IMPLEMENTING BLOCKCHAIN AND COMPUTER INTELLIGENCE FOR UNIVERSITY PROCESS OPTIMISATION: THE QUALICHAIN CASE

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Abstract

The aim of Higher Education is twofold: meet the learning needs of individuals through the development of their intellectual abilities as well as equip them with the necessary skills that will help them enter the labour market. As such, university processes and curricula should be well structured with courses and activities that help students follow their aptitudes, while also providing them with the required level of expertise that the respective job market requires. This paper presents work from the EU funded research project QualiChain that aims to revolutionise the domains of public and private education as well as their connections with the labour market and society at large through the development of a platform that is based on innovative approaches and technologies, such as Blockchain, semantics, data analytics and decision support. To deal with the aforementioned challenges, QualiChain involves a pilot targeting student accreditation, curriculum design and process optimisation within the School of Electrical & Computer Engineering (ECE) of the National Technical University of Athens (NTUA), which will be the main focus of the present paper.

Keywords: Blockchain, Education, Labour market, Degree Verification, Curriculum optimisation, Decision support, Data analytics.

1 INTRODUCTION

Higher Education in the fourth industrial revolution is a complex, dialectical and exciting opportunity which can potentially transform society for the better [1]. In an era that information and communication technologies are transforming much of society and promoting new paradigms in various sectors, Higher Education Institutions (HEIs) are challenged to meet the connectivity demands of prospective students as well as growing expectations and demands for higher quality learning experiences and outcomes [2]. As such, to ensure that the benefits of Higher Education are fully realised, a transformation of these learning environments, in an increasingly electronic world, is critical [3]. According to Young [4], adoption of innovative technological solutions by universities can help them facilitate the commercialisation of research results for the public good, reward, retain and recruit faculty, induce closer ties to industry and promote overall economic growth.

At the same time, HEIs need to stay true to their original goals, by helping their students develop their aptitudes and intellectual abilities as well as equip them with the necessary hard and soft skills that will help them enter the job market [5]. The former requires guidance from the university to help students make the best use of their talents as well as a way to help them track their skills and qualifications, while the latter requires HEIs to follow the developments in their respective domains to maintain a certain level of connection with the job market. As such, HEIs need to be constantly evolving to respond to the ever-changing needs of society such as growing student demands in certain disciplines, embedding workplace attributes to graduates and ensuring that the quality of learning programs is both nationally and globally relevant [6].

Despite the aforementioned challenges and the growing need for universities to become more connected to the job market, oftentimes the curricula of HEIs are shaped with strictly academic criteria without taking into account the demands of the labour market and they are rarely modified to incorporate the latest developments, especially in technology related fields, thereby ending up being obsolete and outdated [7]. Another major challenge is that education credentials such as degrees, qualifications and other accreditations still require paper documentation in most cases and time-consuming processes for their verification. As a result, holders of such credentials must always be dependent on the institutions that issue them, which can create major issues when they want to transfer to another HEI or send their certifications to a prospective employer. Additionally, the increasing amounts of fraud and corruption around higher education degrees and credentials is shaking the trust in the education system [8, 9].

HEIs need to fundamentally change the way they operate to efficiently respond to the expectations of society in the 21st century. However, despite the aforementioned circumstances, the slow digitisation of HEIs is a major concern in the research community [10]. While university IT infrastructures nowadays support most of the logistic processes, their data are held in centralised databases with little or no interoperability and with limited access to the IT staff of the institution [11]. However, such data are representative of student life [12] and university processes and can help HEIs realise shortcomings in the way they operate. The lack of structure and analysis in university data is the main concern of this paper as it prevents such institutions to tackle the challenges they face.

It can be surmised from the above that many of the aforementioned challenges could be solved via the implementation of suitable IT infrastructures. Apart from existing IT systems and infrastructures, there are several innovative technologies that HEIs could take advantage of to develop trustworthy and efficient solutions. Data analytics and decision support can help universities analyse their data to draw useful conclusions and receive recommendations on optimising their operation. Moreover, blockchain technology, as a decentralized, permanent and unalterable store of information can help with the archiving and trust issues around academic credentials [7].

Under these circumstances, this paper presents QualiChain, an EU funded project targeting the creation, piloting and evaluation of a distributed platform for storing, sharing and verifying academic and employment qualifications. QualiChain will take advantage of blockchain to create a secure and trustworthy system for degree verification while also promoting transparent student accreditation via smart badge endorsement as an innovative approach to enhance everyday student life. By combining various innovative technologies such as semantics, data analytics and decision support with a blockchain infrastructure, QualiChain aims to show that the projected solution will not only cover student accreditation but has potential for wider university process optimisation. To showcase and validate the impact of the platform, the project includes a pilot targeting student accreditation, curriculum design, and process optimization within the School of Electrical & Computer Engineering (ECE) of the National Technical University of Athens (NTUA), which is the main focus of this paper.

Section 1 introduces the scope of this paper by presenting the current situation in Higher Education, the challenges that lead to the need for digitisation and how blockchain and other innovative technologies can lead to more effective and secure solutions. Section 2 outlines the methodology that will be followed to realise the pilot case presented in this paper. Section 3 introduces the pilot concept, its stakeholders and initial results as well as the next steps that will be performed. Finally, section 4 presents the conclusions of the paper.

2 PILOT METHODOLOGY

The pilot case presented in this paper will focus on the optimisation of the teaching process and university operation of the ECE School of the NTUA and will revolve around the two-following axis:

1. Provision of analytics and recommendations, through the platform's Decision Support System (DSS) for student guidance as well as the redesign and update of specific courses and by extension the entire curriculum of the school.
2. Smart Badge student accreditation and lecturer validation and recognition through a trusted, immutable and secure Blockchain ledger.

The methodology that will be followed to fulfil the goals of this pilot can be seen in Fig.1 and will be further explained below.

In order to fulfil the goals of this pilot, the labour market requirements of popular professions among the school's graduates will have to be analysed and assessed with the current skill/knowledge profile of the average student of the school. For this purpose, the project's technical team will perform data crawling in well-known job posting sites in order to identify the sectors and specific professions that target Electrical & Computer Engineers. Of those professions, the specific skills and qualifications required will be mapped and compared with the current skill profile of a student of the School, which will be assessed through interviews and questionnaires. The data produced from these activities will be semantically enriched, given structure and fed into a data analytics module that will produce a number of indicators concerning popular careers among the School's graduates.

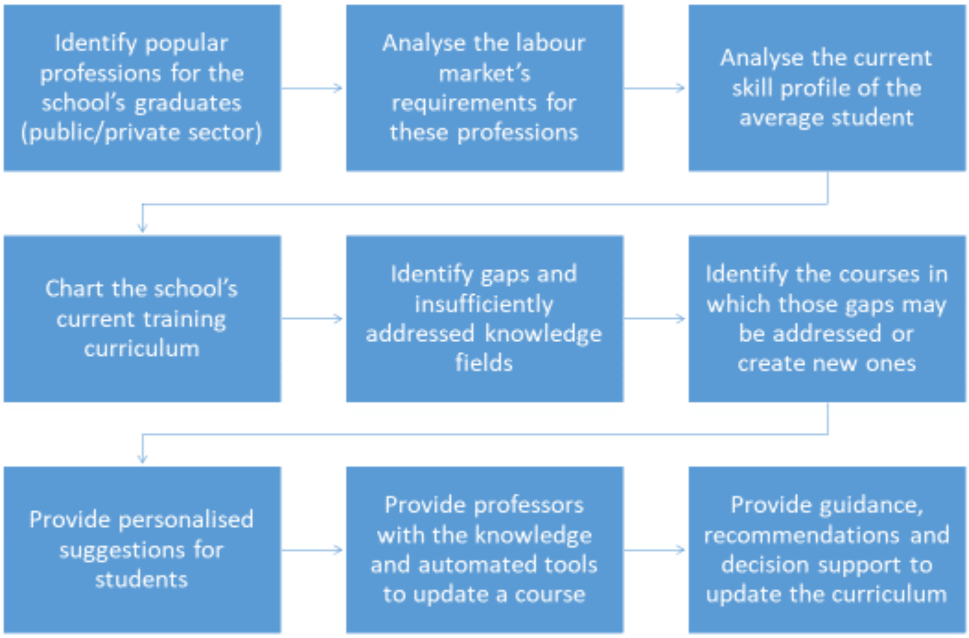

Figure 1: Pilot Methodology

Following that, the pilot will chart the school's current curriculum to identify gaps and insufficiently addressed knowledge fields as well as the courses in which those gaps may be addressed by updating/enriching the course's curriculum. This procedure will have to be performed course-by-course and is projected to be a herculean task given the length and complexity of the School's curriculum. Specifically the curriculum specifies that a student will have to complete 35 core courses in the first five semesters and 25 specialisation courses, selected from three or four out of twelve specialisation flows, in the following four semesters. The 60 courses that the student will have to complete are selected from a pool that includes over 200 courses stemming from various technological and scientific fields, such as software and hardware engineering, electrical engineering, energy efficiency, mathematics, physics etc.

The purpose of the previous task is to extract metadata from the analysed courses and use them in combination with job market required skills as input for the platform's analytics tool that will identify skill and knowledge gaps in the curriculum. This process will generate various metrics and indicators that will feed the platform's DSS tool, which will in turn produce various suggestions for the pilot's stakeholders. These include personalised suggestions for students, recommendations to professors who want to update their courses and overall guidance and decision support for the curriculum update and process optimisation of the entire school. The specifics of the above mentioned procedures and interactions will be further explained in the following section.

3 PROGRESS & RESULTS

The QualiChain project is still at an early stage, which means that no technical solution has been developed yet. Consequently, the initial results of the pilot use case presented in this paper include the theoretical groundwork that specifies the methodology for completing the pilot, user requirements, and process flow that will be followed between the various stakeholders of the QualiChain platform. This section describes the flow that will be followed during the pilot's operation for the optimisation of the various stakeholders' everyday tasks and for the endorsement of smart badges from professors to their students and lecturers. The process flow has been split in three parts to accommodate the different needs of the pilot's stakeholders, i.e. undergraduate student, PhD students and professors, which will be further elaborated below.

An undergraduate student's main challenge with the as-is situation revolves around the lack of recommendations and general guidance for selecting courses and making the choices that will maximise his/her aptitudes and future career plans. The School's curriculum lacks the structure that will allow students to make more informed decisions and there are no added-value tools for filtering and analysing one's choices. As such, they have to rely on the opinion of older students for selecting courses, an opinion that can be in many cases biased. Additionally, especially in the era of digitisation, students lack any kind of personal profile in which they could showcase and digitally validate the skills and qualifications received through their education, in a way that is trustworthy for potential future employers.

PhD students/lecturers are a group that is often overlooked in the various approaches that tackle the domain of Higher Education. In the ECE School, PhD students are responsible for various tasks such as teaching classes, grading exams, performing research and other administrative processes, relevant to the wide range of the university's activities. However, their working experience in academia is not often reflected in their professional profile as many of those tasks cannot be digitally validated and recognised with the School's current infrastructure.

Finally, professors of the School, often face difficulties in performing tasks such as updating a course, assessing student evaluations and certifying students' participation in extra-curricular activities that they organise. The main challenge in this case is the lack of automation and structure in the School's data. As a result, professors need to rely on their own perception when trying to identify pertinent advancements in their respective fields in order to update the syllabus of a course. Additionally, students' evaluations offer no possibility for automatic analysis and they require manual work for the extraction of useful conclusions.

In the context of this pilot, data play the most important role. As it was previously mentioned, it is the lack of structure in the School's data that creates most of the challenges for its stakeholders. For that reason, data concerning the university and the respective job market will be semantically enhanced and normalised to provide the much needed structure for the platform's added value analytics and DSS tools. Such data include but are not limited to the School's curriculum and each individual course, skills developed and students' evaluations, as well as data that will be mined from open repositories, such as job market requirements, popular professions and employment rates for the School's graduates. The following sections, that describe in detail the added-value of the QualiChain platform for the pilot's stakeholders, consider the semantic enrichment of the afovementioned data as a given.

3.1 Pilot Process Flow

3.1.1 Undergraduate Students' Process Flow

In the context of this pilot, students will first have to sign in the QualiChain platform with their verified school credentials and work on their dedicated personal profile. For this purpose, they will use a sub-module of the platform's DSS tool, entitled Intelligent Profiling Module (IPM). The IPM will draw various data from QualiChain (credentials, courses etc.) and students will manually fill in additional data (interests, future career projection etc.) to create their profile, which is then saved in QualiChain.

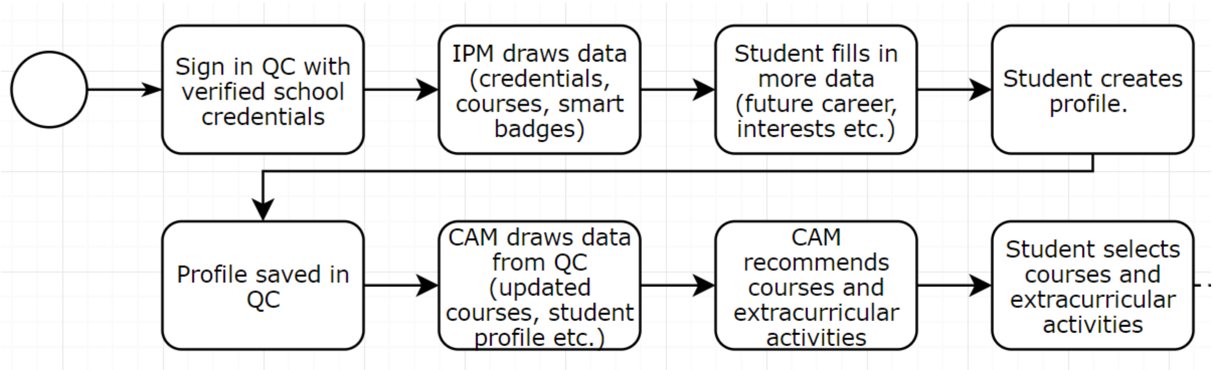

Figure 2: Undergraduate students' process flow

Following that, another sub-module of the DSS tool, the Career Advisor Module (CAM) will take into account the student's profile and the school's curriculum and recommend courses and extracurricular activities.

3.1.2 PhD Students' Process Flow

PhD students, similar to the previous stakeholder group, will sign in QualiChain with their verified credentials and create their personal profile in the platform. The IPM will take into account the students' degree, course involvement, PhD thesis etc. to help them create their profile. It should be noted that while PhD students will have the capability to use the CAM to receive recommendations for furthering and improving their knowledge, skills and career, their main role in the pilot revolves around receiving tokens and smart badges for their involvement in various university related tasks, through the platform's blockchain ledger.

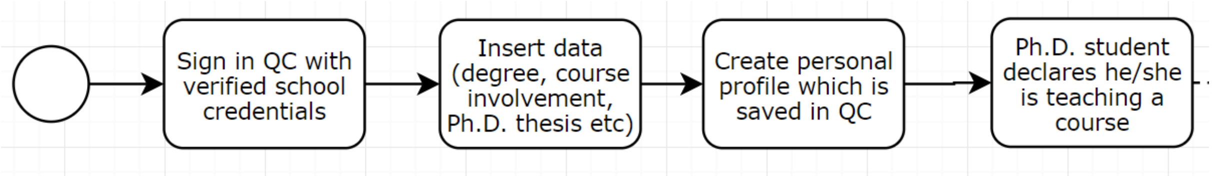

Figure 3: PhD students' process flow

3.1.3 Professors' Process Flow

Finally, professors, after signing in QualiChain, will insert data into the platform that are relevant to their courses (course metadata, students' evaluations etc.). When a professor wants to update a course, such data will be fed into the platform's analytics tools along with curriculum data, job market data, technological developments for the respective domain and job market requirements to produce various analyses. The platform's DSS tool will take as input these analyses and produce recommendations that will help the professors update a course. The updated course is then saved in QualiChain and in case that some of the knowledge gaps identified in the pilot's previous steps were addressed, QualiChain will update the recommendations produced for the other courses as well as the recommendations that students receive through the Career Advisor Module.

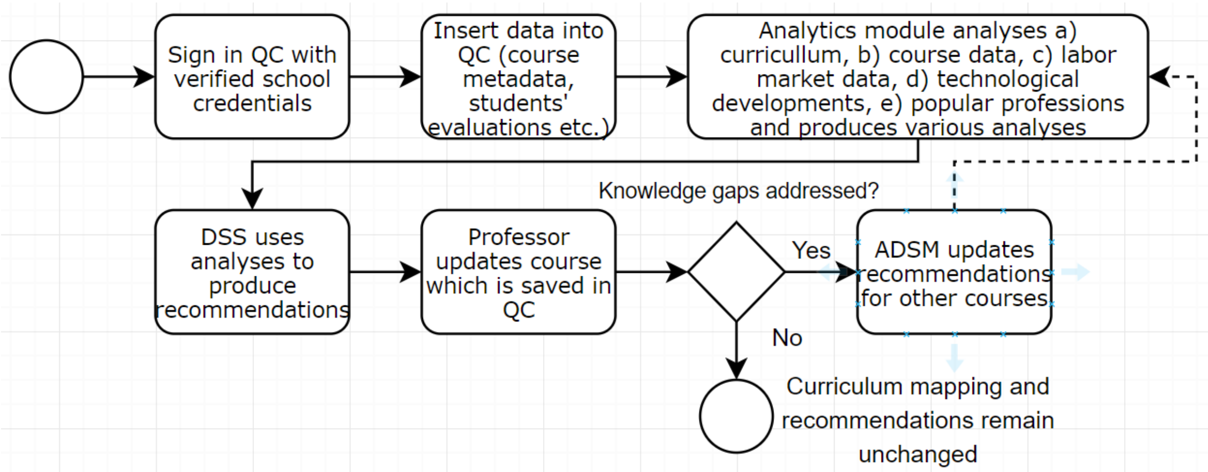

Figure 4: Professors' process flow

3.2 Smart Badge Endorsements

As already mentioned, QualiChain will take advantage of the platform's blockchain ledger for validating, through tokens and smart badges, skills and accreditations that students receive by attending courses, completing assignments and participating in hackathons, seminars and other various extracurricular activities. The same mechanism will be employed to award PhD students and lecturers with smart badges for teaching courses contributing to various university tasks. The process flow that will be followed for smart badge endorsement can be seen in Fig. 5 and is described below.

The most important contribution of the blockchain ledger for this pilot is that professors will be able to award students with smart badges. On the one hand, given that a number of courses include personal or group assignments, professors at the end of the semester will be able to award smart badges to the student(s) that achieved the best results. An example could be the most efficient algorithms in software related courses. Additionally, oftentimes professors organise extracurricular activities such as hackathons, seminars and special lectures. Students that attend such activities will be awarded with participation badges. Smart badges are a secure and trustworthy way to validate that students possess a certain skill or qualification and will be displayed on their personal profile.

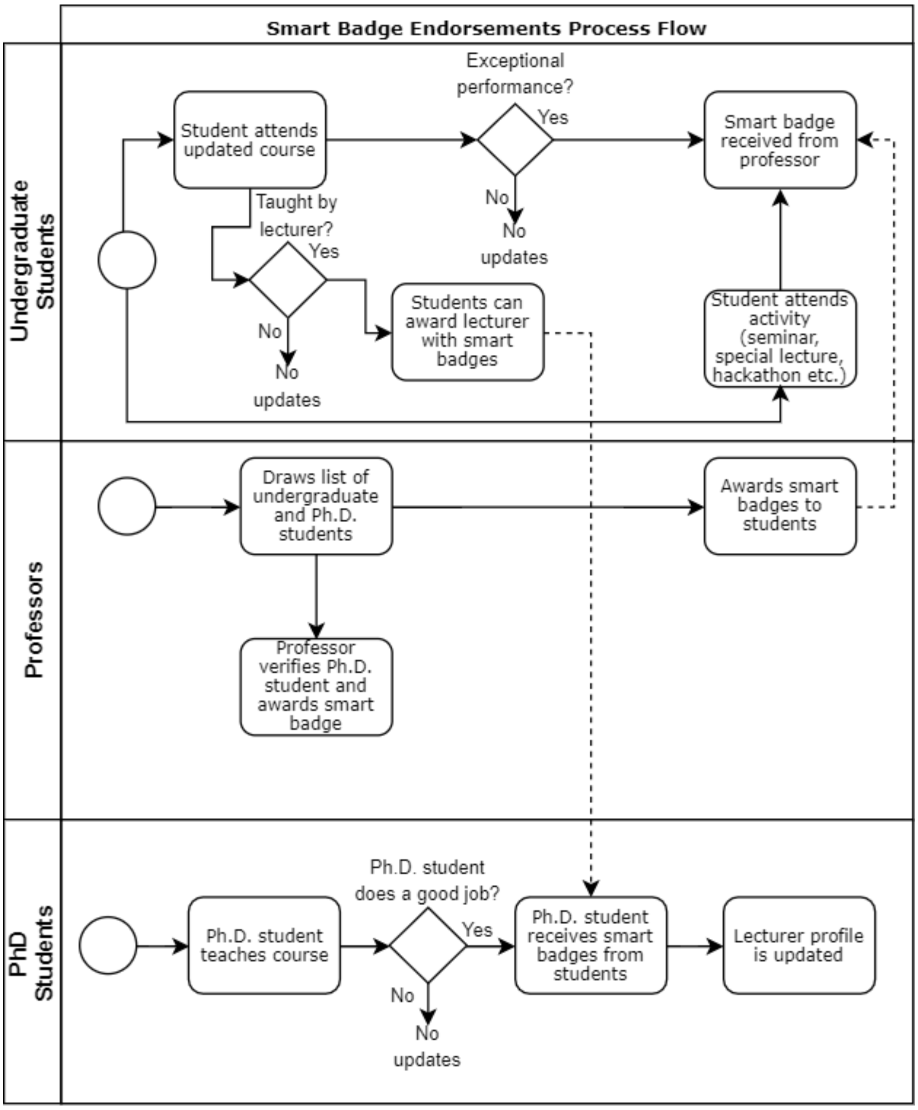

Figure 5: Smart badge endorsement process flow

On the other hand, Smart Badges are an innovative way to verify PhD students' and lecturers' participation in courses and other university related activities. Focusing on courses, a PhD student, who is also a user of QualiChain will be able to declare via the platform his involvement with a specific course. The professor, who is responsible for said course will validate that declaration by offering a smart badge to the PhD student. Through their involvement in a course, PhD students will also be able to receive tokens from the students for performing well during the lectures. For example, students will award lecturers with tokens for being informative, cooperative, communicative etc. and there will be a set ratio of tokens to smart badges (for example 30 tokens for being communicative equal one smart badge). The reason that for this case, tokens are used instead of smart badges, is to keep the smart badge accreditation portion of this pilot under control and avoid overemphasising the contributions of PhD student in courses with hundreds of similar smart badges awarded to them.

3.3 Next Steps

At this stage of the project's lifecycle, the pilot presented in this paper has completed the initial steps of requirement elicitation, specification of data gathering activities and creation of diagrams and process flows that explain the interactions of the pilots' stakeholders with the platform. Next steps involve data gathering via web-forms, questionnaires and interviews with the pilot's stakeholders, semantic enrichment of the school's curriculum as well as integration of the latter to the QualiChain ontology, which will be explained below.

Semantic technology is a major cornerstone of the project, since most data to be processed, analysed and used for value-added services will be subject to the process of 'semantification'. In other words, data behind QualiChain will be semantically lifted onto a knowledge graph that can be uniformly queried and processed by various QualiChain platform components. QualiChain will promote and enforce semantic interoperability through domain-specific standards and ontologies – some of which are already available, and some that are being extended or designed anew. These vocabularies will be brought together through the design of a QualiChain ontology, which despite its name will not only be relevant and of value for the immediate needs of the project, but is independent and can represent any efforts using Blockchain to verify smart contracts and certificates. As such, the QualiChain ontology will be a wide mixed set of existing, extended or new vocabularies that the QualiChain ontology itself successfully integrates.

While there are vocabularies that sufficiently describe and cover course descriptions, skills and qualifications, such vocabularies need to be extended and connected to the specific data of the ECE School. For that reason, the courses of the school's curriculum will have to be analysed to extract data from them and use them to extend existing vocabularies. An example of the information available for each course is presented in Fig. 6.

Decision Support Systems

Code	3.7.3306.7
Semester	7th
Flow	O - Management and Decision Support Systems
Category	Obligatory (half flow)
Credits	5
Class Hours - Lab Hours	3 - 1
Lecturers	Haris Doukas, John Psarras, Maria Flouri (T & R Associates), Ioanna Makarouni (T & R Associates),

Description

Decision making: Decision support models and their use in decision making; Elements and structure of a decision problem; Decision Trees: Decision Matrices The Bayes, Maximin, Maximax and Hurwitz criteria; Problem-solving with sampling information about the states of nature; Values of sampling and complete information. Dynamic programming: Characteristics of a dynamic programming problem; Examples of multi-stage decisions; Schematic representation of multi-stage decision making problems; Linear programming: Characteristics of a linear programming problem; Modeling mathematically a linear programming problem; Possible solutions to linear programming problems; The graphical solution method; The Simplex algorithm; The dual problem; Sensitivity analysis; Simulation: Special features and schematic presentation of simulation; Generation of random observations through probability distribution functions; Time increment techniques; Simulation languages; Laboratory exercises using appropriate software.

Figure 6: Course related data

Information like the course's unique code, semester, flow and lecturers will help in the semantic structuring of the school's curriculum, while information in the course's description will help distil the hard and soft skills that students will possess after completing the course. The data extracted from the courses will be analysed to distil the knowledge gaps of the curriculum, better represent the skills and qualifications of students in their personalised profiles and used as input in the platform's DSS tools to provide suggestions and guidance for optimising the university's processes.

4 CONCLUSIONS

In a rapidly evolving era, Higher Education is still struggling to find the appropriate level and methods of digitisation, while the lack of suitable IT infrastructures is perpetuating yearly problems faced by universities and other institutions. University processes are far from being optimised, validation of certificates still requires a lot of manual labour in most cases and there is a vast pool of university data that are not being exploited. QualiChain, the project presented in this paper recognises these issues as well as the potential of combining innovative technologies such as blockchain, semantics, data analytics and decision support for resolving them. Additionally, the paper presents a pilot case that will be applied in the ECE School of the NTUA, focusing on semantically enhancing the university's data and integrating blockchain and analytics in the school's processes.

By adding structure, security and automation in the school's processes, students will have a more efficient procedure for selecting courses and career trajectories and their own personalised profile where they can showcase validated skills and qualifications. Furthermore, professors will be able to more effectively update their courses and perform other administrative tasks. Finally, the updated curriculum that is the end-goal of the pilot is projected to increase the reputation of the university and the skillset of its students and decrease the time it takes for graduates to find employment.

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