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.

References

[1] C. Kontzinos et al., "Using Blockchain, Semantics and Data Analytics to Optimise Qualification Certification, Recruitment and Competency Management: a Landscape Review," *Mobile, Hybrid, On-line Learn. (eLmL 2020)*, 2020.

[2] M. Turkanović, M. Hölbl, K. Košič, M. Heričko, and A. Kamišalić, "EduCTX: A blockchain-based higher education credit platform," *IEEE Access*, 2018, doi: 10.1109/ACCESS.2018.2789929.

[3] "Digitisation in Academic Education. Our agenda for a future-proof range of degree programmes," 2017.

[4] R. Zhang, R. Xue, and L. Liu, "Security and privacy on blockchain," *ACM Comput. Surv.*, 2019, doi: 10.1145/3316481.

[5] A. Castor, "Cardano Blockchain's First Use Case: Proof of University Diplomas in Greece." https://bitcoinmagazine.com/articles/cardano-blockchains-first-use-case-proof-university-diplomas-greece (accessed Dec. 01, 2020).

[6] D. Serranito, A. Vasconcelos, S. Guerreiro, and M. Correia, "Blockchain Ecosystem for Verifiable Qualifications," *2020 2nd Conf. Blockchain Res. Appl. Innov. Networks Serv. BRAINS 2020*, pp. 192–199, 2020, doi: 10.1109/BRAINS49436.2020.9223305.

[7] "REGULATION (EU) 2016/679 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 April 2016." https://eur-lex.europa.eu/eli/reg/2016/679/oj (accessed Aug. 01, 2020).

[8] N. B. Truong, K. Sun, G. M. Lee, and Y. Guo, "GDPR-Compliant Personal Data Management: A Blockchain-Based Solution," *IEEE Trans. Inf. Forensics Secur.*, 2020, doi: 10.1109/TIFS.2019.2948287.

[9] A. Mahindrakar and K. P. Joshi, "Automating GDPR

Compliance using Policy Integrated Blockchain," 2020, doi: 10.1109/BigDataSecurity-HPSC-IDS49724.2020.00026.

[10] M. M. H. Onik, C. S. Kim, N. Y. Lee, and J. Yang, "Privacy-aware blockchain for personal data sharing and tracking," *Open Comput. Sci.*, vol. 9, no. 1, pp. 80–91, 2019, doi: 10.1515/comp-2019-0005.

[11] T. Berners-Lee, J. Hendler, and O. Lassila, "The semantic web," *Sci. Am.*, vol. 284.5, pp. 34–43, 2001.

[12] "GitHub - ConsenSys/EthOn: EthOn - The Ethereum Ontology." https://github.com/ConsenSys/EthOn (accessed Dec. 01, 2020).

[13] "Open Badges v2.0." https://www.imsglobal.org/sites/default/files/Badges/OBv2p0Final/index.html (accessed Dec. 01, 2020).

[14] "Fraunhofer: SARO Ontology." https://vocol.iais.fraunhofer.de/saro/visualization# (accessed Aug. 01, 2020).

[15] T. W. Liao, "Clustering of time series data - A survey," *Pattern Recognit.*, 2005, doi: 10.1016/j.patcog.2005.01.025.

[16] "MLlib | Apache Spark." https://spark.apache.org/mllib/ (accessed Dec. 01, 2020).

[17] C. Kontzinos et al., "University process optimisation through smart curriculum design and blockchain-based student accreditation," 2019, doi: 10.33965/icwi2019_2019131012.

[18] "Qualification Check - Certificate Global Verification." https://www.qualificationcheck.com/ (accessed Dec. 01, 2020).

[19] "Federal Institute for Vocatiomal Education and Training: Recognition Finder." https://www.anerkennung-in-deutschland.de/en/interest/finder/profession (accessed Dec. 01, 2020).

[20] "European Credit Transfer and Accumulation System (ECTS) | Education and Training." https://ec.europa.eu/education/resources-and-tools/european-credit-transfer-and-accumulation-system-ects_en (accessed Dec. 01, 2020).

[21] "Recognition of foreign qualifications - Swedish Council for Higher Education." https://www.uhr.se/en/start/recognition-of-foreign-qualifications/ (accessed Dec. 01, 2020).

[22] "ServiceNow – Service Now Verification/Certification service." https://www.servicenow.com/ (accessed Dec. 01, 2020).

[23] "British Columbia – Ministry of Education: Teacher Certification." https://www.bcteacherregulation.ca/CertificateServices/CertificateServicesOverview.aspx (accessed Aug. 01, 2020).

[24] "College Degree Verification Services | DegreeVerify." https://nscverifications.org/degreeverify/ (accessed Dec. 01, 2020).

[25] "Degree Equivalency Tool - WES.org/ca." https://applications.wes.org/ca/degree-equivalency-tool/ (accessed Dec. 01, 2020).

[26] "Higher Education Funding COuncil for England (HEFCE): Higher Education Degree Datacheck (HEDD)." https://hedd.ac.uk/#section-what-we-offer (accessed Dec. 01, 2020).

[27] "Norwegian Agency for Quality Assurance in Education (NOKUT): Recognition of foreign higher education in Norway." https://www.nokut.no/en/ (accessed Dec. 01, 2020).

[28] "The Norwegian Directorate for ICT and Joint Services in Higher Education and Research: Vitnemalsportalen Diploma registry." https://www.vitnemalsportalen.no/english/ (accessed Dec. 01, 2020).

[29] "e-CF 3.0 Profiling tool on-line | European e-Competence Framework." http://www.ecompetences.eu/e-cf-3-0-and-ict-profiles-on-line-tool/ (accessed Dec. 01, 2020).

[30] "Council of European Professional Informatics Societies (CEPIS): CEPIS e-Competence Benchmark." https://www.cepisecompetencebenchmark.org/ (accessed Aug. 01, 2020).

[31] "e-Competence Quality: e-Competences assessment and certification assessment." http://www.e-competence-quality.com/ (accessed Aug. 01, 2020).

[32] "ICT-mastery: IT Staffing Nederland." https://www.ict-mastery.eu/index.php/en/#finding-the-best-ict-applicant (accessed Dec. 01, 2020).

[33] "The Open Standard for Blockchain Credentials: Blockcerts." https://www.blockcerts.org/ (accessed Aug. 01, 2020).

[34] "CIMEA: Diplome." http://www.cimea.it/en/projects-list/diplome-blockchain4people/home-page-blockchain-2.aspx (accessed Dec. 01, 2020).

[35] "LinkChain." https://linkchain.supply/ (accessed Aug. 01, 2020).

[36] "Fraunhofer FIT: Blockchain for Education." https://www.fit.fraunhofer.de/en/fb/cscw/projects/blockchain-for-education.html (accessed Aug. 01, 2020).

[37] J. S. Dyer, P. C. Fishburn, R. E. Steuer, J. Wallenius, and S. Zionts, "Multiple Criteria Decision Making, Multiattribute Utility Theory: The Next Ten Years," *Manage. Sci.*, 1992, doi: 10.1287/mnsc.38.5.645.

[38] D. BOUYSSOU and P. VINCKE, "Ranking Alternatives on the Basis of Preference Relations: A Progress Report with Special Emphasis on Outranking Relations," *J. Multi-Criteria Decis. Anal.*, 1997, doi: 10.1002/(sici)1099-1360(199703)6:2<77::aid-mcda144>3.3.co;2-9.

[39] J. S. Dyer, "MAUT-multiattribute utility theory," in *International Series in Operations Research and Management Science*, 2005.

[40] Y. Çelikbilek and F. Tüysüz, "An in-depth review of theory of the TOPSIS method: An experimental analysis," *J. Manag. Anal.*, pp. 281–300, 2020, doi: 10.1080/23270012.2020.1748528.

[41] J. Figueira, V. Mousseau, and B. Roy, "ELECTRE methods," *Mult. Criteria Decis. Anal. State Art Surv.*, pp. 133–153, 2005, doi: 10.1007/0-387-23081-5_4.

[42] B. Mareschal, "The Promethee Methods for MCDM," *Readings Mult. Criteria Decis. Aid, Springer*, pp. 216–252, 1990.