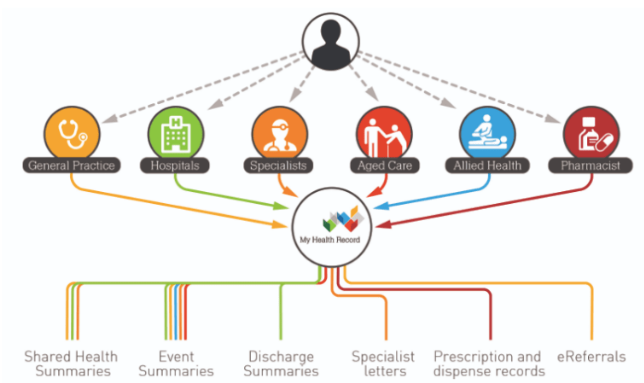

Figure 1. My Health Record System Model: Australian Government, Department of Health

My Health Record is an online platform containing a summary of an individual key medical and health information (including histories). The site provides information for individuals and health practitioners who opted into the service to view medical histories, previous tests, medication (history and current) and diagnosis. The My Health Record platform was piloted in 2016 [41]. The aim of the platform was to provide a single location for all medical details of a patient that is readily available for health practitioners and users. The service is voluntary, there was an opt-out process between 2018 and 2019, where eligible Australians indicated whether or not they wanted the service [41]. To be eligible an individual must be registered with Medicare. Although there are a number of benefits from the provision of the online health record, more than 2.5 million Australians opted out of the platform [42]. The primary reason was privacy concerns, specifically because not only doctors can view the records (any registered health provider can); data can be used for research; once created the record cannot be deleted and there is fear of hacking data [43]. Figure 1 provides a visual representation of how the health record digital platform interacts with the rest of the Australian health system.

F. MyAgedCare

MyAgedCare is an online platform for individuals aged 65 or older which is the starting point on an individual's aged care journey [44]. The site provides information for government-funded services available at home to enable individuals to continue living independently. The MyAgedCare platform has undergone numerous changes since its launch in 2013, aiming to provide a consistent, streamlined and holistic assessment of clients. However a study published in 2018 demonstrates service demand significantly outweighs supply. With 127,748 on waitlists or not receiving adequate levels of assistance based on their needs [45], and the waitlist growing by 20,000 every six months [46]. Furthermore, 96,000 people waiting since 2013 have found nursing home placements faster than their preferred option of home care, and more than 16,000 people died waiting for services [46]. Numbers are impacted by geographical location, types of services, financial outlay and availability of qualified staff. Although this backlog in services is important to note, it is not the key issue raised in this paper, this study focuses on the implications of MyAgedCare as a digital platform and how this, in turn, affects patient centred care and equitable access to identified care needs.

Both digital health eGovernment platforms under analysis are relatively new, having not undergone as many iterations as the ATO myTax platform. However, these platforms have a considerable impact on end users and the Australian population, as they are both critical for providing information and links to information that outline individuals health profiles, where and how to access services and has the capacity to act as a facilitator of medical services in Australia. This research intends to highlight the key lessons learned from the ATO digital experience, to help inform digital health service designers, to provide avenues for designers and policy makers to obtain guidance on how to develop more inclusive digital services in this space. Simultaneously, other eGovernment platforms can take advantage of the key learnings from the ATO digital experience, as this is transferable to eGovernment.

IV. METHODS

A qualitative approach was applied to this research. An integration of both interpretative and exploratory approach to obtain an in-depth understanding of the key barriers to digital adoption and how they were overcome was considered appropriate to the ATO, Services Australia, MyAgedCare and My Health Record cases. This approach provides evidence to describe the eGovernment environment and provide insights to promote ongoing service adoption.

This research has three components, the first component was the analysis of the ATO digital experience. The ATO study component for this research used primary data collected during a 4-week period over July 2018. A survey form was provided to 11 call centre operatives who populated numerous fields outlining reasons for call and demographics of callers; to understand why people were seeking assistance. Once collected the data (N = 3,990) was anonymised through aggregation techniques to group like individuals into similar groups to understand the population. As this research was designed to be exploratory in nature, the focus was to understand the different issues facing users, a thematic analysis was completed on the qualitative data obtained. Additional data was collected in June 2020 from users, seeking an understanding of the ATO's response to COVID-19. Users were asked what they perceived the ATO's response was to COVID-19, this provided insights into how they felt the response impacted their situation.

The second component discusses the Services Australia platform. This data was collected from individuals who sought social service payments after being financially impacted by the COVID-19 pandemic. In June 2020, users were asked what were the barriers to digital adoption while using the Services Australia services. Furthermore, the users were asked what they perceived Services Australia's response to COVID-19 to be, and how it affected them.

The third component incorporates the Digital Health sector platforms, My Health Record and MyAgedCare. For the MyAgedCare component of this research, data has been collected from concerns, interpretations and perceptions of various stakeholders engaged with the MyAgedCare platform (N = 543). Data analysed underpinned the actor's perception on "What do they think of the MyAgedCare platform?". The same method was utilised to explore the My Health Record platform which works on similar digital integration system approach (N = 350). The main focus of the discussions was to understand what different actor's perceptions are on "What do they think of the My Health Record Platform?". The data was consolidated and anonymised when analysed to identify common themes and trends within the responses. The data collected for this component has been treated as a pilot and comparative form to the ATO digital environment and therefore was only based on answering a singular question. The additional analysis conducted was on existing data provided outlining environmental components.

Additional data collection was undertaken to determine how users of health services perceived health response to COVID-19. Table I summarises key demographics of the Health data and Table II summarises Social Services and ATO data.

TABLE I. HEALTH DATA DEMOGRAPHICS

	MyAgedCare	**Health Record**
	N = 543	N = 350
Age Groups		
18-29	10 (1.9%)	40 (11.4%)
30-39	40 (7.4%)	66 (18.9%)
40-49	42 (7.7%)	71 (20.3%)
50-64	223 (41%)	85 (24.3%)
65+	228 (42%)	88 (25.1%)
Gender		
Male	190 (35%)	130 (37.1%)
Female	353 (60%)	220 (62.9%)
Occupation		
Client	391(72%)	252 (72.1%)
Carer	60 (11%)	40 (11.4%)
Doctor	5 (1%)	5 (1.4%)
Allied Health	37 (6.8%)	20 (5.4%)
Nurses	50 (9.2%)	33 (9.4%)

TABLE II. ATO AND SOCIAL SERVICES DATA DEMOGRAPHICS

	ATO	**Social Services**
	N= 3990	N = 170
Age Groups		
<18	1 (.1%)	0
18-29	1,955 (48.9%)	20 (11.8%)
30-39	758 (19%)	15 (8.8%)
40-49	479 (12%)	50 (29.4%)
50-64	519 (13%)	55 (32.5%)
65+	278 (7%)	30 (17.5%)
Gender		
Female	1,799 (45%)	90 (47%)
Male	1,947 (48.9%)	80 (53%)
Undisclosed	244 (6.1%)	0

Table III outlines the breakdown of how the data was used to inform this research, outlining the key findings and themes as per the findings of the Gioia Method.

TABLE III. HEALTH AND SOCIAL SERVICES FOCUS GROUP DEMOGRAPHIC

ATO (N = 3,990)	My Health Record (N = 350)	MyAgedCare (N = 543)
Randomised N= 160	Randomised N= 160	Randomised N= 160
Multiple questions – Digital Adoption / eGovernment digital Interface	Pilot: One key question – Digital Adoption / eGovernment digital Interface	Pilot: One key question – Digital Adoption / eGovernment digital Interface
COVID-19 Implications around 3 key areas: Information Provision, services and the core business: Financial	COVID-19 Implications around 3 key areas: Information Provision, services and the core business: Medical	COVID-19 Implications around 3 key areas: Information Provision, services and the core business: Medical

V. UNDERPINNING FINDINGS: USER CENTRED MODEL

The research adopted an interpretive lens to guide analysis with a systems view. Through the analysis of the 11 call centre operatives' surveys, a conceptual model is proposed for the complete integration of key stakeholders influencing end user digital adoption: User Centred Model (see Figure 2). The key factors and element of this model emerged by observation and interpretation of all the stakeholders and interactive elements within the system and all the parts of the broader environment. The purpose of adopting a systems lens to build this model was to provide a user-centred research approach which can guide policy making as well as provide better support and understanding of the various needs of the different users. This conceptual model contributes to knowledge by initially identifying a number of factors within a user's environment and their degree of impact on willingness or capacity to adopt mandatory digital services. The model also provides the benchmarking factors to explore and categorized the emergent barriers of the above mentioned call centre operative's surveys.

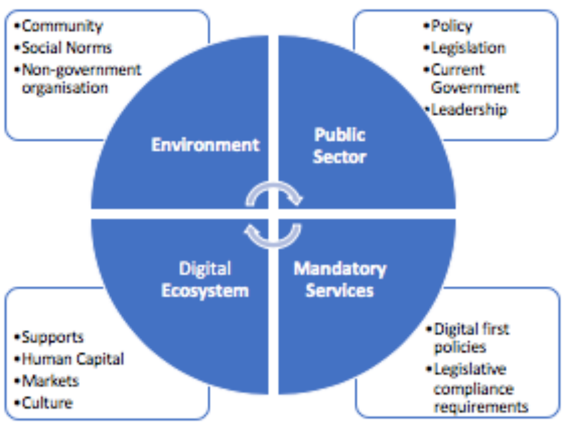

Figure 2. User Centred Model

Table IV outlines the thematic analysis conducted within the ATO, this table demonstrates the different barriers, listed by ascending order, individuals face when interacting with the myTax platform and creates a basis for the analysis of the digital health platforms. The thematic analysis demonstrates that individuals seek assistance and advice on both tax technical components and general platform and technical support. Both of these scenarios are relevant for the digital health space, as language used in services and information provided can have a considerable impact on end users.

When comparing the themes outlined within Table IV, all themes influence an individual capability and willingness to utilise digital services. There are links within each section to legislation, mandatory services and the environmental impacts. From this, the research can infer that there is a lack of understanding of mandatory services, specifically what the legislation is requiring the shift to digital. Therefore, to address this, users need to be informed of the changes and the provision of transparent policies are required, these policies need to be easily interpreted by all users. Furthermore, by understanding how different policies interact with the mandatory services users can be more informed as to the security and safety of their data, without this understanding it is unclear how end users will feel confident and comfortable using the services.

TABLE IV. ATO BARRIERS TO DIGITAL ADOPTION

Themes (listed by priority order)	**Users comments**
Platform support and technical support	- Do not know how to access the page - What are the security measures in place? - How do I link between the MyGov and MyTax platforms? - I have not used this before - where is my prefilled data ? - How do I change my details/or name? - The identification questions were incorrect - I am having technical difficulties
Lacks computer skills, and/or has preference to use non digital	- I want to use myTax by I don't know how to use a computer - I have no email address or digital presence - Do not nor wish to, own a computer - How do I do this digitally? - I always do my taxes this way - Language barriers prevents the use of digital - Only completes old non digitalised forms
Requires education in the system, platform awareness	- How do I lodge? - Why do I need to? - How does tax work? - Why do I have to pay money? - How does income work? - Where do I put information on the form? - What are tax offsets? - How long does this take? - What is a deduction?

When comparing the findings within Table IV to the preliminary findings within Tables V-VI, lessons can be learned in relation to the potential inclusiveness of digital services, especially when looking beyond mandatory systems and simply exploring the various policies and involvement of stakeholders. For example, in both mandatory and voluntary systems, an important issue for end users is the security concerns related to their private data, how they access the digital services and their level of digital literacy. The users for these services also differ considerably, which demonstrates interesting findings when it comes to across the board generalisability of barriers to digital inclusiveness.

TABLE V. ATO'S RESPONSE TO COVID-19

Theme (listed by priority)	**Users comments**
Financial	- I was able to obtain financial business support to keep my employees quickly (job keeper allowances) - Accessed my superannuation - I was able to financial cash flow boosts because my business was struggling financially - Ability to defer debt payments and interest charges
Information provision	- Online information was easy to access - Information was in plain language - Everything was available in one place
Services	- Online support (via email) - Phone support (contacted call centre) even on weekends - Business Portal. - Through my tax agent I was able to get help

TABLE VI. SERVICES AUSTRALIA BARRIERS TO DIGITAL ADOPTION

Theme (listed by priority)	Users comments
Platform support and technical support	- Do not know how to access the page - The page keeps dropping out - What are the security measures in place? - How do I link between the MyGov and Services Australia platforms? - I have not used this before - How do I change my details/or name? - The identification questions were incorrect - I am having technical difficulties
Lacks computer skills, and/or has preference to use non digital	- I have no email address or digital presence - Do not nor wish to own a computer - How do I do this digitally? - Language barriers prevents the use of digital - Only completes old non digitalised forms
Requires education in the system	- How do I obtain support payments online? - Why do I need to online? - Where do I put information on the form? - How long does this take?

TABLE VII. SERVICES AUSTRALIA'S RESPONSE TO COVID-19

Theme	Users comments
Financial	- I was able to obtain financial support after losing my job - Health care card was given to me so that I could afford medical treatments even without a job
Information provision	- I found information online about how to get support - I was able to find the information through social media platforms
Services	- Online application process - Phone support (contacted call centre) even on weekends

The results within Tables VIII-XI, highlight how regardless of platform, the assistance required relates to end-user concerns about terminology, accuracy of information and representation. Furthermore, there is a clear and direct relationship between digital awareness of the operations of online platforms (eGovernment) and the types of questions asked within the digital space (e.g., digital literacy questions, obtaining the correct information).

TABLE VIII. RESPONSES TO "WHY ARE YOU NOT USING DIGITAL SERVICES?"

Theme (listed by priority)	Users comments
Scams/Fraud /Security	- Fear of scams - Not sure which is the real website and which is fraudulent - Computer/cyber security concerns
No computer/ Internet access	- Have no experience utilising a computer or accessing the internet - Unclear on what a digital health service is - Have no access to the internet of computer
Skills	- Lack of skills - Not sure how to use it - COVID impacted access to in person services
Attitude	- Do not want to use it? - Why should I? - I am too old to learn
Other	- How is my data being used? - Inconsistent information - Processes are complicated

TABLE IX. RESPONSES TO "WHAT DO YOU THINK OF MYAGEDCARE?"

Theme (listed by priority order)	Users comments
Phoneline	- Rude staff - Staff demanding to speak to client directly despite acknowledgement of advocate availability - Hearing impairment impacting communication - Language barriers
Confusing	- Terminology used by staff - Questions deemed by clients as intrusive and unnecessary - Inaccurate information provided on website - Clients unable to understand the different services and costs involved – written information only with a lack of visual representation - Sometimes inaccurate representation of available services - Availability of services for under 65 years
Difficultly accessing	- Vision impairment - A lack of comprehension - Unreliable or no internet in the home (particularly rural and remote) - Mobility impairment - unable to leave home to use public access computer - Inability to express urgency
Attitudes	- What is the point? - Do not see value - Poor design - Not compatible with my lifestyle

TABLE X. RESPONSES TO "WHAT DO YOU THINK OF MY HEALTH RECORD?"

Theme (listed by priority order)	Users comments
Privacy	- Confidentially and privacy concerns - Concerns for the ongoing privacy for their data stored online - Unhappy that it cannot be deleted once created - Unclear who can access my records and why? - Allied health services can access my records - What if my medical history is shared an
Confusing	- Terminology used online - Accuracy of information provided on online - Not every doctors client and hospital is represented
Difficultly accessing	- Vision impairment - Do not understand how to use the portal - Low levels of digital literacy - Unreliable or no internet in the home - Mobility impairment - unable to leave home to use public access computer

TABLE XI. HEALTH'S RESPONSE TO COVID-19

Theme (listed by priority order)	Users comments
Medical	- My doctors appointments are now online or over the phone - I had my scripts faxed to the chemist, who delivered them to my house - I am scared about contracting COVID by seeing the doctor and sitting in the waiting room
Information provision	- Information about the outbreak is online - There is conflicting information about the spread of COVID - Information not online was hard to find
Services	- I was able to see my doctor even on weekends

VI. Discussion

More than ever, inclusive digital services are critical to keeping Australians connected during this pandemic. The extent to which the delivery of the Australian health care system is exposed to disruptions including those imposed by COVID-19, has been two fold. Firstly, some of the changes have left health providers more able to provide timely, efficient, and appropriate care for a given individual. However in contrast, the effectiveness of health care is often determined by the characteristics of the delivery system, in this case 'telehealth'. Moving to a learning healthcare system delivered solely online will require the identification of specific areas where system complexities slow or inhibit progress. Findings indicate that an online only approach slows the development of solutions due to the diversity of technological capabilities of the end user (i.e., patients). Overcoming impediments such as lack of computer literacy and absence of technology savvy skills amongst the end users is a priority for e-government platforms aiming digital inclusion between the general population.

At this point of time, it is almost impossible to foresee the horizon past the peak of the COVID-19 disruptions. However, it appears that once we move to the Post Pandemic phase, there will be a chance to reform Australian social service e-systems. The ATO case set the example by being a "fast mover" adjusting their e-services, embracing technology and the new ways of working. In doing so, it appeared that they touch on some of the themes influencing end user digital adoption: User Centred Model (as shown in Figure 2) and maintained a face to face contact when needed (i.e., human phone support access).

Disruptions such as the COVID-19 Pandemic demands a new value network that reinforces all stakeholder participation in the digital ecosystem. Findings show that this has not been the case in the health arena when participants were asked what they thoughts were in relation to My Health Records and the overall response to COVID-19. Information as well as clear accessibility to data were some of the barriers identified. This is of great concern when already analysts are seeing a significant increase in the uptake of telehealth since the outbreak of COVID-19. We must take into account that patients already have an expectation of how care should be delivered when liaising on a face to face health appointment, and these expectations are increased by the virtual care options in which they see themselves having a more personal medical consultation. Table XI shows how participants adopted this system to supplement in-person attendances. Overall, the participant perceptions were positive in terms of having access to an online care system and yet struggled with finding information and allocating the right process to follow.

These care models, which under the current environment, may become mandatory systems, demand health systems that are digital inclusive and user friendly. It is at this point that we argue that a better understanding of the stakeholders' interaction and behaviours is needed to facilitate a rapid and effective integration. The patient's (i.e., end users) perception, is that technology is poised to flip healthcare from scarcity to abundance. Therefore it is highly likely that the type of healthcare online services expected is one that provides them with ongoing / unlimited access. These new models of care provide another layer of complexity to the already complex system in place. However, we argue that in these disruptive complex times, there is a great opportunity to improve healthcare policy and the many aspects of the digital healthcare functions keeping in mind the adoption of a User Centred Model. A User Centred Model, in particular, can focus on the digitalisation of systems that enables ongoing access to patient care; patient and provider experiences; as well as the productivity and efficiency of the health system in allowing full-engagement and understanding of all involved.

There is no doubt that Australia will need to have a structured approach to continue the virtual care motion from the COVID-19 pandemic. This approach can potentially be initiated by a complete understanding of all the stakeholders already involved in the current digital health eGovernment platforms (i.e., MyAgedCare and My Health Records) in order to guarantee a truly inclusive digital healthcare system and an effective telehealth tool. In addition, as the ATO case showed, the stakeholders within the health sector should aim to strengthen partnerships between Australia's technology sector and providers to drive virtual care inclusive systems. Australia is at a critical point in which the assurance of the development of policies balancing robustness with ease to support the adoption of new virtual care technologies is detrimental. As mentioned earlier, a good starting point is to encourage telehealth and other digital systems to connect to the My Health Record and other existing technologies that health professionals use today. However, of great importance is to enable trust levels prior engaging with technology, levels that are often triggered by first hand face to face consultations. Perhaps, this calls for an initial hybrid approach. An approach that can be considered a transitional and user training approach. Particularly in cases where digital health services were told to be unreliable or participants did not have strong internet connections. Therefore attention to the right infrastructure that enable data and information to freely and securely flow must not be left outside the health agenda.

Little was known prior to the experiences of 2020, that the digital divide was to become more complex and generate disruptions to the already challenging environment of mandatory digital systems. The COVID-19 pandemic is a unique disruptive element that will challenge our digital culture in many ways, not least in our expectations of how we receive healthcare and access all government social services. This research highlights that virtual healthcare and the lessons learnt from ATO have had an important role to play in the future of eGovernment digital platforms design and its expected that all the digital transformation in the eGovernment sector that will continue to occur will be as digital inclusive as that seen already in other industries.

Therefore, a systems' worldview, a systems thinking lens can provide the avenues for a comprehensive analysis of the transformational forces within the Australian digital platforms by looking at different stakeholders and their ability to respond to change.

VII. CONCLUSION

The preliminary findings from the digital health space in comparison to the ATO case study demonstrates significant similarities between the digital/online platforms and the issues associated with digital awareness, acceptance, assistance seeking, accessibility and support. As demonstrated within the results of the ATO case study and Services Australia examples, the value of face-to-face or human interaction based assistance is still a necessary component of the success of eGovernment service inclusiveness. Digital health too quickly removed the face-to-face component of assistance in regard to both My Health Record and My Aged care, decreasing the inclusiveness and making it difficult for individuals who preferred face-to-face support. Human interaction support is available in this space, however does not provide the same emotional support often expected within the delicate situations evident in healthcare. However, acknowledging the disruptions caused by the COVID-19 pandemic, we are not critiquing the quick digital response provided by telehealth systems. But we are highlighting the fact that the digital platform of the Australian health care system faces major challenges in aiming for 'a digital inclusive' user interface. Challenges additional to digitalisation are to be consider while transitioning to different ways of working by citizens, these include: the increase of demand for provision of care in aging groups, and the rising costs due to COVID-19.

The responses on perceptions on what participants think about My Health records platform (see Table VIII) indicates that users will expect services to be tailored to their specific needs, to guarantee privacy of personal data and information, and to address their personal preferences in the way they will access the interface. For policy-makers in the design arena, the challenges and implications are around the identification and inclusion of knowing who these users are, responding to their specific demands, and developing platforms that personalizes the experience to what is relevant to them, especially for our more vulnerable users: the disable and aging population. Technology and data are only as effective and efficient as the insights they gain in order to better respond to all stakeholders' needs.

My Health Record and MyAgedCare have a considerable amount to learn from the ATO and Services Australia, who have maintained high adoption and satisfaction ratings within their digital service. Furthermore, through multiple iterations, ongoing improvements were made possible, while ensuring that different avenues for obtaining support and assistance were available to suit the user's needs (e.g., in person, over the phone and through intermediaries). What this research has indicated is that the digital health services have moved too quickly in their transition from legacy to digital services. The ATO learned within their transition to digital first services, specifically what legacy systems they could do without and which ones they need to maintain and improve.

eGovernment services across the various sectors in which they operate must seek to further understand their stakeholders and overcome the barriers experienced in the full digital integration of its users in order to provide a truly optimised experience and maintain ongoing engagement. There are key elements that need to be addressed to be successful, and ones needing further research: such as the concept of "digital inclusion in disruptive times" and the concept of "value exchange" between the user and the service, whereby there must be a benefit for the user to allow access to their data without their ongoing concern of privacy laws and access inequality.

Future research is set to explore the role of digital health and telehealth in greater detail within the palliative care space. In order to assess the challenges and experiences across the different areas of health care.

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Reflexivity, Language Games, and Computer-Supported Cooperative Work

Being an Insider in Engineering Projects: The Case of Designing Maritime Technology

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***Abstract*—Computer-supported cooperative work (CSCW) researchers have plenty to say about designing through texts; however, implementation and the gap between the design material and texts are misunderstood by systems developers in engineering projects in the process of designing collaborating systems. This problem is not new but an ongoing issue of utilizing CSCW insights effectively and correctly in engineering projects. By reviewing a five-year, multiple-site ethnographic study in the maritime domain, this paper reflects on reflexivity and language games. These can be used by CSCW researchers as theoretical concepts to study their own contributions and better position themselves in engineering projects, thus producing the same images and languages between themselves and others. By examining their own contributions, CSCW researchers could reduce the gap between CSCW research and engineering practices.**

Keywords- engineering design; language games; CSCW; reflexivity; practice–research gap.

I. Introduction

For decades, researchers in the field of computer-supported cooperative work (CSCW) have assumed that they are able to inform the design of computer systems. However, this assumption has created gaps between CSCW research and engineering practices [1][2]. Systems developers in industries are considered outsiders by the computer science community and are mostly engineers within the fields of automation, machinery, electrical, and manufacturing and processing. Although information technology has successfully found its own role in the fields above, a common understanding of designing collaborative computer systems has yet to be achieved [3][4]. For example, the collaboration between systems automation and machinery engineering is about integrating machines with different functions. Designing such systems requires systems developers to reflect on the collaboration of machines and the machines' view of the end-user's work procedures.

Although CSCW researchers have plenty to say about designing cooperative systems to support end-users, the researchers have not done enough to translate the theoretical knowledge of CSCW into forms and instruments that can be used by the wider communities who might act on the researchers' findings [5]. Rather than consulting CSCW insights [6], systems developers primarily rely on their own professional knowledge and skills during systems development. This phenomenon causes a problem in which the final design does not involve end-users sufficiently.

The core problem is that CSCW researchers might assume that they are systems developers. To some degree, these researchers overlook systems developers as end-users of CSCW research [7]. Grønbæk et al. argued that the main CSCW challenges in large-scale technical projects are that "[u]sers do not make explicit distinctions between working in cooperative or individual 'modes', they just want to carry out their work" [6, p. 76]. The same could apply to systems developers, who do not always follow their work routine (analyzing, designing, implementing, testing, and iterating the process). Instead, the golden rule is to use and reuse any developed systems models in a new project and then update the development log to show the requirements were fulfilled [8]. This is an ongoing debate in the field of engineering. However, the present paper has no intention to reopen this debate, as this topic has been discussed repeatedly. Instead, this paper considers this phenomenon in seeking an approach that could support systems developers with fruitful and practical CSCW insights for designing maritime technology. The current CSCW literature does not always involve the insights of the systems developers or uncover many important aspects of general interest for work in the engineering setting, because many may not have been uncovered by engineering work routines.

In line with many other struggles in the CSCW community, such as the issues of implementing CSCW systems from scratch [2][7][8], the unsurprising failure to use CSCW insights in engineering projects can also be found in maritime technology. The application of current maritime technologies does not support cooperative work among operators on board [7][9]. The current design of operator–vessel interaction follows the principles of engineering design, including cognitive ergonomics and human factors [10][11]. The fundamental principle is to focus on the design applicability, the scope of the technical process, and the system structures to support the efficacy of machine use [12]. Operators are subjects in the experimental work conducted to verify whether a design is successful. However, the social aspects of human–vessel interaction have been largely dismissed. Moreover, operators are not encouraged to articulate their requirements, and the system design team is composed of various specialists serving as consultants to the project.

If the above are the facts, then how could CSCW researchers contribute to the design of maritime technology as a completely foreign group sharing few common interests with systems developers? In shifting the focus from machines to human challenges, the design of cooperative systems to support maritime operations entails positioning a CSCW researcher in the maritime field. However, very few studies have addressed how researchers can successfully conduct CSCW research outside this scientific community. For example, scholars have tried to extend collaborative computing in a design approach to shape the design processes, to help users articulate their requirements with other specialists in systems design in the aviation and maritime domains [13]–[15]. Thus, it would be worthwhile to discuss how CSCW can be extended beyond the classic discussion about the relationship between ethnography and design [16] to the collaborative effort of computer scientists and sociologists [17].

The remainder of the article is structured as follows. Section II presents the movement in CSCW research and the research question of the present paper. Section III outlines the main case (i.e., designing remote control systems as the fundamental background of the article). Section IV presents reflexivity and language games as the theoretical concepts and methods used in the paper. Section V describes how participants are recruited in designing remote-control systems with respect to CSCW insights. Section VI presents the reflection of using theoretical concepts to guide the work in engineering projects. In doing so, the paper discusses its contribution to CSCW research in Section VII, which moves the historical debate on the relationship between ethnography and design to a new focus on the role of CSCW researchers in engineering projects to support CSCW research. The paper is concluded in Section VIII.

II. The Movement in CSCW Research

The movement in CSCW research has been the subject of debates for several years [18]. Current CSCW research has moved beyond single disciplines, such as sociology and computer science, to establish itself well in a new field. However, in the key literature on the intervention of design in CSCW [18], little attention has been paid to intervention in CSCW research [18]. Even when intervention is addressed, it is not clear how, when, and what could be intervened. Although a few studies addressed how CSCW research can help in design technologies, mainly in the healthcare field, the difference is that the work practices of health workers require CSCW researchers to communicate with developers who, in most cases, share a similar background, such as computer science, software engineering, and the like.

However, it is quite a different story when CSCW researchers work with people who have different backgrounds while focused on control engineering and automation. In such contexts, priority is given to expertise outside CSCW, and interactive experiences of computation and cooperative work become less vital. Operators are affected by usefulness and usability issues in the given technology. Moreover, different priorities in the design process challenge CSCW researchers, who must design systems in cooperation with "outsiders." In protecting their own academic interests, CSCW researchers have to find ways to make sense of CSCW insights beyond their own discipline [7].

As a member of the new generation of CSCW researchers, the CSCW researcher ("the researcher") in the present work has multidisciplinary education ranging from software engineering to social computing. The researcher not only can understand the design site and the object of study but also has hands-on "practice." As Ehn [19] points out, this generation of CSCW researchers understands the language games (referring to a philosophical concept developed by Ludwig Wittgenstein where language use and actions into which the language is woven) [20] of use activities and can transform the bottleneck of computer-supported activities of users in real life into the rule explanations of systems development as procedural and reproducible practices for the design process. This is not a new and one-way approach to understanding practice, but a method addressing Ackerman's definition of "the divide between what we know we must support socially and what we can support technically" [21].

Thus, the research question for this article is formulated as follows: "How do we shorten the distance between CSCW research and its practice in engineering projects?" Unlike studies [1][15] that focused on organization (working division of labor) and CSCW, this paper adds new evidence and insights regarding the use of the concepts of reflexivity and the Wittgensteinian concept of "language games" to probe the practical implications of CSCW design as an evaluating the quality of CSCW research in engineering projects [14]. In the following sections, the design of remote-control systems for autonomous vessels is used as a case. The bottleneck of CSCW research in an engineering project is transformed into a contribution of procedural and reproducible practices in implementing the design process.

III. The Case: Designing Remote-Control Systems

Traditionally, maritime technology focuses on control systems, machinery, and the automation of maritime vehicles of any kind. The design process is purposeful, systemic, and iterative. Systems developers conduct their work in various constraint conditions to find possible solutions for problems, which are usually limited to the given scenarios. Systems developers communicate with a small group of users, for whom the design follows a positivist paradigm with the intention to ultimately test a system. Design requirements are usually based on three principles: corporate, technology, and social [3]. The primary principle is that the corporation must be able to generate design requirements in line with the company's organizational structures, strategic vision, and available resources, based mainly on the knowledge and expertise of the systems developers. This principle does not change until social aspects challenge the company's framework through markets. The second principle, which Gershenson and Stauffer [24] termed "technology," is the knowledge of engineering principles, material properties, and physical laws [12]. User requirements are considered last. The requirements of the third principle are weighed to optimize the trade-off with the requirements of the first two principles and to align them with the needs of the users, including the "must-have need" and the "attractive need."

Thus, in line with the principles, systems developers consider artefacts important for remote-control systems. In addition, systems developers narrow the design specifications to comply with reliability, ergonomics (i.e., human factors), manufacturability, and control ability similar to software engineers, who use models to automatically synthesize an executable code [25]. The philosophy underlying all the solutions is technology-centered design. In other words, by using a certain algorithm to represent situational awareness [26][29], systems are expected to represent information as accurately as possible in human decision making [25][27][28]. The common principle that underpins these previous studies is the assumption that the systems will be well-designed to support human tasks, such as drawing patterns, creating models, and making sense of a machine's actions. Through well-structured technology-centered experiments, as in most engineering projects, systems developers expect that human factor specialists [21][22] can investigate whether interfaces could be built to satisfy the operators. If so, what kinds of "human error" could be investigated? Hopefully, the results can be utilized to reform the systems according to a better vision. As a consequence of this approach, operators are expected, oddly enough, to be re-trained in the skills needed in the autonomous future [30][31]. The others, without protection against the failures, errors, and faults caused by technology, which cannot be called human errors, are treated as regulatory and policy issues [24][25][32]. Politicians, societies, and shipowners require clarification of the potential liabilities (e.g., collisions) introduced by autonomous technologies [33][34].

However, the cost of the running ships may not be decreased as expected. Instead, it might increase significantly due to infinite maintenance and changes in remote-control systems, which will certainly displease operators and shipowners. When changes are introduced, people quickly learn the changes' characteristics and discover how to maximize them. When autonomous technology and remote control are introduced, people react in the same manner.

IV. Theoretical Concepts and Methods

To better understand the role of CSCW researchers in engineering projects, two concepts are of interest, namely, reflexivity and language games. Reflexivity is a method for sharing sense-making between practitioners and an ethnographer in terms of gaining performative knowledge of professional expertise. Language games are a method for guiding CSCW researchers to practice their interpretation of findings in various ways that fit engineering projects for systems developers and the sponsors of the projects (i.e., the shipowners).

A. *Reflexivity*

Calas and Smircich [35, p. 240] define reflexivity as the "constant assessment of the relationship between knowledge" and "the ways of doing knowledge." Through "reflexivity," researchers can pay attention to *"the way* *different kinds of linguistic, social, political, and theoretical elements are woven together in the process of knowledge development during which empirical materials is constructed, interpreted and written"* (p. 9). In conducting a reflexivity study, interpretation is used as a tool for producing scientific knowledge [36]. In doing an interpretation, we reflect on how *"we become observers of our own practice"* [37]. Reflexivity suggests the complexification of thinking and experience or thinking about experience [37]. It is a process of exposing or questioning our ways of doing. In a discussion of the third wave of human–computer interaction (HCI), Bødker [38] calls for a crucial and conventional understanding of reflexivity. Reflexivity, according to her, is different from positivism: Reflexivity is an intervention for data gathering. Bødker does explain how this process impacts the quality of the data itself. In the end, reflexive practices can find structural patterns in what they have observed, thus extending the theory the practices used. However, reflexivity has had difficulty finding a place in HCI and in CSCW literature. Due to the subjectivity of the methods used, it is difficult for reflexivity researchers to open their work to future scrutiny. Geirbo [39] states that reflexivity itself is important as a kind of methodological consideration, which can guide researchers as they attempt to enter a community, phenomenon, or practice considered foreign to the researchers. In the present, it is possible for researchers to share sense-making between practitioners and an ethnographer in terms of gaining performative knowledge of professional expertise. Researchers also have the capability to articulate and analyze such performative knowledge gained through an insider role [40]. In this effort, it is possible to bridge the practice–research gap by enacting researcher-practitioner roles across community boundaries, developing and disseminating new knowledge, and engaging field professionals outside the CSCW community.

Thus, in line with this specific theoretical concept, CSCW researchers can be reflexive about how their ethnographic accounts will affect the research process. This action can help *CSCW peers* gain a better understanding of the choice the researcher has made during the entire research process, including the design, data collection, and interpretation phases. Reporting and discussing the theoretical struggles of interpretive empirical research can also help fulfill the principles of "dialogue" [41] through languages in between the fieldwork material with the reflectivity thinking and engineering projects. The core of the "dialogue" interpretation relates to the experience, so that CSCW peers can understand what the researcher has seen and experienced, and learn how to evaluate that work. In turn, they can sense the socio-technical gap within the CSCW research itself, as well as that between humanity and engineering in general. Meanwhile, in most cases, CSCW researchers have to contribute to other engineering fields. Researchers' writings and insights are also considered in other research and development activities. Thus, evaluating the application of the CSCW insights in dialogue is useful not only for CSCW peers but also for others through some meaningful forms.

B. Language Games

To make sense of the CSCW insights in a dialogue for non-CSCW systems developers in engineering projects, language games [13][35] have been considered in the literature for a long time [1][14]. Wittgenstein speaks of coming to understand what people mean by having someone explain the meanings of the words. He emphasizes that one needs to be trained to learn language games. That is, being able to speak and understand what one said—knowing what it means—does not mean that you can say what it means, or is that what you have learned. Wittgenstein [42, p. 32] gave an example in his book, *Philosophical Investigations*: "*Augustine describes the learning of human language as if the child came into a strange country and did not understand the language of the country; that is, as if it already had a language, only not this one."* In other words, you might see whether systems developers know techniques, notations, and norms by asking the developers what the expressions mean. However, that is not how CSCW researchers can tell whether systems developers can read thick descriptions of identified design issues from the system development. Moreover, it is not what systems developers learn when they learn to practice the technical languages and skills of systems design. Thus, the mandatory skill of using different forms of descriptions of CSCW insights now seems vital to CSCW researchers.

In his Blue book, Wittgenstein encourages us to analyze our own ordinary language as though we want to discover something that goes on in our language as we speak it, but which we cannot see until we take this method of getting through the mist that enshrouds it [20]. As he [13, p. 17] puts it, "The study of language games is the study of primitive forms of language or primitive languages. If we want to study the problems of truth and falsehood, of the agreement and disagreement of propositions with reality, of the nature of assertion, assumption, and question, we shall with great advantage look at primitive forms of language in which these forms of thinking appear without confusing background of highly complicated process of thought. When we look at such simple forms of language the mental mist which seems to enshroud our ordinary use of language disappears. We see activities, reactions, which are clear-cut and transparent. On the other hand, we recognize in these simple process forms of language not separated by a break from our more complicated ones. We see that we can build up the complicated forms from the primitive ones by gradually adding new forms." Wittgenstein further emphasizes in his Brown book [42, p. 81]: "We are not, however, regarding the language games which we describe as incomplete parts of a language, but languages complete in themselves, as complete systems of human communication." With this in mind, CSCW researchers might see people who are taught their "native" language (i.e., engineering techniques, etc.) by such a language game in which they even have their own forms of games. The CSCW researchers' duty is to convert our writing of system design into simple languages that can be useful tools (i.e., activities, reactions, and other forms that are clear-cut and transparent) for the entire systems of communication of the development team. In this sense, we (CSCW researchers and systems developers) are all on the same team and use the same simple languages.

Language games as the second concept are fruitful in this endeavor. This is because they help CSCW researchers move further from reflectivity positions—a somewhat struggling social invention in CSCW system design toward *ostensive expression* [20] of our writing in CSCW research and engineering projects. Language games encourage CSCW researchers to state their insights not only for their peers but also for the outsiders of the CSCW community. A few researchers believe that language games might be a method for helping researchers (CSCW researchers and other researchers in design disciplines) to shorten the distance between humanities and engineering, thus building a bridge to help systems developers recognize what we write and know what we mean through the "signs" [20] that we use, such as Use Case language [3], systems modeling language, or contractual statements [43].

C. Methods

For a long time, the role of CSCW researchers in the maritime domain has been questioned. The researchers struggled to answer this question, because the contributions of CSCW might not remain in their area (i.e., *interpretive ethnography*) but extend to a foreign context in which CSCW researchers would have to change their tone and voice so that those living there could understand the researchers. Although the initial question in 2015 was, *"What is going on in designing maritime technology?"* when fieldwork at sea was conducted, other questions were asked by the project owner about how maritime technology was produced, assembled, and maintained then. These questions were frustrating but somehow easy to answer. After addressing these questions, the researcher successfully demonstrated the importance of CSCW insights in analyzing maritime operations for better maritime technology designs [14]. As an extension of that successful analysis of maritime operations, remote-control systems were chosen, because the ongoing research on automated ships might benefit from the researcher's previous work.

The remote-control systems were designed on land. Due to the natural complexity of the projects, multi-site projects [44] were conducted at sea and on land to observe and interview the people who would become the users of these systems. Seminars, workshops, and conferences were held in which shipowners and various stakeholders, such as systems developers, policymakers, and other relevant participants, celebrated their technical achievements. The researcher is part of a land-based maritime design team. In addition, he also observed, conducted interviews, and then wrote about findings from the fields after conducting fieldwork in different workplaces, such as on board, design companies, education conferences and seminars, and videoconferences. The fieldwork began in the first year when the researcher was a doctoral student at the University of Oslo and continued after he received his doctorate degree.

Although the research project required long-term engagement in the maritime domain, fortunately, the heterogeneous group has not changed much since 2015. A group of professionals, including operators, systems developers, educators, and shipowners, are involved in the study. The present work is a long-term project to observe and interview them in different places at sea and on land throughout European countries. An online platform was established in which systems developers could share information via email, conduct videoconferences, and chat and leave comments on documents. Topics that the researcher did not understand were posted so that someone could explain them by leaving comments and observations. In addition, interactions with systems developers were carried out through individual emails and videoconferences to construct an ethnography of their experiences in design work. Several new participants joined the long-term study, but others have been part of the study since the beginning. Thus, informed consent was not required, and the research was only verbally introduced to the newcomers. Several stopped participating as they were starting new career paths.

However, they kept in touch occasionally in case any questions needed to be followed up.

Table I illustrates the research activities conducted since 2015. Notes were taken during the interviews, seminars, and workshops, but no audio-recordings were made due to ethical considerations. At sea and in land-based simulator rooms, the observations were video-recorded. However, not all videos were transcribed. Instead, only those that were relevant to engineering projects, particularly the design process, were transcribed. This is because cooperation between seafarers at sea and on land is essential.

TABLE I. RESEARCH ACTIVITIES SINCE 2015

Settings	**Methods**		
	Number of Interviews	***Hours of Observation***	***Year***
At sea, on board	72	1838	Autumn 2015–Spring 2016
Land-based simulator room	18	48	Autumn 2016
Conferences on sites	4	-	Autumn 2017–Autumn 2019
Seminars	9	-	Autumn 2016–Autumn 2020
Workshops	7	72	Autumn 2016–Autumn 2020
Emails	232	-	Autumn 2015–Spring 2020
Videoconferences	4	-	Spring 2018–Autumn 2020

The data analysis has been ongoing since 2015, which involved thematically indexing words, such as "cooperative work," "design," "remote-control," "systems collaboration," "team's cooperation," "remote control," and so forth. Themes were also identified. However, these themes were used to describe not only the remote-control system design but also the other works of the project. They were also emphasized during investigation and design in the maritime domain in general. The purpose of the data analyses is to offer an ethnographic account of the practice and associations orchestrated by crossing multiple sites off- and online, particularly in the case of a remote-control system. Moreover, the analyses aimed to direct attention to the researcher's self-reflectivity [45], focusing on language games [1][14][15][35], to bridge the gulf between what Dourish calls the "sociotechnical gap" [23] and Ackerman's definition of "the divide between what we know we must support socially and what we can support technically" [21] without pre-conditions. In other words, this paper addresses the gap between CSCW research and CSCW practice in industrial contexts.

V. IMPLEMENTATION OF CSCW INSIGHTS IN AN ENGINEERING PROJECT

In the maritime domain, operators are rarely involved in the design process. As previously stated, they are used as subjects for testing purposes when a product is being developed. Educators are also rarely involved, because they teach operators without considering their concerns about technology. Moreover, CSCW researchers are also not typically involved in a maritime design project, because their expertise is invisible in the engineering field. Likewise, shipowners are rarely consulted in design projects for various reasons. Thus, in this study, a group of stakeholders was assembled to balance their interests in design for a sustainable solution for all based on the CSCW perspective.

A. Involving Stakeholders in the Implementation Process

In 2016, various challenges emerged. The operators thought the researcher was a systems developer or at least someone who knew how to develop their computer systems. They thought that the researcher was only concerned about examining their work. However, that was not the case, as he was a CSCW researcher who was also trained as an ethnographer. The researcher was on board to evaluate work but also to observe what was going on. The researcher also wanted to interview the operators. Based on those findings, the researcher would work with systems developers to design the remote-control systems.

After the explanation above was provided to the operators, they were worried that what the researcher observed and heard would be documented as evidence for changing the vessel design to automatic shipping. They thought that the researcher could be a spy who was studying them and would try to create a technology that would replace human operators. Although the purpose for being on board was thoroughly explained, and they had given informed consent to participate in the study, they initially misunderstood the researcher's basic objectives. However, later, the operators apologized and added that they actually hoped that their expertise and knowledge could someday be acknowledged rather than overlooked when remote-control systems are designed. Since then, the researcher also noticed that not everyone welcomed the possibility of shifting to a remote-control system.

On board, one of the operators expressed his concern that he did not believe the systems could do what he was good at. He felt that his experience at sea could not be simply cloned into a machine. He also felt anxiety thinking about the possibility that the shipowners just wanted to save costs and did not care about the operators. The researcher did not know how to respond to such concerns at that time, because it was hard to promise that they would be assisted rather than replaced by the remote-control system. It was also not easy to say that their expertise would be acknowledged and used in designing maritime technology. Moreover, the systems developers adopted a concept called "human-in-the-loop" anyway, which meant that the machines would interact without human assistance, and human operators would simply serve as a backup if a problem arises.

This concern was not unique. In 2018, the same worry about remote-control systems was expressed by maritime educators. These educators expressed their concern during a conference on upgrading the skills of maritime operators for digitalization in the future. In a panel discussion, several educators questioned remote-control operations and worried that no one knew how to teach the technology as no one had actual experiences using it. Although the educators believed that re-training themselves was needed, they did not believe that the simulator-based system was the best solution. In addition, although the educators said they might be re-trained, systematic training was not available. Simply put, remote-control systems have yet to be fully delivered to users. The work was mainly conducted in engineering projects firms, and only systems developers ran the design work. However, systems developers assumed that they had knowledge of remote-control technology, and that it was less important to observe current maritime operations or consider the concerns raised by other stakeholders. During a design workshop at a company held during the autumn of 2018, a question was asked: *"What was the purpose of the remote-control technology?"* One system developer replied that a remote-control system aimed to replace human beings on board due to the unsafe operations brought about by human errors. In this case, human operators must be relocated on land to learn new abilities to control an object that they would not actually touch. Another concern was also raised at this point: the cybersecurity issue.

The answer was not convincing, as the skills referred to by the systems developer were not clear. The developer was asked about the new skills, the issue of cybersecurity, and who would take responsibility for the control vessels. A satisfactory nswer was not given. Instead, the systems developer assumed that skills were about interaction. Operators must take responsibility for handling any problems and make decisions or interventions if needed. To give a reasonable answer, the systems developer guided the researcher to a lab, in which a huge screen with much information was presented. A systems developer sitting in front of the screen brought out four small screens to simulate a case. The case was about a vessel that was remotely controlled but under attack from unknown hackers. The systems developer said he would lose control of the vessel, so he was finding ways to solve the problem. The solution was to protect the user interfaces through developed software. Using the mouse, the systems developer opened a software application and ran it to protect his user interfaces. The developers believed that it was a method related to remotely controlling a system and that no operators had had a chance to learn it. It was not surprising that systems developers expected to train everyone to use the new technology. However, it was strange that operators needed to be trained to click a software application to protect the vessel.

In terms of other factors, such as the weather, waves, and swimmers in the fjord, if the simulation was not real, why would educators worry about training? Operators could become familiar with the interaction styles in the new technology. However, although the educators were eager to welcome remote-control systems, they often mentioned that their goal was to obtain educational funding and not improved outcomes of their teaching and students' learning. They said nothing about learning how to interact with computers. However, this is not new in maritime studies. When the researcher discussed this issue with an educator at another conference in 2019, the educator replied that simulator-based training was a kind of computer game and not a true operation at all. Thus, the whole shipping industry may have misunderstood a basic question: "*What learning outcome and what level do we expect to achieve in simulator-based training*?"

Interestingly, the educator knew it might be questionable to accept the systems developers' proposal to conduct training with simulators. However, the entire maritime domain seems to follow the systems developers' wishes. The educator cannot challenge that value. Although the researcher tried to play a mediating role between the engineers and operators, there were invisible hands pushing for engineering projects to be conducted as quickly as possible.

B. The Role and Activities of the CSCW Researcher in Implementation for Design

The scenario above indicates that intervening directly in the design process is difficult. This situation is not like an empirical study conducted before the actual design process has begun. In the maritime domain, systems developers assume that software and computer systems follow mathematical models, but this assumption is incorrect [46]. In 2019, by chance, the researcher was able to observe the application process for innovative educational programs for maritime studies. There was a call for applications by nautical science departments at universities to use a bottom-up approach to position students in the center of designing new study programs. The objective of the call was to establish an ecosystem to support life-long relationships among technology, engineering companies, educational institutions, and most importantly, operators. As the researcher was engaged with the educators, he invited systems developers during the application process and wanted to contribute to making the voices of operators heard. However, it did not happen in the beginning, because how they would react to such a call was vital. In that case, the researcher might help with translated CSCW insights in the following workshop with systems developers. In CSCW research, balancing outsider–insider roles and avoiding inserting the researcher's biases into the project are important. Although CSCW insights may help design technology, it is unclear whether those insights would pose difficulties for systems developers, challenge their professional expertise, or even interfere with their work on the ground. The same applies to working with educators. In addition to using CSCW insights to shape technology design, the intention is to scrutinize the usefulness of such insights outside the CSCW community. The power relations between different stakeholders could be balanced by their own interests rather than by an external force, such as the role of the researcher in the present project. Thus, instead of interviewing the stakeholders, as most ethnographers would have done, a few challenging, structured questions were asked, with the aim of fostering a new way of thinking about design.

The researcher participated in a design workshop again in 2019, in which the systems developers were asked how they understood a bottom-up approach in the design process. The goal of the researcher was to investigate how CSCW insights can be used in engineering project. There were no clear answers. However, no one doubts that in systems developers' eyes, a user is the person who pays for the project: the shipowner. During the dialogue in the workshop, the operators were not mentioned even once. The researcher reflected on the fact that multidisciplinary design is a challenge that requires the reconciliation of diverging design perspectives [47]. Although software engineers and CSCW researchers in software design projects in the CSCW community can share and integrate their viewpoints in the design process, such a process could still miss important aspects of the design problem [48]. If that were the case in the CSCW community, then this would also apply to the engineering field [49]. Systems developers lacked the ability to demonstrate the effects of their design concepts because of their insufficient thinking and reflection about such effects. CSCW researchers may also be unaware that systems developers are also the end-users of CSCW insights. In line with these arguments, during the workshop, the researcher translated what he observed from the remote-control design into Use Case techniques. A diagram-based description [15] of the system was used to show the systems developers how operators work in reality and how current systems failed to support the operators' work. If we are trying to move cooperative work on board to the land control room, we must support their natural work practices as they are offshore. Then other technical considerations, such as cybersecurity, will make sense to operators. In this case, systems functions for the needs of products fully respect the expertise and professions of the operators. The final component, training through simulators (a colon version of a true remote-control center) could answer the educator's question: *"What is the final outcome of learning?"*

This workshop was successful. The systems developers were happy to design together with the researcher, and they stated that this workshop was different from other CSCW research in which only storytelling was delivered. In this workshop, the researcher stood in their situations to discuss with them how systems functions could be designed from the stretch. The researcher was not just a researcher in the project; he also played roles as a systems developer and an operator to draw a comprehensive image of maritime operations—something that no systems developer has ever experienced.

For CSCW researchers in the maritime domain, the work is about breaking the circular relationship: "shipowner–engineering designer–shipowner." In the article "Located Accountabilities in Technology Production," Suchman reflected on her experience in addressing a similar problem as *"a central dilemma of CSCW researchers' participation in increasingly complex divisions of labor and professional specialization were the layers of mediation between each of us and the consequences of our work"* [50]. Although it was the responsibility of the research to the process of technology production, the researcher, his or her participation, of course, can break the relationship into pieces. The question for the systems developers was about investigating whether they wanted to take responsibility for tracing the usefulness of the production. However, they simply hand off the production after delivery, and they might never revisit it until someone requests updates or changes. In the present study, one of the systems developers discussed the following with the researcher privately after the conference: *"The whole industry works in a mechanism like a design-test-deliver-maintenance loop. It is about business. Our motto is that users know very little about what they do and what they want."* This is not, however, a convincing explanation. Bannon [51] warned that users are as professional as anyone else about their workplace and tasks in designing computer systems. They have an insiders' overview of their work and the tools (including technology) that assist them.

CSCW researchers are challenged in thinking about how to assemble different insights to propose balance between design and use. According to Suchman, she dwelt uncomfortably in the gap between design and use for many years in the 1980s. Trying to find a balance between design and use forced her to think about her role in technology design projects. She concluded that she, as an anthropologist of technology, could only translate her practice into design terms. However, because of the division of professional labor, the problem was caused by neither her ability nor that of the design team [50].

After studying the maritime domain for several years, the researcher's feeling is different. As the researcher is part of the new generation of CSCW research, the origin of the problem is known: the mismatch of design problems across multiple disciplines, such as design, science, and engineering. We also knew where, when, and how to contribute to a project to benefit everyone. However, we could not fully address the issue. The reason was not the capability but the role of the CSCW researchers in the projects: There was simply no chance to intervene in the design process from the very beginning. Due to the rapid marketing changes and technological development in the shipping industry, technology companies would like to respond quickly to shipowners' expectations. Thus, CSCW researchers will always intervene late in a project. In fact, in the worst cases, CSCW researchers are expected to focus on how their studies can be used in future projects based on the results of investigating current technology. However, could this also be a good chance to make a contribution?

On this occasion, the situation was changed. Although no one has actually developed remote control, for various reasons, researchers could intervene during an early stage to learn how to position themselves in potential projects. In this case, the researcher must be sensitive about the ongoing discussion in the industry, as well as the intersection between engineering departments at various research institutions and project funding organizations.

Thus, when continually asked whether systems developers can predict the future of remote control, none could provide a definite reply. Instead, the chief developer said there were too few opportunities for them to learn from the operators. The systems developers knew where to gain knowledge, but they chose to ignore the chance because they had very limited time to read the thick and rich descriptions written by CSCW researchers. When the researcher was continually asking and inviting operators to design workshops, however, recruiting even one participant became a challenge due to various reasons. Although the operators did not accept the invitation, they seemed happy that their messages were delivered through the study. However, to some degree, it seemed that the researcher not only managed to get the developers to accept the idea that other opinions are also important in technology design but also inspired systems developers to read the diagram-based design texts to work from scratch. Moreover, the researcher inspired the operators to share their experiences and expertise with others. The researcher unconsciously stepped into the project to play the two roles of designer (i.e., guiding systems developers) and user (i.e., inspiring operators). On several occasions, the researcher formatted and reformatted the ideas and opinions of the operators, educators, and systems developers, and even his own reflections, into a language game [19] between investigation and design [41].

C. Evaluating the CSCW Research Outcomes as Contributions to Implementation for Design

Including only operators, educators, and systems developers in this study was not enough. As previously stated, the design requirements are given by shipowners. Without their participation, the design work would be unrealistic, and there would be problems if requirement conflicts arose among the operators, educators, and shipowners. The research results were documented in various formats. However, considering the differences between traditions in CSCW research across the Atlantic, it is notable that a few previous studies concentrated on how cooperative technologies could be created with a focus on articulating the work of users [52], as in the European CSCW tradition. Some studies focused on how to intervene in the design process and how such an intervention is implemented in design [18]. In interviews with Volker Wulf and Myriam, Lewkowicz, Richter, and Koch [53] observed that the term practice-based CSCW was descriptive. Lewkowicz argued that the importance of CSCW was that it enabled designers and social scientists to use the same communication channel. However, the researcher of the present work does not fully agree, because according to many CSCW studies, at least in the European context, the true design process is conducted by systems developers. Thus, it would be questionable how an intervention could be implemented realistically without a monitor. Moreover, most CSCW researchers have evaluated the outcome of the design, which can actually be seen as the performance of technology. However, only a few studies utilized CSCW insights during the engineering design process. The problem of how we can evaluate the quality of the CSCW research in engineering projects, that is, the design work in connection with CSCW research, remains.

Bratteteig and Wagner [54], in the field of participatory design, asked the following question: *"What is a participatory design result?"* They argued that *"[i]deally, a project outcome should be evaluated in a real-use situation when users have had a chance to integrate it into whatever they are doing and (eventually) develop a new form of practice"* (p. 142). As a participant in designing remote control systems, did the researcher improve the knowledge of the systems that are supposed to be designed? Through the activities to assemble participants, did the research introduce a better "tool" for all stakeholders in the projects? Did it inspire them to understand that all their voices were important (but no one had priority)? Similar to the reply of the chief developer, they acknowledged that without information from operators, it would be impossible to ensure the quality of remote-control systems in the future. The educators replied in a similar manner. Therefore, to evaluate the quality of the CSCW research in the engineering project, the researcher interviewed three shipowners at their offices at different times from August 2019 to February 2020. The aim was to enable them to develop a realistic expectation of remote control and evaluate CSCW research in engineering projects from an outsider's point of view. In turn, it was also an opportunity for the researcher to communicate his descriptive findings in a language that might not be difficult for outsiders to understand. Videos of several cases based on fieldwork conducted in 2015 and 2018 at sea and in land-based simulators were shown to the owners. The shipowners expressed their astonishment after they watched those videos. They saw a great difference between realistic operations and training using simulators. Although they all invested money in training courses for the operators, after seeing the videos, the owners expressed uncertainty as they addressed the usefulness of the current training programs. It seemed no one was sure that there was a link between training and real work in ensuring safer operations. However, everyone wanted to hear from the operators, at least the most experienced ones, and recognize their voices in decision making about technology design, including decisions about material artefacts on board (e.g., dynamic positioning systems).

In February 2020, while talking with the operators and educators during a seminar in Athens, both were offered a chance to participate in designing a remote-control system. A positive answer was given this time: *"If that could happen, it would be great that we were not just treated as tools. We do not need to bind ourselves to the terms and conditions offered by systems developers through their productions. We will not outsource our decision-making and capabilities to someone who has no knowledge of our business. We are the core elements of technology*."

Today, operators, educators, and shipowners gather in public and in private to discuss their opinions regarding design. One example is the joint call for proposals funded by the Education, Audio-Visual and Culture Executive Agency (EACEA) of the European Commission, the European Shipowner Association, and the European Transportation Workers' Foundation. They are meant to develop a bottom-up approach and a learner-centered, lifelong action plan involving education, research, shipping, and maritime technology, which are considered vital and mandatory [55] [56]. It seems timely for the maritime domain to respond to such calls rather than for the researcher to work on re-assembling them. In this way, the CSCW research work will not only describe the bottlenecks of the designed systems but also will become truly engaged in design work, representing knowledge from operators, the other stakeholders, and most importantly, the language games of the CSCW researchers.

VI. Discussion: Stakeholders' Design and Reform Design Policy of Engineering Projects

Being a CSCW researcher is about helping design stakeholders and shaping the work policy of the projects. It is about guiding various user activities to help CSCW researchers and project stakeholders comply with communication and facilitate research activities at the same time. Traditionally, however, CSCW researchers have not yet gained sufficient experience to do both jobs. The researchers mainly focus on reporting what is going on in the field, but somehow fail to technically shape the direction of the project to support cooperative work and privilege local knowledge from all stakeholders. In this section, a reflection from the experience of designing maritime technology is presented. The CSCW researcher is involved in the process of co-investigation and co-participation, and is a co-subject of the change and evaluation activities of the engineering projects. Through the experience, it is important to reflect stakeholders' design and the roles of CSCW researchers in shaping research policies and activities in various engineering projects.

A. Stakeholders' Design

User participation is currently being discussed in the CSCW community. Thus, it is essential for CSCW researchers to involve end-users, particularly weak parties - operators, during the design process [54]. Thus, CSCW researchers bring invaluable discussion on how to inform design to meet users' needs or in CSCW terms, the "usefulness of the technology" [57]. This discussion is similar to participatory design researchers' argument regarding the evaluation of the outcomes after participation.

However, CSCW researchers might have traditionally overlooked systems developers as end-users. In addition, shipowners are end-users, too. Thus, how can CSCW researchers balance all the interests of different stakeholders to achieve a good design outcome? Bratteteig and Wagner [54] asked the same question in participatory design research (i.e., *"Should researchers take sides in a project?"*). This question is relevant to the CSCW community. Traditionally, CSCW researchers have not been involved in the political issues surrounding design projects. Thus, can CSCW researchers represent different interests for an effective design solution?

In the present study on remote-control systems, the researcher took one side. In the beginning, the researcher started the fieldwork at sea to learn how operators work and see what was actually happening. After half a year, it was clear that the operators were not following the work procedures as instructed by systems developers on land. The stories and observations from the sea pushed the researcher to think about his role in the project. The question was, *"As a CSCW researcher, am I learning at sea and informing myself to develop systems to support cooperative work for the operators?"* As stated in the beginning of this paper, it was not as simple as the researcher supposed. Control theory, automation, and many related fields are the core concepts in the maritime domain. Although the researcher's background was in software engineering, this helped only with understanding some basic principles of designing maritime technology in the very beginning.

After a few field studies, the researcher's role shifted from a systems designer to a facilitator. Informing design was out of the scope of the CSCW researcher; instead, the important task was to convince systems developers to use CSCW insights from the field in a practical sense. This led the researcher to work on translating the insights into language that might be familiar to developers. The translations of the CSCW insights should be seen as activities and reactions that were clear-cut and transparent [20], just as the CSCW researcher did in the present project (i.e., gathering participants and evaluating his own work from a non-CSCW viewpoint). In that case, CSCW peers can recognize in these simple process forms of language not separated by a break from our more complicated ones.

Thanks to the multidisciplinary background, this translation work was not difficult, but it still required the CSCW researcher to spend some time understanding how systems developers work. This translation work also pushed the researcher to jump from the CSCW community to seek an external evaluation within the engineering project regarding the quality of CSCW research. For example, through several workshops from 2016 to 2019, a brighter picture of systems developers' work practices emerged. Not surprisingly, systems developers in the maritime domain perform the same tasks as the software engineers. Their work involves following orders from the project owners and carrying out their own work habits. Operators are not truly "users," as their work is to respond to the requests of the owners via the fastest and cheapest approach. Systems developers stated, "*The whole industry works in a mechanism like a design-test-deliver-maintenance loop.*" The researcher learned that knowledge from the participatory design field might help.

To involve participants to achieve a win-win situation [58], the researcher considered that a design process should respect the operators' cooperative work, as well as respect the systems developers' work practices. Additionally, the process must gain support from shipowners and show them that there is room for improvement if they want a safer and better workplace for the operators. In addition, if shipowners want more professional operators, the owners need to know who might have first-hand knowledge in the field. Although such knowledge might not be directly useable by systems developers, at least shipowners should acknowledge that the maritime technology might not be as good as they believe.

These relationships among systems developers, operators, educators, and shipowners helped the researcher draw a picture of the complexities of designing maritime technology. User involvement and the desire to understand work practices and processes are different. The researcher realized that it should be the responsibility of the CSCW community to coordinate all the considerations from various participants so that they all fit with their production and to come up with a schedule of completion for a design project [59]. The engineering project team had various types of knowledge about the work of users in the maritime domain. This was a side taken by the researcher to allocate the different interests and lead the communication to drive the design progress. Achieving good design in an engineering project seems to be a challenge for the new generation of CSCW community to balance the interests of stakeholders with better cooperative systems from the CSCW viewpoint. The decision making for a design process depends on how CSCW researchers lead the project with professional judgment based on several kinds of cooperation: between operators and maritime technologies, between operators and systems developers, between CSCW researchers and systems developers, and between CSCW researchers and project sponsors. Without this capability, it would be difficult for CSCW to step outside its own community.

Conducting CSCW research in engineering projects pushes a researcher to reflect on whether to keep the traditional CSCW work practices, focusing on the technology performance to support cooperative work, rather than adjusting the research to achieve the goal of creating something new by applying methodology against some design principle. However, the CSCW researcher may lose the chance to develop cooperative systems in the process. Carr [59, p. 9] states, "*The systems designers in either the instructional design or performance technology context must address issues of power and resistance, working with the leaders to help them see the hazards of leaving the users out.*" Thus, the present work with stakeholders might create an ideal design team and empower users to create visions apart from the agenda of the engineering project. Instead of controlling the stakeholders group, stakeholders must engage in the different takes of negotiating and working with the researcher toward a better maritime technology. This shift from expert systems developer in an engineering project to design facilitator exemplifies the design of systemic change movement, which facilitates the evaluation of CSCW insights and the work of CSCW researchers in engineering projects.

B. *Shaping Engineering Projects with CSCW Insights*

The dynamic role of CSCW researchers in an engineering project requires a long-term engagement in the investigated domain. Normally CSCW researchers must follow the domain effectiveness variables of performance and other indicators after one project is complete. In the present study, informing the design of a maritime technology should be successful outside the maritime context for which the technology has been developed. To achieve such a goal, CSCW researchers should provide a workable framework for generating and sharing sufficient knowledge about a solution that may be potentially transferred to other contexts. For example, when researchers discuss remote control and safety with shipowners, the researchers must know how to use their knowledge to tell the shipowners what can be done technologically and what should be avoided through the policies of the project. As Balka et al. [60] argued, developing a framework or tool to open up discussions about planning and implementation of information systems is important. This discussion is a step toward using CSCW insights to shape an engineering project, from the policy level to work practices.

For years, CSCW researchers have called for reforming policies through CSCW insights; however, researchers have had few opportunities to engage in political discussions and policy making [2][5]. In the present study, the researcher showed the possibility of shaping the policy of engineering projects through language games with systems developers, educators, and shipowners. He also used his knowledge to draft a scientific infrastructure and expertise [5] of the organizational complexities of distributed collaborative practices among systems developers, educators, shipowners, and operators. Using the form of CSCW insights into an engineering project, systems developers would no longer struggle to understand the effects of individual users and the ties of their own roles in the engineering projects with other stakeholders. The researcher removed the barriers of design models in the engineering fields and established crucial relationships among systems developers, operators, tools, and all aspects of practical work, thus demonstrating how CSCW can make a great contribution to supporting and improving policies, designs, and practices in engineering projects. This likely goes beyond the debate of power issues in participatory design research [54][58][61] (e.g., power to and power over [62][54]), but mainly addresses how CSCW researchers can use power as a leverage point [63] among stakeholders for designing engineering projects based on CSCW insights. Although the present work achieved a small success in shaping the engineering project, more studies can further explore how CSCW insights could guide policy making before the start of an engineering project.

VII. Reflection: Being a Reflexive Insider

This reflection may help CSCW peers understand the choice to combine reflexivity, language games, and CSCW research in exploring the maritime domain. The CSCW researcher is still active in the maritime domain and has helped introduce changes according to feedback based on observations, and where he must intervene to improve maritime technology. The intention of this combination is two-fold: 1) to deploy useful CSCW research in engineering projects, and 2) to contribute to CSCW research with practical feedback from the front line of engineering work. If the CSCW work on assembling participation and mediating outcomes between social and engineering phrases is a practical activity in language games, then the reflection on the roles and contributions of the researcher to the CSCW community is the highest achievement.

A. *Interest-driven CSCW Research in Maritime Design*

Nygaard and Bergo [64] suggested that designers, particularly participatory designers, take sides in considering the following: 1) improving the knowledge on which systems are built while aiming to build a better "tool" for users [60]; 2) enabling people to develop realistic expectations and reducing resistance to change [65]; and 3) increasing workplace democracy by giving the members of an organization the right to participate in decisions that are likely to affect their work [66]. Different from the objectives, the researcher does not side with operators, educators, shipowners, or systems developers. Nevertheless, the first two suggestions are firmly followed.

Eyal [67] warned that researchers must consider carefully who are the actual experts and who are the lay experts. As outsiders in the maritime domain, CSCW researchers may not have convincing expert judgment. Although all stakeholders have an interest in improving maritime technology, "better" is understood differently. For example, operators and educators believe that their experience and expertise are vital in remote-control systems. Systems developers rely heavily on their procedure-based design process. Shipowners seek to effectively invest in a project and reap the benefits. All these interests involve few or no political conflicts. In this case, how could CSCW researchers dare to say who is a better participant in designing remote control systems? The only certainty is that CSCW researchers can balance these interests and explore a design point via *languages* for system developers, and that such languages could represent all stakeholders in designing organizational frameworks for actions and in designing industrial relations [54]. However, unlike participatory designers who discuss political and policy contexts in design projects, CSCW researchers are interested in collaborating with systems developers to bridge the gap between CSCW research and CSCW design practice. Some CSCW researchers focus on recognizing various materials that have different qualities depending on how they are used in specific places as intervention areas. However, regardless of how the material is bounded through time and space in a cooperative work among stakeholders, it is completely static, irrespective of the execution of the coordination the material prescribes. Thus, CSCW researchers must consider that materials stipulate articulation work (e.g., a standard operating procedure in a social order) as an invention [68] and that such materials can be inscribed as a result (language games) of the delegation of social roles to nonhumans [69] and humans. In this manner, CSCW researchers can identify different aspects of interest in a design project and find the most appropriate engineering language (techniques) to translate the CSCW insights into various formats that can be understood by different stakeholders. Although the formats differ, the core interest of the engineering projects is held by CSCW researchers; thus, it is a "win-win" situation [58] that simplifies, rather than complicates, engineering projects. In this way, CSCW researchers can be spokespersons who address interactive relations among end-users (operators), artefacts, computer systems, systems developers, educators, and project sponsors (i.e., shipowners in the present study), thus improving their cooperation in such actor networks.

In the present case, as maritime technology becomes increasingly computer supported, the researcher feels that he has the responsibility to ensure that the final design benefits all stakeholders. By doing so, CSCW insights into designing maritime technology should be best used to change the mechanism of design in the maritime domain, including information technology [70]. In other words, stakeholders' insights do not pertain only to requirement specifications that inform design. By representing their interests, the researcher should trigger a *modus operandi* [15] for intervening in the project, which can be done by taking specific actions regarding when, where, and what forms in the design process to support interactive relationships between actors within the social–technical associations between humans and nonhumans. Such interactions are badly needed in engineering-oriented fields.

B. *Insider Roles Across Communities*

Regarding the issue of whether CSCW researchers could potentially address the social–technical gap, the CSCW community is divided. Some believe that it is possible, but others think that it will take a long time to achieve the division of what we knew socially and what we can support technically. Although some researchers advocate for intervention [18] as a solution, their peers remain uncertain about how to follow the "the guidelines" [37] owing to the lack of reflexivity in interpretive writing. In the present study, the researcher worked with a heterogeneous group. The work of CSCW goes beyond the CSCW accounts of epistemological and theoretical bases. Instead, we must understand not only the nature of the ethnographic encounter and its methodology but also the data sets collected in engineering work. Instead of discussing people as the objects of study through the so-called participant observation, the present study points out that CSCW researchers must take their own embodied experiences in the context of personal relationships to gain and exchange knowledge with stakeholders. It is not just a matter of methodology, such as writing detailed field notes and showing videos about practices. It is also a matter of relational epistemology in which a kind of language game is used to translate the CSCW insights into images that make sense to the stakeholders. Otherwise, if a CSCW study is inherently experiential, then it loses the voice in its writing, which in turn, limits our insights into the data and our ability to use them in design. Thus, a constant assessment of the relationship between knowledge and "the ways of doing knowledge" must be undertaken.

Positioning CSCW research in engineering projects also concerns reciprocal relationships with stakeholders [71]. In Beaulieu's [71] definition, the value of relationships in different fields in ethnographic studies goes beyond the central notion of face-to-face interaction to the co-presence with the ethnographer during the research. As the present study shows, the relationships among the stakeholders and between the stakeholders and the researcher had nothing to do with negotiating the conflicts of interest. Rather, the relationships among them were based on self-interest and then extended to integrate their willingness to participate in the network of actors. The participants all want their interests to be traceable and consistently represented by someone. The researcher of the present study coincidentally crossed various sites and moments during the research to successfully formulate representations that were useful to all. Perhaps another researcher could do the same.

Thus, a few years after completing the research work, the researcher feels that he has no value-neutral stance in his research work in the maritime domain. CSCW researchers should make themselves explicit to stakeholders so that the latter can better understand their own interests, which, along with their reasons and motivations, are articulated by CSCW research. In this manner, CSCW researchers should make explicit their ideological assumptions to allow CSCW peers to see the world in which a researcher is embedded. Moreover, CSCW peers could create their own interpretations of the case study of engineering projects and reflect on their own assumptions and mindsets relative to the projects. On one hand, the purpose is to triangulate the sources of evidence with other peers although they use different contexts. Regardless of whether the context is the maritime domain or the healthcare domain, they all work with and within a heterogeneous group. In such cases, how should they share their reflexive insiders' views of epistemology and methodology in deploying CSCW insights in the design process? [39]. On the other hand, it is not a matter that only a CSCW researcher must address. It is also a matter of how CSCW researchers communicate with others, i.e., a way of creating opportunities to participate in an engineering project as early as possible. In the present study, the researcher, systems developers, and shipowners did not share the same mindsets in learning from experience. Thus, a dialogue between the three forms of knowledge helped promote mutual improvement and anchored the relevance of the CSCW research in policy making for design projects in the maritime domain. The change was created in the present work to influence epistemological assumptions, whereas the previous experience in the field influenced the dialogic process. It is likely that the best option is to position people (including the researcher) in the center when designing the usefulness of technology. Through the dialogue and the leverage point between stakeholders engaged in the research, it would be possible for peers to investigate and criticize the accounts of interventions, thus assessing whether the interpretations are valid.

C. *Connecting Communities of Practice*

Owing to the unique background of the researcher in the present work, his involvement in a group designing maritime technology was more than a quest to improve current design practices in multidisciplinary fields. To make sense of the problems, the researcher faced the issues in the maritime domain and attempted to create something new. Representing the group of practitioners–researchers in systems design, CSCW research is different in the engineering field, not only because it is new but also because it is considered a foreign element that is typically rejected by a group of professionals. The nature of the work practice of a professional community is to transform the status quo by new ways of working and interacting rather than by accommodating a completely new element. CSCW insights are examples in the present study.

Jackson et al. [5] proposed that CSCW has fewer concerns about translating its theoretical knowledge into forms and instruments that can be used by wider communities. The researcher initially faced similar challenges while working on the design of maritime technology, in which remote-control systems comprised only one of several design projects. The new generation of CSCW researchers may be different from the first-generation predecessors in that the former know about human-centered computing, how to do fieldwork, and how to translate their findings into special formats that can be easily communicated to systems developers [7]. However, the new generation of CSCW researchers may miss long-term engagement and design-sensitive analysis in dealing with their reflections on how they connect different communities. Most CSCW research is iterative in terms of the design process and does not challenge the lack of reflective voices [45] in the community. When researchers seek intervention as a bridge between research and practice, they might fall into their existing cognitive knowledge and create their own artificial worlds as they seek their own language in doing design. They may focus on exploring the inner symbolic space of a paradigm and try to convince others to believe that their languages are universal and useful. This, however, might be wrong.

If they do not accept procedure-oriented engineering work, is it correct to assume that CSCW can provide a solution? Suchman [72] suggested that we might need to find a customized solution rather than a universal solution for each engineering project. The challenge behind this idea is not only the cognitive aspect of engineering work and CSCW research. Rather, it requires the development of radically new forms of scientific inquiry. In this article, the researcher reported and discussed his theoretical struggles and success in interpretive empirical research to fulfill the forms of scientific inquiry in connecting communities of practice. In a heterogeneous group, collaboration in designing a remote-control system is not a straightforward process. When reading the CSCW literature, the researcher always turns on the software engineer mode to review praxis [40]. It is quite a challenge. Although he holds two sets of knowledge (CSCW and software engineering), he should have different perspectives on what has been read and should be considered equal contributions to knowledge. However, in a heterogeneous group, this inner attribute of his CSCW knowledge becomes both “he/him” and “others.” This is because the designer of remote-control systems is not the CSCW researcher or the CSCW practitioner. Instead, most of the work still depends on control engineering principles, and the scientific inquiry entails extensive empirical data and practical requirements, as well as a theoretical framework that might be perceived as disconnected from social construction [73]. Thus, for a CSCW researcher who has been uniquely trained in two fields, working in the complete unstructured maritime domain is a challenge. CSCW researchers must give their peers the tools to criticize their accounts of the work practice in the workplace. The researchers also need to play language games with systems developers to investigate the usefulness of the contribution from the CSCW perspective.

In the present work, although no one forced the researcher to make notes and work-in-progress drafts made available to all members of the project, he realized that opening up the data sets helped fulfill hermeneutic cycles and multiple interpretations. In interviews with systems developers, the CSCW perspective of maritime technology led to further discussions. Thus, multiple interpretations of the benefits and why the project should design alternatives became possible. The CSCW approach also made it possible for the systems developers, operators, educators, and shipowners to discuss the situation and switch from a cooperative project in which everyone had his or her own spot to engage in truly collaborative work. Moreover, the systems developers and the CSCW researchers recognized the value of reflectivity and language games. This is important in the discipline of design within CSCW and engineering. All stakeholders of the engineering projects could find a way forward to be comfortable with the various interests presented and reflect on them via a language game to find the optimal solution.

VIII. Conclusion

This paper discussed the use of reflexivity and language games in CSCW research when working across different communities. A case study of reassembling participation to improve the design of remote-control systems for all stakeholders was used as the background story. The reflective writing in this article offers a view of how CSCW insights and engineering practices have been transformed during the engagement of the CSCW researcher in designing maritime technology. In the last seven years, the CSCW interpretation of designing maritime technology suffered from blind spots.

However, following interpretive research and the knowledge and experience gained in CSCW research, the reward was not the creation of meaningful change. Instead, the reward came in the form of a better understanding of the challenges and opportunities related to bridging the gaps between applying CSCW insights and conducting research in CSCW within and outside the CSCW community to make real contributions to other fields.

As a result, the article suggests that the development of CSCW insights in the engineering fields should strongly focus on the participation of stakeholders, not only those who would use the technology but also those who fund and develop the technology. By doing so, CSCW researchers could learn more about self-reflection, self-revelation, and self-evaluation in making a contribution to the industry and the positive influence they may have in terms of encouraging policymakers to rethink framework development in the engineering field. In conducting research in the maritime domain, the CSCW researcher found that the best way is to reinterpret one's own research findings and activities and combine them in a wider scientific discourse by using the Wittgensteinian concept of the language games.

If intervention is an unavoidable condition of CSCW research in engineering projects, then by being there, the researcher could connect communities of practice and help make a difference by affecting the practice being studied. The case in this paper, the translation of the research work, the qualitative inquiry developed in the paper, and the reflective materials the researcher wrote are all tools that could serve the CSCW community and the community from which the CSCW insights emerged. The rest is up to others, within and outside the CSCW community, who want to confirm their own values to balance their position with the CSCW insights in their own work. As a result, the gap between research and practice within and outside CSCW research could be reduced.

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Situated Abilities within Universal Design – A Theoretical Exploration

The Case of the T-ABLE – A Robotic Wooden Table

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***Abstract*—This paper investigates Universal Design through the idea of *designing for situated abilities,* rather than focusing on designing for disabled users. This shift in perspective from disabilities to abilities is explored by designing a domestic robot that familiarly integrates into our homes. We explore the concept of *designing for situated abilities* through a proof-of-concept robotic wooden table, the T-ABLE, as an alternative design for domestic robots. Finally, the paper identifies four dimensions of situated abilities.**

Keywords-robotic wooden table; design; Universal Design; situated ability; elderly.

I. INTRODUCTION

This paper reports further on our previous work [1][2][3] on investigating the use of robots in the homes of the elderly. It presents a proof-of-concept robot design, illustrating design for situated abilities. The design and the embedded concept of situated abilities represent an alternative way of thinking about, discussing, and designing with a focus on human beings' abilities in terms of everyday situations, rather than focusing on their disabilities.

Specifically, this study investigates an alternative design for domestic robots, such as wood-based designed robots, for better integration in the home environment. Thus, we present a proof-of-concept robotic wooden table called the T-ABLE. The name of the robotic table originates from the terms "table" and "able" or "abilities." The design of the prototype itself is grounded in the original definition of Universal Design (UD), which addresses design that is suitable for as many individuals as possible. In this paper, we move beyond the idea of UD associated with disabilities and propose a shift in perspective to a new dimension of UD, namely one focusing on designing for *situated abilities*. We argue that individuals' abilities are strongly connected with the context and situations they find themselves in. At the same time, familiar things can represent a good point of departure for designing for abilities rather than disabilities.

Thus, the research question in this paper is: *How can we shift perspective from disabilities to abilities when talking about Universal Design?* This research question can be explored in many ways. One approach is to explore how we can design domestic robots that fit humans' abilities and integrate into individuals' homes in a familiar way.

The paper continues in Section II by presenting the background of this work. Section III includes a presentation of related work where the current research on abilities in design is discussed. Section IV focuses on the theoretical grounding for situated abilities. Section V presents our work in detail as it impacts the elderly in terms of the Multimodal Elderly Care Systems (MECS) project, leading to this study's proof-of-concept. Section VI provides a discussion around the initial stated research question, the proof-of-concept design, and situated abilities. Section VII includes the conclusion and further work to close the article.

II. BACKGROUND

This section presents the current state-of-the-art regarding the use of robots in the home. We continue thereafter by defining Universal Design (UD) and explaining the lack of a legal framework for UD for robots to be used in the public sector, such as healthcare or homecare services. We end the section by stating the motivation for the study before proceeding further with related work.

A. State-of-the-Art

Several studies have developed theoretical frameworks used in studying robots in the home, such as the product ecology framework [4][5], the Domestic Robot Ecology [6], the facilitation framework [7], and the automation of work tasks framework [8]. We have learned from these studies investigating domestic robots' use that individuals will often carry out changes inside their homes to fit a robotic product.

At the same time, Dautenhahn [9] argues that the Human-Robot Interaction (HRI) community's current focus should be on user studies, along with HRI design, theory, and methods. She argues that the HRI community has moved forward from the classification of robots and "variation" in robots. She says that the HRI communities should focus instead on long-term interaction with robots in "real-world environments" with "real people" (p. 4:2). She says that this shift in focus from the use of robots in the labs or living labs to the use of robots in real environments with real people move also focus from studies on investigating short-term interactions to long-term interaction between the human and the robot. She argues that researchers should study and learn from real people's use and engagement in real situations.

Moreover, we have also learned from the previous studies that the studies focus on using the product, rather than on the human, or the user using the product and its abilities to handle the situation at hand [5]. Compared to these previous studies, our study proposes looking at the interaction between individuals and the robotic product from a socio-relational perspective [10]. Our study also focuses on the individual's experienced abilities and the design of a domestic robot in the context of the abilities of the elderly (not their disabilities!) as the point of departure for our design.

Earlier studies show that once moving devices are introduced in the home, such as a robot vacuum cleaner, several fundamental changes need to be made in terms of the structure and infrastructure of the home [2][5][6]. If the design of a robotic product is good enough, however, the human should not have to adapt to the product itself: the robot should integrate itself into the home environment. However, just a few of the current designs of domestic robots fit the home environment and integrate well within existing home environments. For instance, some studies have explored the idea that aesthetics, functionality, and robot design should fit in with the human context. Such an example is PARO, a robot with a seal appearance used for older adults [11][12][13]. PARO seems to integrate well in home environments for the elderly, such as those who have Alzheimer's, giving them feelings of calm with its plush appearance. Since an animal's company has been shown to have beneficial psychological effects for relaxation, positive physiological effects, such as improving vital signs, and social effects among the elderly, PARO is proven in research to be a robotic example that fulfills these criteria [12]. It is recommended that elderly people with Alzheimer's have pets around, but the people with Alzheimer's are often unable to take care of a pet or even themselves. PARO is a good example of a robot fulfilling this need.

In addition, other previous studies focus on humanoid robots, such as Nao and Pepper. Although these robots have a humanoid look, they also have a plastic appearance. Beyond cost and other physical properties, one reason for going with a plastic look could be to avoid a user's feeling of uneasiness from the uncanny valley [14]. Studies have also shown that people assume different abilities and assign different attributes to robots depending on their appearance [14][15]. Others have suggested that a focus on the robot's movement can turn people's attention more to the movement than the robot's appearance [17] even if the motion has the potential to make the uncanny valley effect more pronounced.

B. Universal Design and Design of Robots

UD is described as "the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design" [18]. UD is based on seven core principles. These are indicated and exemplified in TABLE .

Many people often associate UD with people with disabilities. Historically indeed, UD was often related to people with disabilities along with The Americans with Disability Act (ADA) [19]. These movements have greatly impacted the focus of UD on designing products and services that can be used by as many people as possible. According to the Norwegian Digitalization Agency, however, UD is about designing surroundings that consider "variation in the functional ability of inhabitants, including people with disabilities" [20]. A universally designed solution aims to reach out to as many people as possible without the need for adapted solutions [20].

Further, certain aspects of robotics, such as Socially Assistive Robotics (SAR), aim to help people with different conditions such as Autism Spectrum Disorder (ASD), dementia, and also in the area of care for the elderly [21], but this refers specifically to assistive technology for these particular groups. Aside from suggestions for incorporating UD as a way of making a robot work better in a home environment [22][23], UD is an underexplored area in Human-Robot Interaction (HRI) literature. Indeed, given the limits on a robot's processing capability, poor sensors, and limited movement, robots themselves might benefit from UD's perspective.

TABLE I. Universal Design Principles.

#	UD Principle	Example objects in everyday use
1	Equitable use	Use of a ramp for getting into a bus: it provides equal ability to step onto a bus for both people in a wheelchair and without a wheelchair, such as a woman with a stroller
2	Flexibility in use	The use of a table with an adjustable height is good for both abled people, people with back problems, people sitting in wheelchairs, or children
3	Simple and intuitive use	An iconic example is the iPhone design with its buttons in the same place in different versions.
4	Perceptible information	Consistency in using symbols for volume or radio buttons, send- or save icons on buttons
5	Tolerance for error	The undo button provides reliable feedback. Another example is the oven lock button for children's safety.
6	Low physical effort	The height of ATMs provides easy access and low physical effort for people of different heights, including children and people sitting in a wheelchair
7	Size and space for approach and use	The gates of a metro-station or security control at the airport should be large enough to accommodate individuals of different sizes, or people sitting in a wheelchair

On the other hand, much of UD's focus in ICT has been on making information accessible by applying the Web Content and Accessibility Guidelines (WCAG) [24] when building web sites and mobile applications. Typically, a robot is not presenting information the same way that a computer or mobile device would. Therefore, there is no straightforward way to apply the WCAG to a robot. For instance, Norwegian laws and regulations regarding UD in Norway [25] include aspects of the design of ATMs, payment terminals, and digital learning environments in education and training, including Higher Education. Norwegian Law, however, does not include regulations regarding the design of – and interaction with – robots, nor does it cover robots to be used, for instance, in healthcare or home care services in the public sector. In other words, the Norwegian laws and regulations relating to the Universal Design of these technologies are lacking, while the adoption of robots in health- and homecare seems to be ongoing.

At the same time, the elderly population (those over 65 years old) is increasing. The elderly population in Norway, is predicted to increase from 16.5% in 2016 to 17.5% in 2020, to 20.2% in 2030, and 27%, in 2070 [26] (p. 360). Moreover, expectancy is also expected to increase in Norway by 0.2% (around two years) by 2070 [26]. In addition, the number of expected care recipients in Norway will increase from 367 000 in 2016 to 387 000 in 2020, to 485 000 in 2030, reaching 815 000 in 2070 [26, p. 362]. Out of this population, the number of home care recipients will increase from 200 000 in 2016, to 212 000 in 2020, to 263 000 in 2030, reaching 420 000 by 2070 [26]. These numbers are the highest amongst a reference scenario composed of recipients of institutional care, home care, and cash benefits (compared to institutional care that will increase from 45 000 in 2016 to 131 000 in 2070, and to cash benefits that will increase from 121 000 in 2016 to 264 000 in 2070) [26].

Moreover, the aging population seems to be the *key driver* in developing and adopting robots [27]. New forms of ICTs, such as robots, are being introduced into the home of the elderly to prolong their independent living [27][27][28]. The integration of robots into the homes of the elderly is argued for by the statistics regarding the aging population, but also by longer life spans accompanied by corresponding disabilities due to age, by difficulties in Activities of Daily Living (ADL) experienced by the elderly, and even increased costs and a lack of (human) resources for supporting the elderly through home care services [30].

In addition, policies and political agendas are being introduced concerning integrating robots in home care services. These usually focus on studying robots in terms of how they meet societal needs. EU Active Assistive Living (AAL) and the EU Horizon 2020 Robotics Roadmap are two of these agendas [30].

If such robots are to be adopted in the public sector, including the health- and homecare sectors, these robots need to be designed in such a way that several users, including medical staff, care recipients (elderly or patients), informal caregivers (family members if the robots are to be used in the home), as well as technical staff, can use them. This also means that robots need to comply with specific standards and requirements to suit several types of users and/or actors (individuals, organizations, and settings). Thus, this implies that the robots need to be universally designed, i.e., a minimum of requirements or standards must be fulfilled by the robot design for it to be used by diverse users. Many of these potential future categories of users of health- or homecare robot services are not disabled people from a medical point of view. They also often lack digital or “robot” literacy.

C. *Motivation*

Although similar studies have analyzed robot performance in homes [31][32][33], there are still many robot forms and services to explore. The elderly people in our previous studies were keen to have robots that they could understand, could manage easily, and were meaningful for the elderly [1]. In other words, robots must be designed to meet the requirements of comprehensibility, manageability, and meaningfulness, fin line with Sense-Of-Coherence (SOC) theory [34].

Thus, a table robot that can move around, and is made of wood, may feel more familiar to elderly people with a design that can eventually meet these requirements. Some similar attempts have been made previously in other contexts, such as in studies investigating skeuomorphic design [35], or designing for simplicity and prolonged elderly’s mastery of technology, as shown in [36][37][38][39]. Many of these studies, however, have a focus on static technology, i.e., the technology that does not move semi-autonomously in the home. Its design is based on the original definition of UD and its seven principles.

III. Related Work: On Abilities In Design

This section presents the related work on abilities in design. The section starts by presenting the concept of abilities in design viewed from a general UD perspective. Thereafter we continue by briefly presenting the Ability Based Design (ABD) perspective.

A. *Abilities in Design*

UD is studied at the micro-, mezzo- or macro-level [40]. At the micro-level, there are often studies examining individuals or groups in UD to understand human characteristics. Specifically, studies at the micro-level focus on human factors and psychology. These are usually studies in Human-Computer Interaction (HCI). At the mezzo-level, there are often studies on computer science for engineering that investigate the use of technology as a mechanism of participation. Specifically, these studies are within the fields of informatics and computer science. These are usually carried out at an organizational level. Studies at the macro-level focus on the social and legal aspects of an issue. Such studies include using ICTs or digital learning environments in Higher Education and investigating laws, regulations, and legal frameworks [41]. Micro-, mezzo- or macro-level studies may include investigations on inclusion and accessibility [41][42] or diversity issues [44]. However, many of these studies focus on the dichotomic pair of abilities-disabilities. This is, indirectly, a *pathogenic view* since disabilities are a focus. A pathogenic view refers to seeing the individual in terms of what is wrong with them and regarding the disabilities as needing to be corrected.

Further, others do not enter the polemics of UD; however, they address people’s abilities or capabilities from a Participatory Design (PD) perspective. For instance, Joshi [36] wrote his Ph.D. thesis on the topic of designing for capabilities. He has co-authored several papers on designing for experienced simplicity [37] and prolonged mastery among the elderly [45].

Furthermore, Frauenberger [46] has elevated the idea of designing for abilities by talking about “designing for different abilities.” However, his work focuses on designing for medically-diagnosed individuals, such as designing for the abilities of autistic children [46][47]. Thus, the dichotomy of abilities-disabilities is indirectly present when indirectly adopting a pathogenic perspective.

However, a few have adopted a *salutogenic view* in terms of designing for abilities; this view begins from the perspective that there is nothing wrong with the individual, but rather with the environment surrounding him. Within this salutogenic approach, some talk about Ability-Centered Design (ACD) [49], whereas others talk about Ability Based Design (ABD) [50]. Although there are nuances in these two design types, they have the same common goal: putting the individual's abilities into focus. To illustrate the idea, the concept of ABD is presented in more detail below.

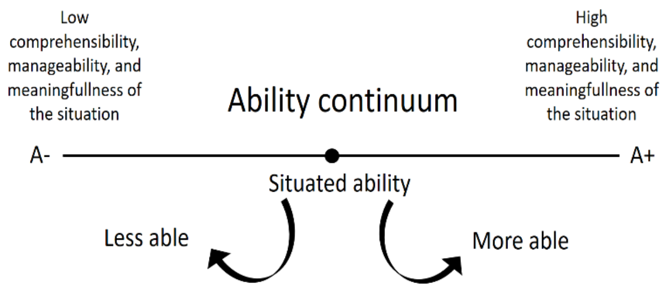

Figure 1. The ability continuum [51].

B. *Ability Based Design (ABD)*

Wobbrock [49][50][51] introduced the idea of ABD. It refers to designing for the abilities of people, rather than their disabilities. He and his colleagues argue that one cannot have disabilities in the same way that one cannot have "dis-height" or "dis-money" [50] (p. 91). The ABD concept is described according to a set of principles supported by examples [50]. Specifically, ABD systems focus on the individual's abilities, on what an individual can do, where the system has some kind of awareness about the user's abilities, such that it can adapt and accommodate their abilities [50].

According to the authors, the challenge with ABD systems is that there is a high variation in the abilities of users. However, ABD systems can be regarded as ideals, where the systems themselves are able to adapt and be reconfigured to users' abilities. This implies that the responsibility for being able to interact with an ABD system shifts to the designer and not the other way around, to the users [53]. This idea is similar to the one presented in this paper, which focuses on designing for situated abilities, where the individual user can interact with any system at any given time. This would require a Global Public Inclusive Infrastructure [52][53]. Finally, ABD design is centered around a disabling environment and situations, rather than around an individual's disabilities [53].

IV. Theoretical Grounding: On Situated Abilities

This section presents first the origins of the concept of "situated abilities" and its development. It continues thereafter with some examples of possible experiences of situated abilities by the user in different situations.

The term "situated abilities" was first mentioned in the work of Wobbrock and colleagues [53]. However, it was never defined, framed, explored, or further anchored. Saplacan [51] has attempted to revitalize the concept. The framing of situated abilities was inspired by the work of Antonovsky's [34] and his salutogenic perspective on the health and ease/dis-ease continuum. His work was grounded on the idea that we should study what makes people healthy, e.g., "at ease," not what gives them "dis-ease." Along the same lines, the author [51] framed situated abilities as a point of departure for the individuals' abilities rather than his disabilities. Thus, the author framed situated abilities as the human being's ability to comprehend, manage, or find meaning in an interaction with a system or technology [51]. Further, the author [51] explains that ability, if viewed on an ability continuum (Figure 1), can be understood in terms of a lesser- or greater scale, depending on how the individual, as a human being, experiences a situation where she interacts or uses a digital system or technology.

We present some examples of situated abilities below:

- **Example 1** on robots. The human needs to install, understand the technicalities and feedback from "autonomous things," facilitate and adapt to them and divide and share their work tasks with them [3]. Examples illustrating this type of situated abilities can be found in studies on the use of a semi-autonomous robot, such as a vacuum cleaner robot [2][3] or a robot lawnmower [8]. These studies illustrate situations where the human's abilities are situated, i.e., they have lower or higher abilities to interact with the robot, depending on their familiarity with the respective robot. However, in many of the situations presented, humans need to adapt to the robot's work to make it work, not the other way around.
- **Example 2** on Digital Learning Environments used in Higher Education. Although there is a regulation in Norwegian law in The Discrimination and Disability Act, Chapter 3, on universal design [56], the law addresses UD only from the single-use of individual websites. This, however, does not cover the user's experience as a whole when, for instance, using several websites or platforms, such as in the case of the cross-use of digital learning environments [57]. Examples of such situations have been illustrated in several studies [54][56].
- **Example 3** on chatbots. An example of experienced situated ability is when the human user interacts with a chatbot, but the chatbot does not understand what the user wants even though the user knows what the user needs help with. This situation often occurs not because of the chatbot design itself and not because of the user's disabilities. The user would solve the problem much more quickly by talking directly to a human instead of using the chatbot. However, the use of the chatbot lowers the situated abilities of the human user in that situation. Several studies on chatbot design have been undertaken with people without any disabilities and people with disabilities (see for instance [57][58]).
- **Example 4** on using a different operating system: Another example is when a Microsoft user is asked to use a Mac computer. The human user will encounter lower situated abilities when using Apple's operating system, but higher situated abilities when using Microsoft's operating system.
- **Example 5** on ordering a book via the e-library system. Another example is when an old person without ICT literacy is asked to order a book via the e-library

system. The person will encounter lower situated abilities in the interaction and use of the e-library system, whereas they will experience higher situated abilities if they place an order at the library's desk. This example was also presented in [51].

These examples indicate that the situated abilities are contingent and highly specific to both the person using the technology and the situation in which it is used.

V. Case and Proof-of-Concept Design

This section starts with the case brief. Thereafter, it continues by presenting the initial findings from the research project that led us to propose the current design for T-ABLE. The design of the T-ABLE is then presented, followed by our initial tests.

A. *Case brief*

The study is part of the Multimodal Elderly Care Systems (MECS) Research Project. MECS investigates the requirements, specifications, and design of a safety alarm robot for elderly people living independently in specially designed accommodation facilities dedicated to the elderly ($\geq$ 65 years old).

B. *Initial Findings*

From 2016-2019, the authors conducted a series of studies with the elderly on domestic robots to be used in their homes. Through workshops, user studies, individual interviews, and group interviews [1][3][59], we learned that a robot's functionality is the most important aspect for the elderly, although appearance and aesthetics are also important, especially for female users.

Throughout our investigation, we were interested in developing knowledge about the preferences of elderly people in terms of a safety alarm robot, how the safety alarm robot should be designed, and what functionalities it should have. Although the research interest was in a safety alarm robot which ultimately had mounted sensors and perhaps an RGB or an infrared camera that could detect and track the health state of the elderly user, it was soon noticed that the elderly were not familiar with this kind of advanced technology. Although we tried to talk about safety alarm robots with the elderly, the elderly indicated that they were more in need of assistive or servant robots. They explained that they needed a robot that could help them move things around in the home, a robot that could bring them objects, or a robot that could help them with household activities. Simultaneously, the elderly people wished for a robot that did not occupy too much space since their apartments were generally limited in size, usually composed of a kitchen space joined to a living room, and a bedroom, a bathroom, and a small entrance hall. Many of the home spaces were cluttered with furniture, personal items, art objects, books, rollators, or wheelchairs that occupied much space. In 2018, vacuum cleaner robots were placed in the homes of the elderly, and participants were given a notebook and a pen and asked to write down notes each time they ran the robot, in the form of diary notes, inspired by Gaver et al.'s [61] idea on probes. During this phase of the study, we found that many elderly participants encountered challenges with interacting with the robot. For instance, the technical feedback which displayed errors as digits were often indecipherable even for the non-elderly participants. One participant complained about an error message that she received when she used the app to control the robot, which said that it "cannot connect to the cloud services" – she did not understand what the "cloud" was [60]. This is a specific situation where human beings' abilities cannot handle the design of a technology: either because of the English language or because of the technical language the device used for giving informative feedback.

During our initial investigations for the MECS project [3][7][60][62][63][64][65][66], several challenges and requirements were encountered relating to what a robot being used in the home should look like, how it should behave, what size it should be, or what it should do. However, one particular participant posed the question: "What if a table could be called upon and bring me the telephone and carry a cup of tea? What if it could keep the telephone always charged and in reach?". The robotic wooden table was created in response to this request. We took up this challenge and are currently designing, making, engineering, evaluating such a table and listening and talking to home dwellers, and observing their use of the table. To illustrate the use of the T-ABLE, a persona and a scenario have been developed together with elderly participants. This is illustrated in Figure 2.

C. *Design of T-ABLE*

The design of the T-ABLE was inspired by the modular design of a stool (*krakk* in Norwegian). The stool is a versatile object; it is a jack-of-all-trades of homes and can be used as a chair, side table, telephone table, footrest – and to reach the top of the shelf by standing on it. The stool has proved useful for all age groups, genders, and people with varied abilities, in different stages of life and a variety of situations. In contrast to other specialized objects, such as chairs, dining tables, and ladders, the stool, with its smaller size, is flexible and adaptable to more users and use situations. The stool design is versatile and, as such, it may fit many different uses and situations. Inspired by the design of a stool, similarly to the mechanical ottoman from Sirkin et al. [67], the T-ABLE, the robotic wooden table, is designed to hold small items and transport them around the home, as a servant robot would do. It can also re-configure the home on the fly, keeping the same natural look of the home, with its wooden appearance: like the old TV-sets, in wood, that was part of a home's furniture. The T-ABLE has a horizontal, flat top surface. It is made in three iterations, illustrated in Figure 3. All the prototypes are made from various types of wood, wheels, and control mechanisms. The top surface is 40×40 cm, and the height is about 40 cm. It is ruggedly made so that it is also possible to sit on top of it (maximum weight 200 kg).

The T-ABLE prototypes have three or four wheels where two of the wheels are hub motor wheels (Electric Wheel Hub Motor). The wheels' diameter is 12 cm, which makes it possible for the table to travel over carpets and uneven surfaces. Furthermore, the wheel and the way they are fastened to the table is rugged, so that it is possible to, for example, sit on top of the table (maximum 150 kg). An on-board LiPro battery powers the wheels' motors and the ECR (Electronic Speed Control). The speed of the two wheels is regulated with an RF (radio frequency remote control) directly, and in one prototype with an Arduino box between the RF and the ECR. The two hub motors wheels make skid steering possible for the table, and hence it can be controlled to move accurately around at the command of the person with the RF. The maximum speed is set to 1.3 m/s in order to keep it safe. A prototype is given in Figure 3 (*a–d*). The prototype was fitted with a specific point for charging the telephone. The T-ABLE is equipped with a battery that powers the engines for driving the table and charges the phone on top. The battery is then charged when the T-ABLE is connected to the home's central power system at the charging station, for example, at one of the locations where it sits for a reasonably long period. One version of the prototype was modular, with an extra tabletop that could be removed. This gives double the table space and can work as a scriptorium.

Further development is needed to work both on the ways in which the control and steering of the table are achieved. Technically, the motor system controllers are both interfaced with an RF remote control with Arduino hardware. Plans are in place to run the Robot Operating System (ROS) via a PC. This would allow the user to interact with the table in various ways (voice, buttons, gestures); additionally, fitting sensors to the table would allow for input to the navigation, wayfinding, and obstacle detection functions of the table.

D. Initial Tests

Instead of the table having to be lifted or pushed to the preferred position in the room, this can be done by way of command in a remote-control fashion – or it can be programmed to move based on input from the environment, for example, the time of day, following the person when the person gives that command, or in other ways.

The proof-of-concept was tested through the Wizard of Oz (WoZ) techniques, similar to the tests carried out by Sirkin and colleagues with their mechanical ottoman [see 67]. Both voice and the use of a bell-button were used to give commands and steer the T-ABLE. The person operating the RF controller, the Wizard, listened to the voice commands and recognized the user's key presses. Based on the commands such as come here, follow me, go there, she steered the T-ABLE in the correct direction and position. During these WoZ tests, an external button to T-ABLE acted as the command button that executed different commands at the user's request. Four motion design commands were simulated through WoZ: COME_HERE, FOLLOW_ME, DOCK, and UNDOCK. Specifically, if the user pressed the button once, the T-ABLE performed the COME_HERE task. If the user pressed the button twice; consequently, the T-ABLE will perform the FOLLOW_ME task. The DOCK and UNDOCK command accompanied the other commands. Another simulated order was fetching a cup of coffee or dishes.

Eve

Eve is 92 years old (born in November 1928), in good spirits, and able to walk when she uses a walker for support. She is living independently at home.

Eve has had a fixed telephone from 1960 to 2009 at home. The fixed telephone was previously placed in the hall, fixed to the wall with a cable and placed on a telephone table. That is, the telephone table was stationary, always in the same place, albeit with a long cord so it could be used in the region near the hall.

In 1999 she got a mobile phone. After ten years of using the mobile phone, she ended the subscription for the fixed telephone, and at the same time, reconfigured the hall by removing the telephone set. That is, Eve currently owns only a mobile phone, and does not have the fixed telephone anymore.

Issues such as: "where is the phone?" or "is the phone charged?" did not previously pose any problem for Eve, since the fixed phone was situated in its permanent position, in the hallway.

In 2012, Eve got a safety alarm from her children, a wristband device with a red emergency button. She wears it when her son is visiting, otherwise it is placed in the bathroom. The mobile phone is indeed vital for safety for Eve. It can be and is used for contacting family, friends and others in case there is a problem. However, the problem of finding the phone and making sure it is charged are challenging.

She imagines the use of the T-ABLE. The mobile phone now has a telephone table to rest on, and is always charged there. The way Eve imagines using the t-able is to let it sit by her bedside during the night, and then have it set up to move to the hall during the day. If she needs assistance, the t-able will move to where she is and assist her.

Figure 2. Scenario designed together with the elderly

The current prototype has been tested only in two homes so far. The tests were performed in one home with one senior adult (≥65 years old) and another home with two adults, two children, and one cat. The tests were documented through photos and videos. However, no systematic testing or evaluation has been done so far, but informal sessions have been conducted where joy and excitement were expressed when the robotic T-ABLE was moving around in the home. There are two reasons why systematic testing has not occurred yet. First, The COVID-19 pandemic does not allow easy access in the homes of the elderly and non-elderly people and has limited further testing. Second, this paper focuses mainly on the proof-of-concept design of robots for everyday domestic use regarding their UD dimensions. Therefore, this is outside of the scope of this paper.

However, the initial tests have demonstrated that our participants are positive about the domestic table robot. Figure 4 (a, b, c) shows an illustration from our early tests with participants.

Further, the initial testing showed that the users needed to understand the T-ABLE world to be able to negotiate with it and feel comfortable with it. Three themes emerged. First, the participants wished to know what information was sensed by the T-ABLE or what kind of input it gets. The second theme was related to the movement of the T-ABLE itself. The participants wondered how they could best attempt to move the table along – in a “follow-me” fashion, or how the T-ABLE moves while they are sitting still themselves. The third emerging theme was about the relationship a user, as a human being, may develop with such an object and how this relationship could potentially inform the UD and a diversity of uses and individuals in their everyday life.

In this paper, the discussion and reflection upon the last theme that emerged are of particular interest since it aligns with our theoretical approach.

VI. A Theoretical Exploration of Everyday Situated Abilities

The MECS research project’s original idea was to create a safety alarm robot for elderly people (≥65 years old) living independently. This was an attempt at a pathogenic design (designing for their disabilities). That is, the idea of having a safety alarm robot in the home was in line with a medical model’s premise that older people at home need a device to track and detect them so that they can get help when something bad happens, such as if they fall. This approach neglected, however, their situated abilities. It seems they needed or wanted something that could help them at home, e.g., a servant robot to help them with household chores or a robot that could bring or carry things, or keep the phone in a standard place and always charged. This is in line with a salutogenic approach, where the robot’s design is in line with what the user, as a human being with his abilities, can do or a need the user has.

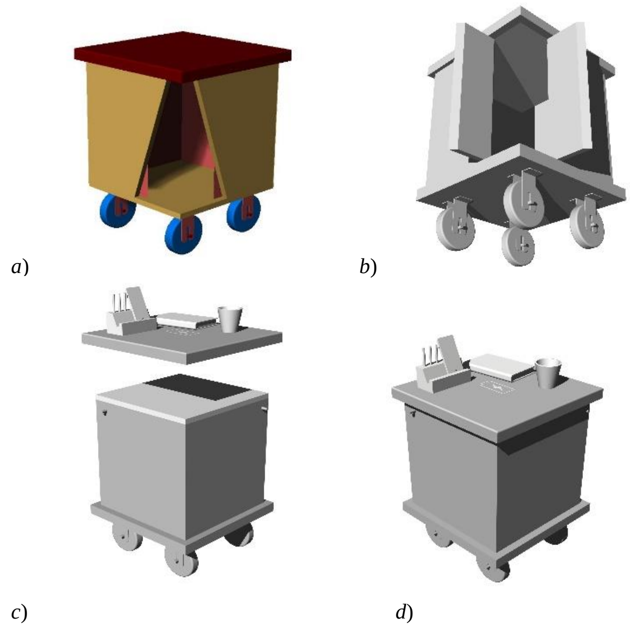

Figure 3. *a*) Iteration 1 – T-ABLE drawing by Nicholas Ibicheta; *b*) T-ABLE with telephone and charger; *c*) T-ABLE with an extra tabletop extending the horizontal surface; *d*) version of the T-ABLE with a place for depositing items.

Thus, to understand the human experience, a phenomenological approach was adopted, and the focus was on the first-person experience [68]. That is, the human experience in a situation with a vacuum cleaner robot based on our earlier work was taken into account, as well as some insights from the human experience with the T-ABLE robot. At the same time, the T-ABLE was designed with UD in mind. To understand and go beyond the T-ABLE design as a robotic wooden table, the discussion around UD and the T-ABLE design is elevated to a theoretical level in the next three sections, where the initial stated research question is answered.

A. *T-ABLE from a Universal Design Perspective*

The T-ABLE design considers situated abilities and attempts to blend in with the home environment. For instance, the T-ABLE was designed to fulfill Eve’s situated abilities, but it can also fit other users. The T-ABLE fulfills at least some of the UD principles. We explain how below.

1. **Equitable use**. The robotic wooden table can be used by young and old users, children, or people sitting in wheelchairs.
2. **Flexibility in use.** The robotic wooden table has a modular design and can be used for multiple purposes: for carrying items, for charging the mobile phone, or for depositing things.
3. **Simple and intuitive use.** The robotic T-ABLE has the familiar look of a piece of furniture – a wooden table.
4. **Perceptible information.** The form of the robotic wooden table indicates how it is to be used.

a)

b)

c)

Figure 4. *a*) and *b*) Prototype of T-ABLE transporting things in the home *c*) Prototype of T-ABLE where an elderly participant uses it to bring the home fixed phone and the mobile phone closer to her

5. **Tolerance for error**. It does not have buttons or interfaces that display error messages that may confuse the user. Instead, the robotic T-ABLE is based on the use of habituated objects such as a table.
6. **Low physical effort.** The height and size of the T-ABLE provide easy access and low physical effort for people of different heights, including children and people sitting in a wheelchair.
7. **Size and space for approach and use.** The T-ABLE blends in with the home environment with its natural material-look. It fits better than, for instance, other robots that have a plastic appearance.

While creating a prototype for the safety alarm robot is still being worked on, the T-ABLE has already generated joy for those who have experienced it and are interested in seeing what a future investigation can turn up.

B. Shifting Perspective from Disabilities to Situated Abilities

The research question addressed was: How can we shift the perspective from disabilities to abilities when talking about Universal Design?

UD is about making technology accessible, understandable, useful, and usable for as many people as possible. Ideally, UD includes people of all ages, sizes, and abilities. UD is increasingly vital for the HCI community in more and more everyday life areas and involves the use of digital technology. UD is about social equity on the macro-level [40]; it is about human diversity, accessibility, and usability of things and the environment, and it is about a participatory process – acknowledging and respecting human autonomy, its dignity, and integrity. According to Lazar [69], deaf people who use sign language do not see themselves as disabled people, but rather as people who use sign language. This reminds us that we humans, as users, wish to keep our dignity and integrity – we do not want to see ourselves or for others to see us as disabled. For instance, we as researchers of design or designers often forget that some users lack digital literacy or do not know how to interact with advanced technologies, such as robots, although they are not medically diagnosed as disabled.

Human diversity as a starting point for developing technologies that include all users is often a challenge. According to Trevanius, there is an optimization process in which the edges, extremes, and diversity are lost [70]. Along the same lines, several UD models are known that address the (dis)abilities of people from different perspectives. Amongst these UD models are the medical-, social-, relational-, expert-, empowering-, charity- and economic models. However, many of these models are strongly connected to disability studies, although UD, at its core, does not focus on disabilities but on designing for as many people as possible.

If we shift focus from disabilities to abilities, albeit using some of these existing UD models, situated abilities could be discussed as having several dimensions. Thus, situated abilities can be identified as being at the cross point of several of these models, however focusing on abilities instead of disabilities. Four dimensions of situated abilities have been identified through the T-ABLE proof-of-concept design.

a) A social dimension – the user can place the technology within his understanding of the environment surrounding him

The social dimension refers to the fact that the environment must be corrected because it disables and oppresses the individual [9][70]. For instance, in the T-ABLE design, the social dimension is represented through the design of the T-ABLE itself: the robotic wooden table is designed to fit into the home environment of elderly people, rather than being designed with a robotic zoomorphic or anthropomorphic look. Thus, the T-ABLE fits into the users' home environment in the way it is designed, most notably in that it is a piece of furniture designed in wood. In other words, the user can place the technology in his understanding of the environment surrounding him.

b) A relational dimension – the user can relate to the design of the technology through its embedded familiar elements

The relational dimension is inherited from the Scandinavian or GAP model [71]. This dimension focuses on the relationship between humans and the environment. The Scandinavian or GAP model is against humans' categorization between abled and disabled individuals, acknowledging human diversity and individual experiences [71]. Thus, situated abilities look at individuals as abled individuals who may have lower or higher situated abilities in their everyday interaction and use of digital technologies or systems. In addition, the idea of designing for situated abilities is incorporated in the T-ABLE design through the familiar elements of a table, with a natural look. The users, including elderly people, are more used to having tables in their homes than navigating robots. In this way, their relationship with the T-ABLE is assumed to be more familiar than with robots that do not necessarily have a natural look. That is, the user can relate to the design of the technology through its embedded familiar elements.

c) A socio-relational dimension – the user sees the technology as a habituated object

The socio-relational dimension assumes that the abilities are theorized, subscribing to the socio-relational model. The socio-relational model talks about disabling mechanisms as part of the environment that can be avoided or removed through different measures, including physical ones (Carol Thomas, 1999 in [10]). This dimension indicates both a social and a relational dimension, namely that the individual experiences the abilities as an embodied experience in the environment the individual is part of. Thus, the T-ABLE design's socio-relational dimension refers to removing some of the physically "disabling" mechanisms, such as interacting with an unfamiliar robot, through buttons, displays, or interfaces. The T-ABLE design itself as a robot removes some of these barriers since the majority of users can interact with tables and are familiar with this kind of habituated object [72].

d) An empowering dimension – the user feels in control of his or her abilities to interact with the technology

The empowering dimension focuses on the individual's abilities by empowering the individual through the design of technology. This dimension subscribes to the UD empowering model that trusts the individuals' autonomy, decision-making power, and control, and the professionals are regarded only as advisors rather than experts [73]. The model instead assumes the individual as the expert on his own body [73]. This implies that the design of the technology respects the user's autonomy, dignity, and integrity. The user knows how to interact with an object. In the case of the T-ABLE, this dimension was taken into account by the inquiry of one elderly participant who posed the original question: "What if a table could be called upon and bring me the telephone and carry a cup of tea? What if it could keep the telephone always charged and in reach?"

C. *The T-ABLE from a Phenomenological Perspective anchored in Heidegger's work*

At the start of the paper, one of the authors' consideration was how to design domestic robots that fit humans' abilities and integrate into individuals' homes in a familiar way, rather than designing robots for their disabilities. This statement regards the human being as an abled individual in terms of what she can do, rather than what she cannot do. Similarly, humans' everyday life that Heidegger examined and described had tables, chairs, writing equipment, radios, hammers, rooms, and many other examples of human-made things and nature and trees. The relationship between Heidegger's Dasein (human being) and this equipment is best understood through the use of and engagement with the "in-order-to" as Heidegger describes it, in addition to what such items are used for. There are different levels of this in-order-to towards a final cause, the for-the-sake-of-which. Heidegger's central premise was that the human-made things, primordially, are not understood as detached, isolated objects for use in everyday life. Furthermore, there is no such thing as "equipment" (Zeug), but a totality of equipment and equipment nexus. A table does not primordially exist in everyday life as an isolated object, but together with chairs, table-legs, a tablecloth – all of these represent in one form or another an equipmental nexus.

Further, in the lectures before Being and Time [73], Heidegger did a phenomenological analysis of how the home dwellers were oriented to and around the table and how the table was oriented in the room. The way they placed the table in the room, the way they oriented themselves towards the table, and how the table was part of the daily life at home with his family and friends were used to flesh out the central role that objects and equipment played, and the reciprocity between the table and the dwellers. Only later was a well-known example of various ways relating to the hammer-in-use was employed.

Thus, T-ABLE is an example of familiar technology. In the German language of Heidegger, the familiar is described as *vertraut* or *bekannt*, that which we are used to or that which we know. Heidegger's early writing is not concerned with inclusive design or UD specifically, but it addresses the question of being-here. Heidegger claims that the basis for understanding "being-in-the-world" lies in the everyday lives that we all live and understand our familiarity with it. Our behavior in our everyday life activities with each other and the equipment surrounding us give insight into everyday living with familiar things. Familiarity is, hence, about what is well-known, what is familiar to us. This knowledge is not primordially theoretical but essentially a skill related to our situated ability to act, do something, or interact with a robotic device. Furthermore, involvement or engagement is a condition for the possibility of being familiar with something. Interacting or engaging with a robotic product is conditioned on the design of the product itself, first and foremost, and the skills of the individual user.

D. Discussion through the lenses of the existing HRI literature

Designing for situated abilities seems to be strongly linked to designing with familiarity in mind. Our findings are confirmed and supported by several earlier studies. We start the discussion in this sub-section by first presenting a few other examples of robotic furniture, such as the mechanical ottoman [67], the Roombots [75], and the PEIS robotic table [76]. Thereafter, we continue with reflections and discussion on long-term interaction with robots in the home by bringing for- and contrasting arguments for the T-ABLE study.

For instance, a robot similar to T-ABLE was first developed by Sirkin and colleagues [67], namely the mechanical ottoman. The mechanical ottoman is a robotic footstool where the participants engage with the robot by placing their feet on the footstool or taking them off. The robot is also able to adjust its cushion and to navigate the plane environment. However, it does not have an anthropomorphic look; thus, the participants are encouraged to engage with the robotic footstool through a joint, at times, negotiated action between the human and the robot.

A second example is given by the study from Sproewits et al. (2009) [75] on Roombots. Roombots are described as self-reconfiguring modular robots acting as adaptive furniture [75]. The Roombots are a combination of Information Technology (IT), roomware, and robotics. They started from the idea that humans and technology will co-habit future working and living environments seamlessly [75] (p. 4259). Their building blocks are made of attachable/detachable simple robotic modules with connectors in-between these.

A third similar proposal to T-ABLE is the PEIS robotic table [76]. The PEIS robotic table is designed as a robotic service table used in domestic settings as part of a smart home environment. Like the T-ABLE, the PEIS table is envisioned to be a robot butler that can move around the home, carry objects on top of it, bring objects at the command, and be able to dock/undock itself [76]. The authors' vision is that many such autonomous robots as PEIS may orchestrate their actions and ecologically fulfill the users' requirements – this view is rather opposed to having one robot "doing it all." The study argues that besides the robots' functionality, the robot should adopt a furniture-like design [76]. According to the authors [76], the design of such artifacts will not be perceived as "foreign bodies" by the human, "but rather as a natural extension of their usual, familiar environment" (p. 245). The authors also argue for the familiarity of movement that should both be perceived as safe and safe for the human user, with a high predictability rate of the robot's behavior [76]. This robotic motion is also explored in previous research: the current literature includes studies on how a relation to moving things in the home can be classified based on the type of movement the human or robot is doing [25]. The current research also suggests ways of finding familiar movement relationships that contribute to the design of robot motion. A such example is the more recent research on natural-looking motion, using the idea of slow in-slow out from Schulz et al. [64][65].

Further, current studies also argue for the robot's non-invasive wooden appearance to increase its ecological familiarity-look similar to a piece of furniture [76].

However, a contrasting study to ours and the ones described above on furniture robots is the study from [78]. Although the study from [78] does not talk about robotic furniture to be used in the home, but rather about robots to be used in public spaces, such as museums, the study's arguments still support our study. The main argument is that robots, in general, are designed to either be used in the lab, living labs, or non-real world environments, or they are designed to be used in public spaces, with a short-term interaction in mind [9]. A few examples of such robots are receptionist robots in hotels, greeting robots in shopping centers, or robots in a museum [9]. Minerva and Rhino [78] are examples of such robots used in museums as tour-guides. They are service robots that assist people in everyday life; however, they are designed for short-term and spontaneous interactions, where people spend only a limited amount of time with the robot, e.g., around 15 minutes. They were designed with some humanoid features, such as avatars displaying different moods, e.g., happy, serious, sad; however, they are not considered humanoid robots.

One essential aspect of their design is that this avatar moods feature was chosen to enable a representation of human emotions that the people would easily recognize. This, in its turn, enables the humans to easier relate to already familiar social aspects to them, according to [78]. In addition, the physical features, such as legs and arms, were not emulated as humans specific characteristics, i.e., these were not designed as real human legs, arms, heads, or faces. However, this kept the robot design simplified, still giving familiar physical aspects that are easily recognizable by human users. Further, the authors [78] argue that incorporating familiar features in robot design, however, without anthro- or zoomorphizing the robots, is essential to enabling smooth interaction between the human and the robot and a higher acceptance of the robot amongst the human users. This is also in line with our view and arguments in this paper, confirming that familiar features embedded in the design of robot facilitate the integration of robots in domestic settings, and may support long-term interaction.

Compared to the authors investigating Minerva and Rhino robots [78], the authors of the study on Roombots design [75] focused on the robots' function rather than their appearance. The authors envision that such robots can be useful when they autonomously can orchestrate themselves into different types of static or dynamic structures, such as into different pieces of furniture, i.e., from stools and chairs to sofas and tables, and from robotic arms picking up objects to servants robots transporting the objects, depending on the users' needs and requirements [75].

Further, the authors insist [67] that long-term interaction with such robots, to be used in the home, is needed. The authors also argue that such work has not been done so far. Instead, the focus on human-robot joint action was so far on task handover, similar to when robotic vacuum cleaners are used in the home or when a robot is part of a distributed system, such as a smart home ecology, e.g., see the study from [76]. They also confirm that people tend to usually show more acceptance of robotic furniture and their use in their homes. Similarly, Sirkin and colleagues [67] argue that it would be great if robotic vacuum cleaners, such as Roomba, would have a humble look of the furniture, such as a stool. This look challenges the HRI community to shift the focus from mechanical-, anthropomorphized-, zoomorphized- or biologically inspired robots' appearances to furniture-like robots.

Moreover, several studies on familiarity focus on the appropriation of technology by making their design familiar to the user [75][78]–[81]. At the same time, an extensive body of research exploring UD and familiarity is available [81]–[85]; however, none of these explore familiarity and UD in robot design.

All in all, although the studies from [78] on Minerva and Rhino, the study from [75] on Roombots, and the study from [76] on the PEIS table are very contrasting, all studies agree that incorporating familiar features in the robots to enable long-term interaction. Thus, this confirms our theoretical findings and discussions on this initial study on T-ABLE. However, none of these studies focus on how the robotic piece of furniture can be designed with UD in mind to enable as many users as possible to use. This aspect both argues for our own positioning of this study, as well as catalyzes further our motivation for continuing this investigation in more rich empirical settings.

Thus, the authors inspired by the work of Heidegger, argue that familiarity might be used as a concept when working with inclusion and UD. Hence, we have illustrated the idea of designing for situated abilities through a domestic robot's design. The T-ABLE prototype incorporates some familiar elements. First, the robot is designed with a table's look, rather than having a humanoid appearance that may lead to the uncanny valley phenomenon [14]. Second, the domestic robot's wooden appearance is a design that fits better in the existing home environment, appropriating its design to the existent furniture in the home, rather than the appearance of a machine with a plastic look. Last, the design of the robotic T-ABLE is modular, allowing for multiples uses.

Finally, designing for situated abilities is not only about UD. It goes beyond the design of a product or service. It is an abstract concept, a theoretical approach that begins with the abilities of the human being. UD is rather focused on service products that serve the human. In other words, designing for situated abilities to increase the individual's abilities on the ability continuum in a given context or situation involves incorporating familiar elements in the design of the product (or service).

VII. Conclusion and Future Work

This study proposes the idea of designing for situated abilities, rather than disabilities, adopting a salutogenic, e.g., a positive-laden approach, to design. The initially stated research questions were answered by presenting an alternative design to domestic robots, wooden-based robots that fit naturally into our home environments and are based on a theoretical elevation of everyday situated abilities. The idea of situated abilities anchored in a UD approach was then introduced; however, it was different from existing UD studies, which have emerged from disability studies. The idea proposed in this paper is the idea of designing for abilities rather than disabilities. The definition of situated abilities as indicated in Saplacan [51] was used: "Situated ability is the ability to comprehend, manage, or find the meaning in the interaction with a digital system." (p. 9). However, this design approach is close to the relational models, such as the Scandinavian or GAP models [72], with a twist on the disability perspective – focusing instead on abilities and enabling environments. In other words, the disabled environment or a disabling design is recognized as being part of the problem. These arguments were based on our previous research, as described in the Background Section of the paper. Further, it was argued that a good design for a product, be it a domestic robotic product or another type of product, is good if the product fits the individuals' environment AND the individuals' abilities and needs, rather than the individual fitting the product. Thus, four dimensions of designing for situated abilities were identified: 1) a social one, 2) a relational one, 3) a socio-relational one, and 4) an empowering one.

This work could be further explored in the context of the HCI/HRI debate in several ways, including responsible robotics, AI, and new paradigms of HCI and HRI.

For instance, Boden et al. discuss the importance of responsible robotics, especially now when more and more robots leave the research lab [86]. In this sense, the authors have developed a set of principles that regulate robots in the real world. Amongst the designed principles, they describe principle 2, saying that the robots should comply with the existing law, including privacy. Principle 4 says that robots should not include the "illusion of emotion and intent" and be used with vulnerable users (p. 127). Further, principle 5 refers to being able to identify who is responsible for any robot.

Further, aging and the need to create a global infrastructure that involves inclusion- and ability-based design have been on the UD agenda for a while [52][53]. This could be explored further. Moreover, indirectly through this paper, a debate on the ethics and responsibilities of design is introduced, along with the relationship between humans and (digital) things seen from the UD perspective, specifically in terms of the idea of designing for situated abilities, and the idea that our abilities are situated on an ability continuum. This perspective fits well with the ideas discussed in Frauenberger [87] and those discussed in his earlier work [46] on designing for different abilities rather than designing for different disabilities. Finally, this work can catalyze discussions in the debate explored in Ashby et al. [88] on the fourth HCI wave, on value ethics and activism for positive change within HCI.

Other possible open research questions aligned with the future directions to be explored are:

a) How can the challenges posed by the design of robots concerning UD, i.e., robots designed to be usable by a diversity of users (care recipients, informal and formal caregivers, medical staff, and technical staff), be addressed?

b) What legal implications does this have concerning the UD of products used in the public sector, including the healthcare sector?

b) How can UD set an ethical regulatory framework to ensure adequate development of AI in robots?

c) What are the technical benefits and challenges set by a UD framework when developing robots to be used in healthcare or the public sector?

It is hoped that our approach to designing for situated abilities may help to result in a shift in the perspectives of current UD studies focusing on disabilities, though the importance of such studies is acknowledged. Finally, we argue that a salutogenic approach to design, such as designing for situated abilities rather than disabilities, can be beneficial in finding new alternative designs.

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