DIGITAQ

Création de Capacités Digitales pour le Pilotage de l'Assurance Qualité dans l'Enseignement Supérieur Algérien

D1.5- Architecture du système d'information globale

Projet n.: 617768-EPP-1-2020-1-DZ-EPPKA2-CBHE-SP

Cofinancé par le programme Erasmus+ de l'Union européenne

Création de Capacités Digitales pour le Pilotage de l'Assurance Qualité dans l'Enseignement Supérieur Algérien / DIGITAQ

Livrable	Une architecture du système d'information globale
Référence	Lot 1-5- Une architecture du système d'information globale

Lot de travail	Lot 1 : Préparation - cadrage du projet et préparation de la donnée
Date de publication	25/03/2023
Statut	Version Finale

Partenaires du projet

Université des Sciences et de la Technologie d'Oran-Mohamed Boudiaf (Algérie)
Coordinateur

Université du 8 mai 1945 de Guelma (Algérie)

Université Larbi Ben M'hidi d'Oum El Bouaghi (Algérie)

Université BenyoucefBenkhedda - Alger 1 (Algérie)

Université KasdiMerbah de Ouargla (Algérie)

Université Lumière Lyon 2

(France)

Ministère de l'Enseignement Supérieur et de la Recherche Scientifique (Algérie)

Union des Universités Méditerranée (Italie)

Université Mohamed Khider Biskra (Algérie)

Université Nova de Lisbonne (Portugal)

Université Mohamed Lamine Debaghine - Setif 2 (Algérie)

Université de Liège (Belgique)

Université Abderrahmane Mira -Bejaïa (Algérie)

Université Mustapha Stambouli-Mascara (Algérie)

Information du Projet

Numéro du projet	617768-EPP-1-2020-1-DZ-EPPKA2-CBHE-SP
Action code	CBHE-JP
Acronyme du projet	DIGITAQ
Titre du Projet	Création de Capacités Digitales pour le Pilotage de l'Assurance Qualité dans l'Enseignement Supérieur Algérien / DIGITAQ
Programme de financement	Erasmus+ KA2
Date d'approbation CP	03/12/2020

Information du document

Titre	Le questionnaire et sa mise en place et son analyse.
Date de publication	25/03/2023
Numéro du livrable	7
Lot de travail	Lot1 : Préparation - cadrage du projet et préparation de la donnée
Numéro Tâche	T1.5
Numéro d'activité	D1.5
Partenaire responsable	UNL
Partenaires impliqués	U. Ouargla
Statut	Final
Niveau de Dissémination	PP

Historique des versions :

Version	Date	Référence	Auteur (s)
Ver.1	22/06/2021	1er Draft	João SARRAIPA
Ver.2	30/09/2021	2éme Draft	Joao Sarraipa –UNL /Joao Giao – UNL Artem Nazarenko – UNL / Andreia Artifice - UNL
Ver.3	31/01/2022	3éme Draft	Joao Sarraipa -UNL
Ver.4	31/03/2022	4éme Draft	Joao Sarraipa -UNL
Ver.5	31/05/2022	5éme Draft	Partners
Ver.6	30/09/2022	6éme Draft	Artem Nazarenko – UNL Joao Sarraipa –UNL
Ver.7	26/10/2022	7éme Draft	Artem Nazarenko – UNL
Ver.8	01/11/2022	8éme Draft	Aicha SEKHARI
Ver.9	10/11/2022	9éme Draft	Sylvai Touchard
Ver.10	30/11/2022	Finale	Aicha SEKHARI

Cofinancé par le programme Erasmus+ de l'Union européenne

Table of Contents

List of Figures

List of Tables

Tableau 1: Liste des abréviations

Terme/abréviation	Définition
BPM	Business process Management. Les anglo-Saxons utilise très souvent le terme de processus d'affaires (business process).
Processus d'affaire	Correspond au processus opérationnel en France.
Processus	Pour éviter toute ambiguïté, BP est traduit par le terme «processus» qui englobe toutes les natures de processus (opérationnel, support et pilotage)
SMQ	Système de management Qualité

Tableau 2: Historique du document

Date	Nom	Description
22/06/2021	Joao Sarraipa –UNL	Construction plan.
30/09/2021	Joao Sarraipa –UNL Joao Giao – UNL Artem Nazarenko – UNL Andreia Artifice - UNL	State of the Art – Chapter 2
31/01/2022	Joao Sarraipa -UNL	Architecture Vision definition
31/03/2022	Joao Sarraipa -UNL	Architecture Vision definition
31/05/2022	Partners	Comments feedback
30/09/2022	Artem Nazarenko – UNL Joao Sarraipa –UNL	Final improvements
26/10/2022	Artem Nazarenko – UNL	Improvement based on the reviews, adjustments of figures
01/11/2022	Aicha SEKHARI	Review
10/11/2022	Sylvai Touchard	Review
30/11/2022	Aicha SEKHARI	Closed and submitted to Review

1 DIGITAQ Platform Definition and Vision

DIGITAQ platform provides the necessary support for the higher education institutions and corresponding authorities to create, manage and update processes related to education and administration aspects. The designed processes have to be monitored through a set of performance indicators, based on the process performance that the controlling authorities can give their assessments. The overall procedure is supported by the specific Dashboards used for visualisation of the process core parameters.

1.1 Introduction to the DIGITAQ platform building Process

A software platform is an operating environment hosting various smaller applications that are executed within to deliver corresponding services [51]. Additionally, a software platform is one specification of infrastructure with the focus on creating and making specific content usable by interested parties. Software platform intends to bring solutions to address specific needs of users (e.g., training and learning services), make various connections (between internal and external tools, hardware and software, teams, data, and processes), and consolidate the data that might be scattered in different sources (e.g., online and printed pages) [52]. Moreover, Software platforms offer distinctive value propositions for platform owners, app developers, and users. Each of these has distinctly different needs and motivations for participating in a platform ecosystem. Therefore, a platform-based business model must not only meet these distinctive needs but must also do so in a more compelling manner than a standalone product or service business model [53].

The software platform design is the process of defining software methods, functions, objects, and the overall structure and interaction so that the resulting functionality will satisfy your users' requirements and deliver the requested capabilities [56]. The growing complexity of the modern Information Systems (IS), which can be considered as a type or collection of platforms [58]. With hundreds of components and corresponding interfaces has raised the need to use a certain logical construct or architecture during the design process [59]. Thus, the key elements of the design process are the business model and the platform architecture [54, 55]:

- Business model identifies the services that you plan to sell and/or deliver, its identified target market, and any anticipated expenses. Before the most important processes and functions can be identified, the business model of the software platform has to be described.

- Platform architecture involves designing comprehensive computer systems which are used for storing, delivering, and optimising a range of considered information. The software platform architecture represents the design decisions related to overall system structure and behaviour. Architecture helps stakeholders to understand and analyse how the system will achieve essential qualities such as modifiability, availability, and security. The following are matters related to the function of software platform architecture as a blueprint. The blueprint will define a structured solution so that it can meet all technical and operational requirements. Besides the mentioned aspects, the blueprint must be able to optimise general attributes such as performance and security. This blueprint will involve a series of critical decisions about the organization regarding the software development process, and each of these decisions can have a significant impact on the quality, maintenance, performance, and overall success of the final product.

To support the design process, we consider the TOGAF – The Open Group Architecture Framework, as the baseline for the system design. The TOGAF is the tool used for development, acceptance, use and maintenance of the IS architectures [60]. It allows considering the IS as a set of building blocks that are grouped together and form a system. A building block represents a component of designed system capability that can be combined with other building blocks to deliver architectures and solutions [60]. In the case of TOGAF there are the following key building blocks: the Architecture Building Blocks (ABB) defining the required capability of the architectural element (in other words a single aspect of the model) and the Solution Building Blocks (SBB) defining the components and tools to provide the capability defined in ABB. Important is to mention that ABBs define the functionality and high level aspects of their implementation without the detailed design.

The specifications of ABB are as follows:

- Fundamental functionality and attributes: semantic, security capability and manageability
- Interfaces: chosen set, supplied
- Interoperability and relationship with other building blocks
- Dependent building blocks with required functionality and named user interfaces

On the other hand, the specifications of SBB are:

- Specific functionality and attributes
- Interfaces; the implemented set
- Required SBBs used with required functionality and names of the interfaces used
- Mapping from the SBBs to the IT topology and operational policies
- Specifications of attributes shared across the environment (not to be confused with functionality) such as security, manageability, localizability, scalability
- Performance, configurability
- Design drivers and constraints, including the physical architecture
- Relationships between SBBs and ABBs

Another important element of the TOGAF is the artefact, which is an architectural work product that describes an aspect of the architecture. Generally speaking, artefacts can be represented as catalogues (lists of things), matrices (showing relationships between things), and diagrams (pictures of things). Examples include a requirements catalogue, business interaction matrix, and a use-case diagram (see Figure 1). An architectural deliverable usually contains multiple artefacts.

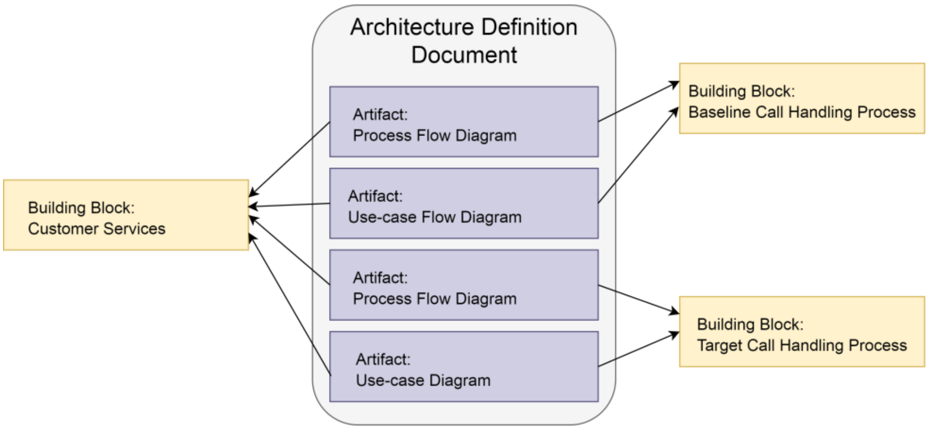

Figure 1 – Example of Architecture Definition Document

Figure 1 shows an example of an Architecture Definition Document demonstrating relationships between artefacts and building blocks [60]. This document contains a number of complementary artefacts that provide descriptions of the building blocks relevant to the architecture. For example, a process flow or a use-case diagram (an artefact) may be created to describe the building block, in the example target/baseline call handling process. In this example the types of building blocks are not defined. However, an artefact can describe both the ABBs and the SBBs.

1.2 DIGITAQ Platform main objectives and challenges

The main objective is to allow the Algerian Ministry of Higher Education to use the quality information and quality assurance database supported by corresponding dashboards in order to carry out accreditation and audit through well-established performance indicators. Dashboards can be designed more specifically to track the implementation of educational plans or governance policy of higher education institutions.

Another core objective is to come up with a global architecture for the digitization of the quality assurance system for higher education in order to guarantee the proper assessment of the process performance of established projects and the quality assurance mechanisms. The architecture encompasses the structure, scope and nature of the information recorded in the overall architecture.

The architecture addresses the two-level structure:

- Regional level: regional institutions get the necessary support in terms of external evaluation, self-assessment and steering.
- National Level: includes the establishment of a quality centre of excellence through certification, coaching of trainers, recommendation and benchmarking.

The overall procedure that should be introduced includes a set of steps. During the first step education related processes are formulated and the objectives are set. To be able to track the performance of the process and the fulfilment of the objectives a set of performance indicators or metrics should be formulated to be later applied for assessment. Based on these the processes are designed, for instance, using the BPMN tools. After the processes are ready, they are launched and constantly monitored using the performance indicators introduced during one of the previous steps. And finally gathered information about performance is used to improve the processes.

1.3 DIGITAQ Platform specific requirements

As mentioned in the previous section the overall architecture consists of two levels: the regional and the national ones. Thus the requirements can be also divided into two parts:

- One of the main actors on the National Level is the Ministry of Higher Education and Scientific Research (MESRS) that formulates the national strategy for the educational institutions all over the country. Besides this, MESRS performs an audit and analyses the performance of individual institutions and based on this performs accreditation. The core requirements for the MESRS remain the possibility to track the performance indicators and collect the data into a central repository for further accreditation. Moreover, it is important to be able to adjust the strategy/vision based on the situation assessed. The second actor on the National Level is the Centre of Quality Excellence that performs certification, trainers coaching and benchmarking. For this entity the critical requirement is to be able to extract the knowledge from the quality information to provide the high standards of coaching and benchmarking.

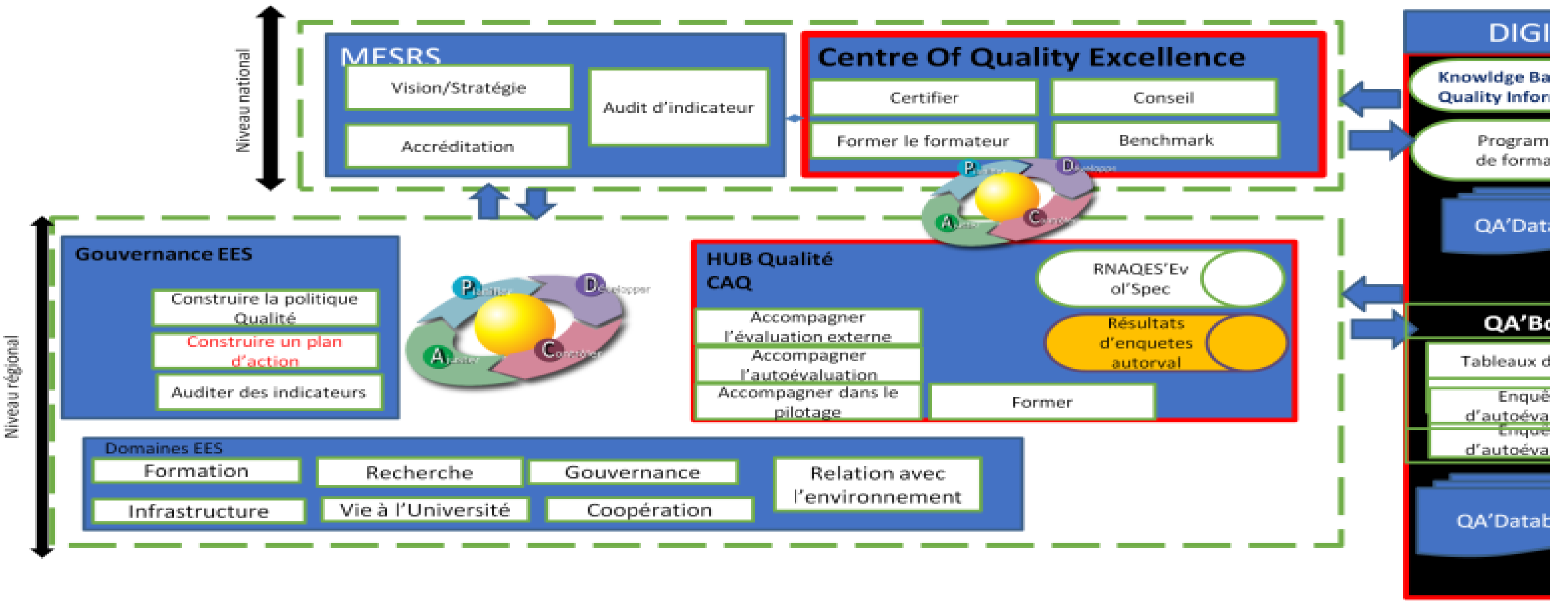

Figure 2 – 1st vision of the DIGITAQ architecture

- On the regional level Quality Hub is responsible for support of external and internal evaluation of the higher educational institutions and thus requiring the constant feedback loop with the Centre of Quality Excellence to adjust their actions. Another entity that is situated on the regional level is the Governance entity constructing the quality assurance policy, actions' plan and monitoring the performance indicators on the regional level. This entity turns the general policy formulated by MESRS into a concrete plan of actions. The critical requirement here remains the ability to monitor the performance indicators to assess the quality and to be able to adjust the processes on the regional level. And the last entity is the higher education institution itself that possesses the infrastructure and is responsible for implementation of the quality assurance actions and processes. For the institution is important to have the relevant information on the policy prescriptions to adjust internal processes accordingly.

1.4 DIGITAQ Platform Vision

In general, the main goal of the DIGITAQ initiative is the provision of an environment with corresponding mechanisms to provide quality assurance in higher education with particular focus on Algeria. The environment has to communicate with a distributed national database, fulfilling the needs on exploitation and forecasting. In the preparatory phase the lack of a business process management system that is able to assign and track the KPIs of academia-related processes was ascertained, forcing the project to come up with its own proposal for such a system.

In this chapter we discuss the potential scenario and corresponding architecture. There are some core actors in the scenario:

- Students, job seekers.
- Supervisors, Professors and Teachers.
- Administration – is responsible, for instance, for issuing certificates.
- Other interested stakeholders (e.g. employers).

The objective of the DIGITAQ platform is to enable the design of various academic processes with ability to assess them through a set of metrics or KPIs (Key Performance Indicators) used to make informed decisions in order to improve the management, quality of training and research. The processes can be related to different aspects of the university's life from curricula design to organisational issues. To assess the quality of the different academic processes a set of KPI have to be established and assigned to each of it, so that at run-time, parameters derived from the process are checked to fit the threshold or a time frame. Thus, during the process design phase, not only the stages of the process are defined, but also the KPIs or metrics are set. After the process is designed and deployed at the run-time, the KPIs will be constantly monitored and visualised using the corresponding dashboard that will be a part of the DIGITAQ platform (see Figure 3).

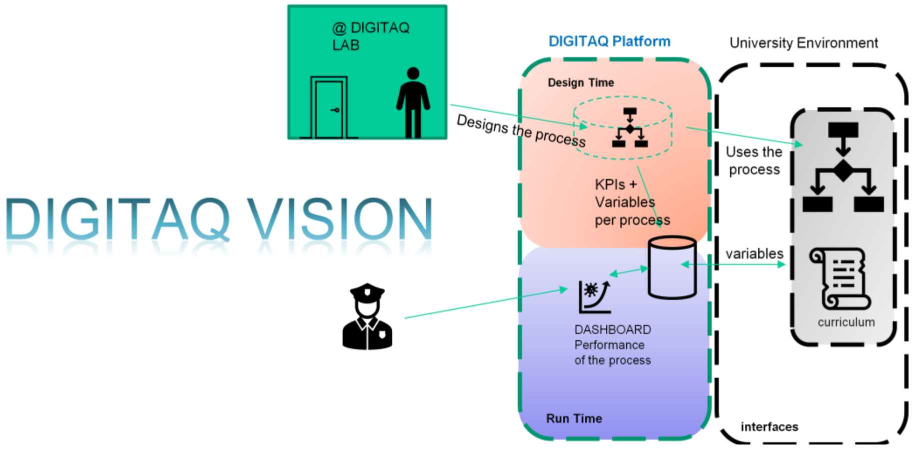

Figure 3 – The DIGITAQ high-level architecture

DIGITAQ platform allows for different stakeholders (students, supervisors, administration, etc.) to manage different academia-related processes (e.g. curricula management) at the design-time, as well as monitor the data and track the KPIs using the dashboard at the run-time. The Process Designer tool is used for the designing purposes. In this case, a limitation of traditional Business process management (BPM) solutions such as, focus on internal workflows within a single organization need to be overcome for the formation of a peer-to-peer BPM system that enables multiple entities to exchange information directly with counterparties while promising the integrity of the process.

However, the challenging issue is to ensure the secure and flexible communication between the DIGITAQ platform, the university ecosystem and other involved stakeholders. In this regard, a distributed database or any other similar technology may be used to secure the information flow and to authenticate the communicating parties to avoid the date leaks to the non-authorised users. Moreover, the DIGITAQ platform will provide a set of APIs (associated to the interfaces in the right side of Figure 1) that can be used by the university to access the capabilities of the platform. Such platform agnostic approach also contributes to the interoperability, which is the corner stone for the collaborative systems.

Some specific software mechanisms that may be distributed to control processes involving multiple parties/universities following specific regulatory rules and able to trigger alerts to some users must be defined. For the designing and further control of the processes the system has to share documentation, interconnect information, and track different states of transactions according to security and safety standards. The communication with the University and the DIGITAQ environment will be accomplished through the set of easy-to-use APIs. Thus, such APIs are integrated with BPM solutions and the legacy university systems extending functionality and improving security and data integrity. The low-level security can be assured through, for instance, the physical unclonable function, i.e. fulfilling the IoT non-repudiation requirement, ensuring that a device cannot dispute its authorship, or the validity of a message sent by it.

During the project it is planned to design a set of academia-related processes that will be evaluated in the scenario in cooperation with corresponding university. However, besides the ready-to-use processes, the DIGITAQ platform will provide the opportunity for the users to design they own new customised processes or re-adjust the available ones to be later deployed at the run-time. Thus, the DIGITAQ platform provides a kind of a feedback loop, when the user (i) develops the process assigning corresponding KPIs in the DIGITAQ laboratory, (ii) deploys it at the run-time and (iii) is able to re-adjust the process based on the KPIs monitoring feedback acquired in the dashboard. The KPIs will be used to evaluate every process step to check its quality. In the dashboard, admin can check the results of the process performance based on the KPI measurements (values, parameters) provided by the University side. In fact, the dashboard reflects the current process status at the run-time.

1.5 Implementing the DIGITAQ Platform: a generic and global use case scenario

One of the main purposes of the DIGITAQ platform is to enable the process design through the BPMN tools and the design of performance indicators that are utilized to assess the process performance. The BPMN tool ensures the customised development of education-related processes. This includes definition of the variables/parameters that the designed process will contain, the main actors involved in the process, as well as flow of the action blocks. After the process design is accomplished, it should be stored in the database supporting the storage of BPMN flows. Figure 4 shows the example of the BPMN process addressing the new curriculum establishment procedure. The established process can be then checked on the compliance with the regulations of corresponding authorities. In other words, the authority should have a copy of the process for formal check.

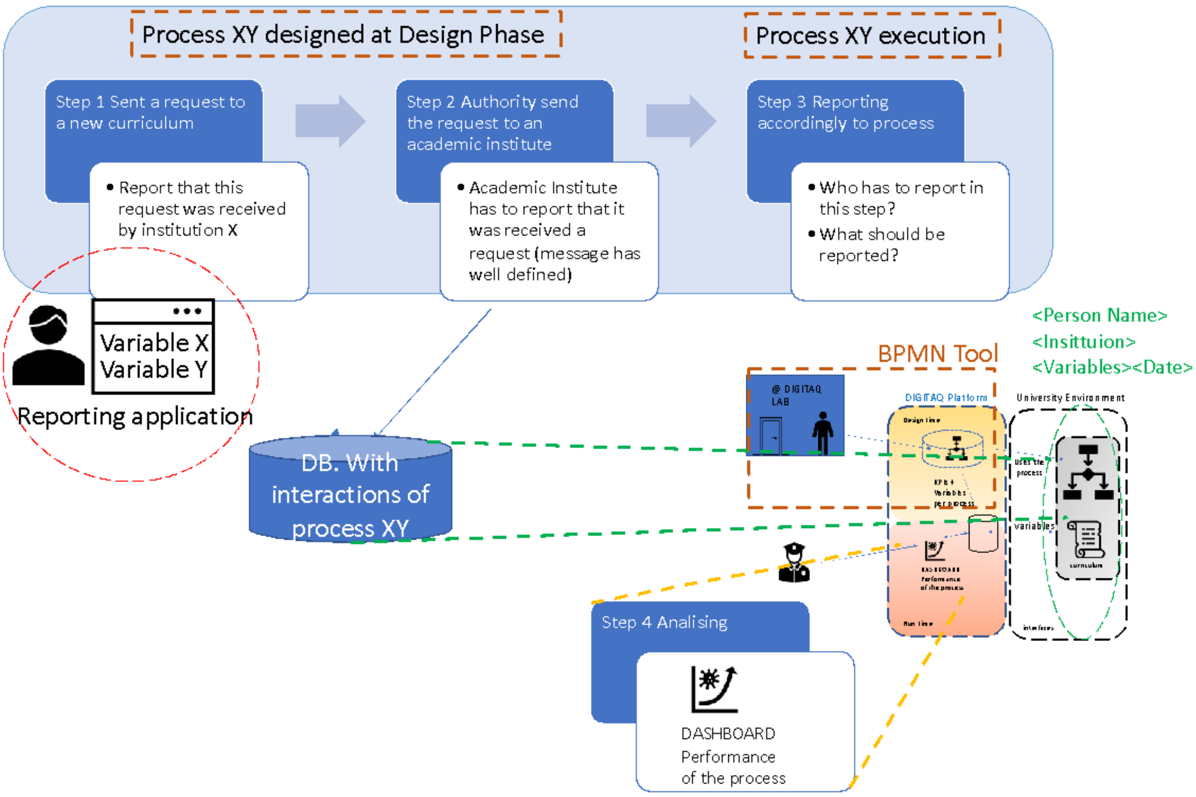

Figure 4 – example of the process piloting

Another critical stage is the formulation and the design of the performance indicators that are used for assessment at the run-time. Those performance indicators should be formulated and designed during the process design phase itself. Moreover, the indicators have to be also aligned with the governance authority regulations. After the process is deployed and the performance indicators are assigned for monitoring, the reporting tool comes into play to report any possible deviations from the performance indicators previously set.

It is also critical to keep a general picture over the performance of individual entities/institutions or even set of entities. For this purpose, AI Analytics and the Dashboarding components have significant role. The AI Analytics can be applied to the data gathered based on processes performance indicators monitoring to reveal some hidden patterns that can be used for process optimization. The Dashboarding component can assist in development of customized Dashboards that can be used for the monitoring of the situation on different levels, both individual and national wide.

2 Analysis of Platforms for Quality Digitalisation

In this chapter a state of the art of various technologies approaches as platforms for academic quality assurance is reported.

2.1 General introduction to digitalisation and QA in HE

In a study entitled ‘‘*Digital Campus - A future former investment in education for a sustainable society*’’ [39] it has been proposed how a digital campus might ensure quality assurance of teaching, research and administrative management, using innovative technologies. The solution considers anytime and anywhere access to universities, learning, research, and meeting industry. The services considered are joined in four different groups next described (*Figure 5*).

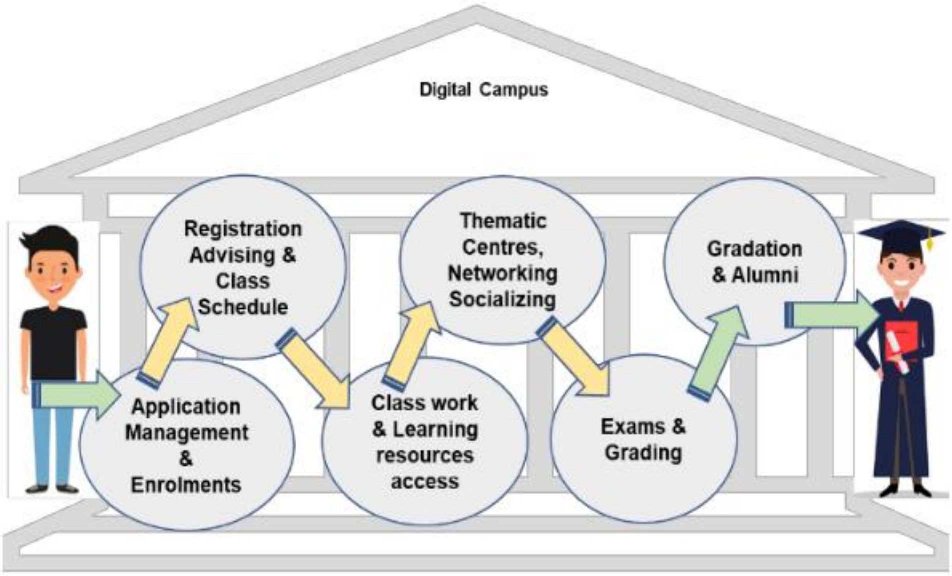

Figure 5 – Student's journey within Digital Campus [39]

Application management & Enrolments includes the portal of the university, enclosing services such as the enrolment process. The Registration Advising & Class Schedule, encloses the processes that are opened until the conclusion of the student degree. Thematic Centres Network Socialization, which is an important part of networking, offering different clubs for a variety of areas. Exams and Grading considers social restrictions due to Covid19 pandemic. It that context it has been used applications such as: MS Teams, Zoom, Sype for Business, Office 365, etc. In Gradation & Alumni block, might be considered that on one hand transcription can be performed online, on the other hand it is possible to achieve the learning developments and research projects in partnership with industry.

Those services have been considered in the digital campus architecture (*Figure 6*), grouped in a variety of areas namely: academics, accreditation, Industry & Community Connections, Digital Student Journet, Administration, and IT & Security.

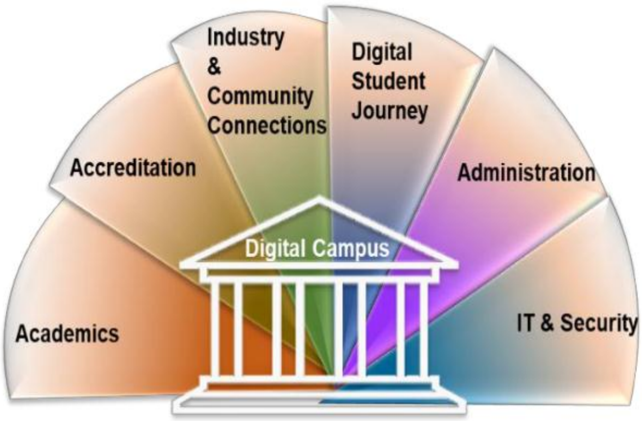

Figure 6 – Digital campus architecture

Academics area encloses items such as learning management systems (LMS), virtual and blended learning, learning analytics and assessment models, library and CMS. Accreditation area includes, for instance, the quality of teaching and learning, i.e the academics and institutional performance concerning both research and academia, infrastructure, ranking, quality management, real time management. Area of Industry and Community Connection are considered regarding their connection to the university, as a crucial part of process of teach and research. Digital student journey area encloses the services delivered by the university to the student, ensuring remote connection to the campus. Administration and IT and Security includes components connected to human resources, finance, accounting, welfare, support functions, security, mobility, secure data warehouse.

Recently, Sailer et al. [40] proposed the cb-model for local and distance learning environments in higher education, of contextual facilitators for learning activities involving technology. It clarifies teaching learning research, proposing a roadmap for future research through sustainable learning activities. It encloses the cognitive processes of students using digital technologies. In a broad view the model encloses an integrative framework considers the following branches of research: cognitive research on learning process supporting digital technologies, research on skills and attitudes using digital technologies in schools and higher education, research on educational development concerning digital innovation, additionally tool centred research focused on technology-enhanced scenario. The architecture encloses the following interconnected activities (*Figure 7*):

- higher education teachers, skills;
- Higher education teacher's digital technology use;
- Higher education teachers' qualification;
- Institutional, organizational, and administrative factors;
- Higher education teachers', digital technology equipment;
- Students learning activities involving digital technology;
- Student's knowledge, skills, and attitudes;

- Student's digital technology equipment.

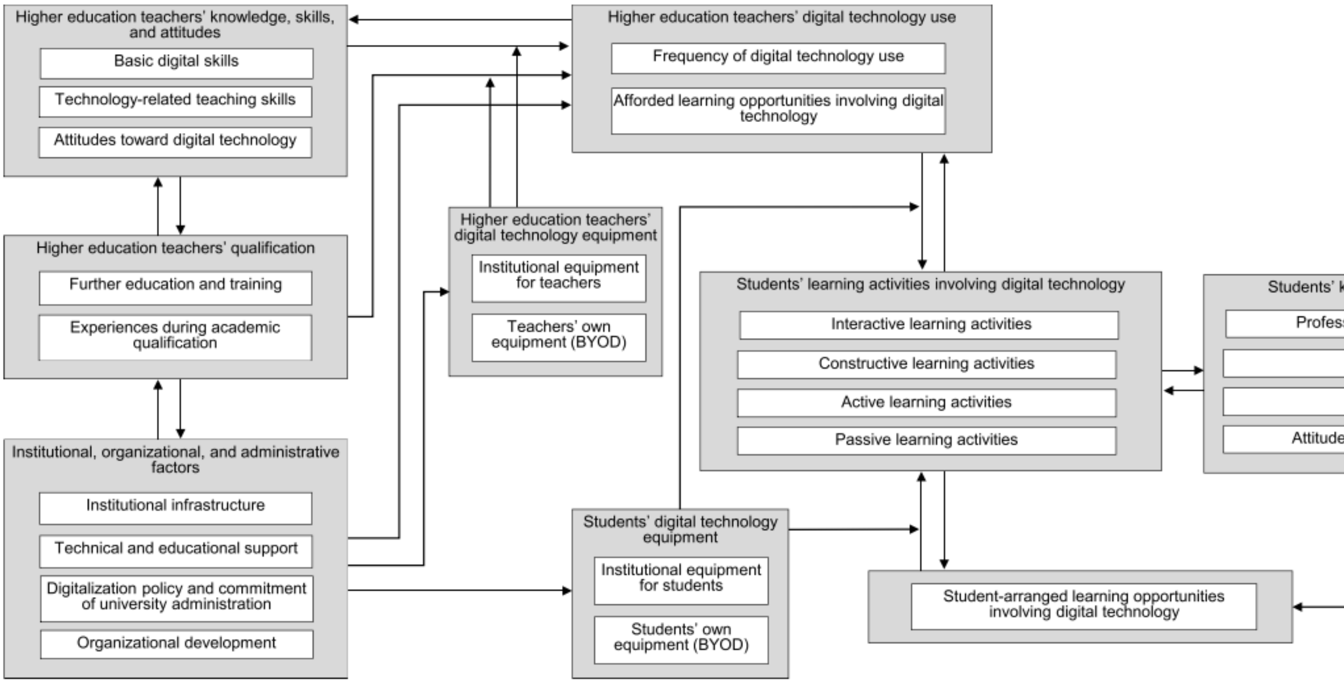

Figure 7 – Cb-model for distance learning environments in higher education [40]

A study [41] proposes an institutional reference framework for eLearning in higher education *(Figure 8)*, which is based on layered patterns. The technological infrastructure layer, enclosing three sections: management and governance, physical infrastructure, and logical infrastructure. In online learning, the technological infrastructure presents a solution combining different aspects, including for instance servers, storage space, audio-visual content. According to the same authors, the quality eLearning should consider: a) non-presential initiatives must have institutional virtual spaces; b) non-attendance must have should maintain the same structure (academic and quality); c) student's size defined considering collaboration and interaction; d) flexibility in asynchronous components; e) ethical aspects must be considered; f) assessment systems should consider the diversity of students; g) teachers must have adequate preparation. According to what has been previously said, the following functions are considered: a) contents creation; b) virtual environment (contents, activities, tools, resources); c) synchronous teaching through video conference; d) Asynchronous tutoring and monitoring; e) Mentoring or personalised follow-up avoiding drop-out.

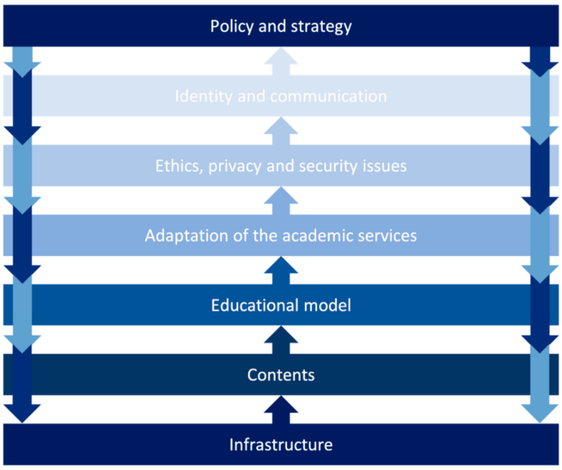

Figure 8 – Institutional reference framework for eLearning [41]

In a study entitled "Towards a Framework for Assessing MOOC Quality and effectiveness: the case of quality assurance in higher education" presents two studies which aims to introduce teachers' activity in blended practice. Framework is seen as tool to support quality and learning experience. Features: a) openness to learners, and flexibility to study, b) digital openness, c) learner-centered approach, d) independent learning, e) media-supported interaction, f) recognition options, g) quality focus, h) of diversity. The research work refers to implement the design in a quality-oriented approach, based on equity, social inclusion, quality, diversity, autonomy and openness. The authors argue that centres of excellence have top quality standards in both research and MOOC development. Additional features: specification of learning outcomes, process for assessing learners', learners' retention, identification of transfer and progression routes, recognition of prior knowledge. Results revealed a positive trend concerning high MOOC quality in agreement to valid principles: learning concepts, education instructions, guidelines and good practice.

In a study, Tsiligirisa and Hill [42], proposed a model that aims to solve the gap between quality management and student experience. The focus is to measure quality in international higher education. That Integrates: a) quality control, which focus is to check when standards have been achieved; b) quality assurance, is focused on stakeholders achievements; c) quality audit, might be seen as the process that assures that strategic objectives concerning teaching and learning mission have been achieved; d) quality assessment, might be seen as the process of evaluation; e) quality enhancement, it is mainly focused on improvement; e) quality management, that refers to processes supported policies and systems, which allows to enhance quality in education. According to the authors the latter encloses other expressions of quality in an expectations-perceptions model. The same study it is presented a conceptual framework that models the process of service quality (*Figure 8*).

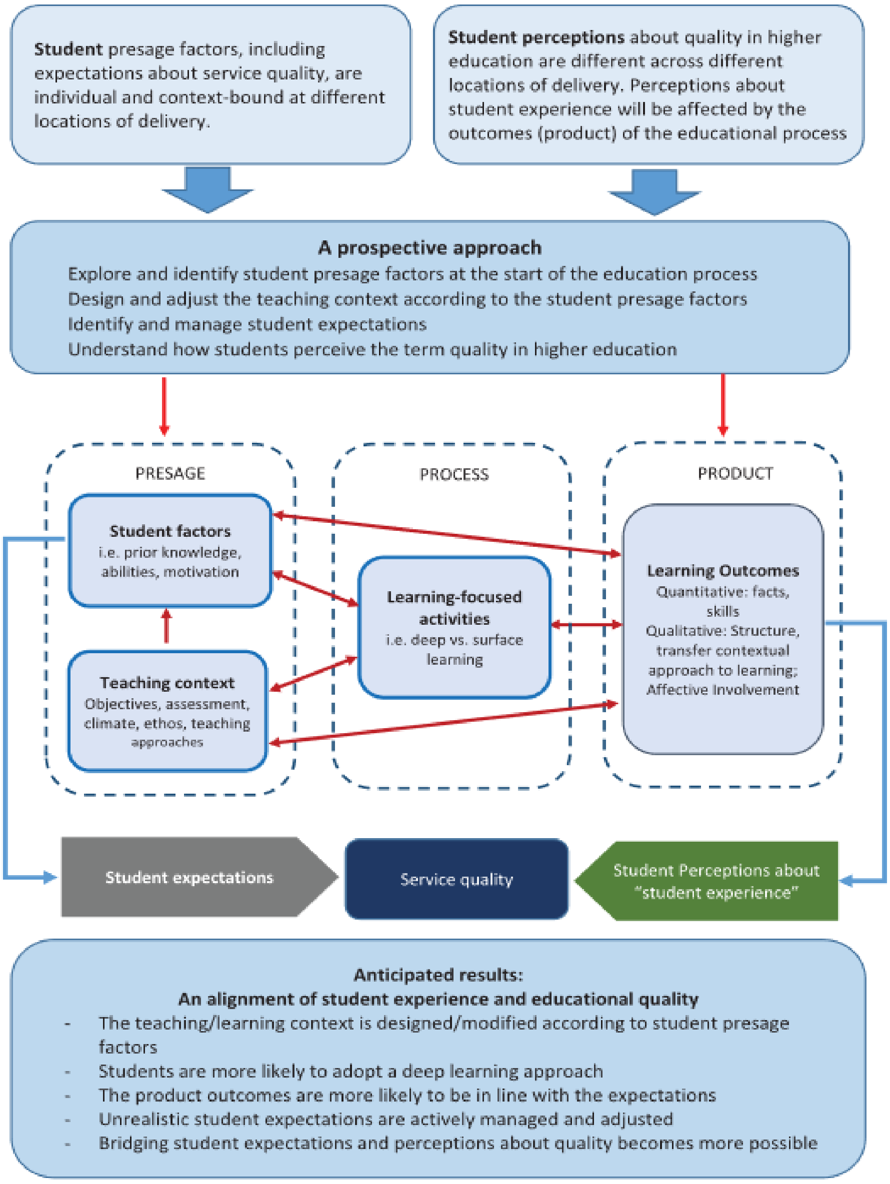

Figure 9 – Framework modelling process of service quality [42]

A study entitled «*Human and Infrastructural Resources for Quality Assurance in Polytechnic Office Technology and Management Program*» [43], quality indicators for quality assurance of Polytechnics. The study included a questionnaire applied to 87 lecturers and instructors. Focused on standards in the field of curriculum design, implementation and evaluation, staffing, school facilities, students support services, staff professional development, and program management structure. In contrast to human resources quality indicators, it has been found that infrastructural indicators were inadequate for quality assurance.

Quality indicators are very important to be considered in the process of quality, especially for business intelligence proposes. In a study dedicated to the quality in teaching learning processes [44], refers to a variety of quality indicators concerning teaching learning in computational intelligence in digital pedagogy. Those consider the following aspects of quality in higher education:

- Curricular aspects – which considers the mission and the vision of the institute concerning the target programmes. That considers employability, innovation, and research in the design of the curriculum.

- Teaching aspects, learning and evaluation – might be seen as aspects that directly indicates the level of professionalism of the teachers.

- Research, consultancy, and extension – encloses the following indicators: quality of research is one of the most important indicators of research.

- Infrastructure and learning resources – enclosing indicators such as well-being of students, and employees. Maintenance of the campus might be a part of it.

- Student support and progression – in this scope might be enclosed mentoring for development of the students, encouraging them to participate in community and social activities.

- Governance, leadership, and management – are crucial for resource mobilisation. Ambitious institutional vision and leadership has been seen as an effective strategy for institutional development, and faculty empowerment.

2.2 Examples of Platforms for Quality assurance

One of the aspects that pushed further digitalization of the processes in academia was the COVID pandemic. The following research [50] investigates how the pandemic has affected the higher education landscape in Taiwan. The institutional transition to online learning under the COVID-19 crisis has established remote working models with dependable IT infrastructure, which indeed challenges the tradition mode of external reviews undertaken by quality assurance (QA) agencies. On one hand, the conventional model of QA has quickly shifted into virtual mode; on the other hand, the accreditation validity would likely be extended due to limitation of technology and travel. Many issues of QA in higher education became immediately apparent as a result of COVID-19, and this will facilitate QA agencies to adopt a more flexible, innovative and contextualizing method to ensure students' learning outcomes. Therefore, a theoretical framework of crisis management to examine the interconnectedness among government, higher education and quality assurance was created in three dimensions of autonomy, digitalization and flexibility as follows (Figure 10).

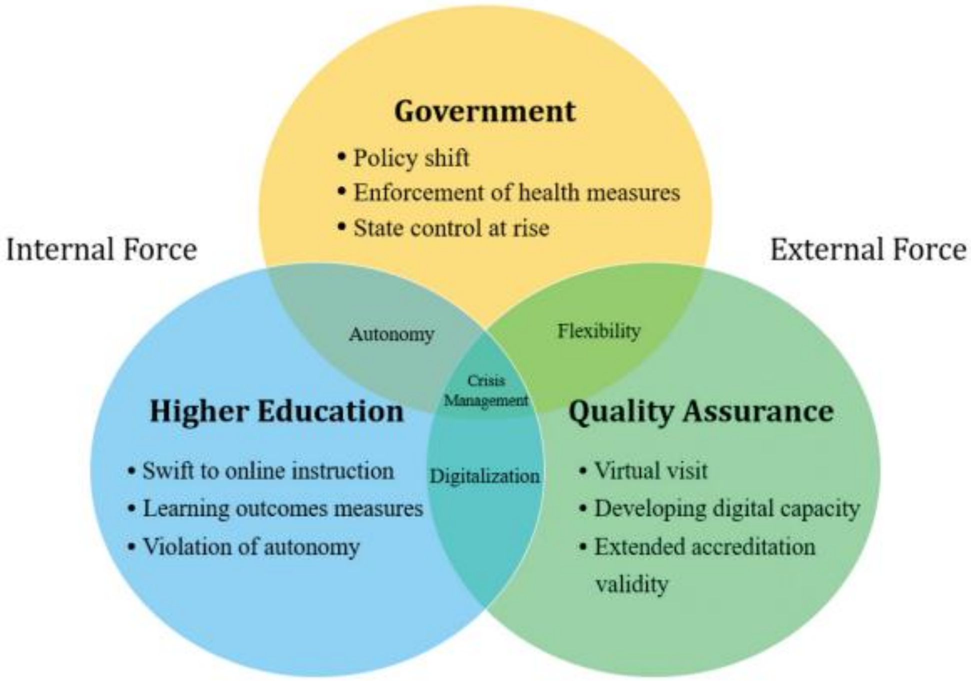

Figure 10 – Theoretical framework of crisis management in terms of autonomy, flexibility and digitalization [50]

In the study [45] authors analyse a schema for the design and approval process of the Massive Open Online Courses (MOOC) at some UK universities. A MOOC [49] is an open-access online course (i.e., without specific participation restrictions) that allows for unlimited (massive) participation. Many MOOCs provide interactive elements to encourage interactions among students and between students and the teaching staff, although the latter is not a defining requirement. In [45] authors state that the approval process for conventional courses/programs considers the quality assurance requirements such as: breadth and depth of subject content, students' engagement in monitoring and influencing the curriculum, etc. Moreover, the process of course/program approval should be aligned with indicators from Quality Assurance Agency and the university's strategy.

Five universities, being analysed, use similar main steps in the MOOC design and approval process, which is mainly derived from the platforms' criteria. These steps start by choosing the main topic around which to create the courses, followed by designing the content and assessment, the technological design, and finally approval of the courses. These steps can be interspersed by some internal quality assurance procedures. Based on data analysis for ongoing quality assurance at the five universities, Figure 11 shows the consensus of the universities regarding the main steps in the MOOCs design process. One conclusion made in the study is that the approval process for MOOCs is 'lighter' than the process for conventional courses, which is described as a 'rigorous' process in comparison.

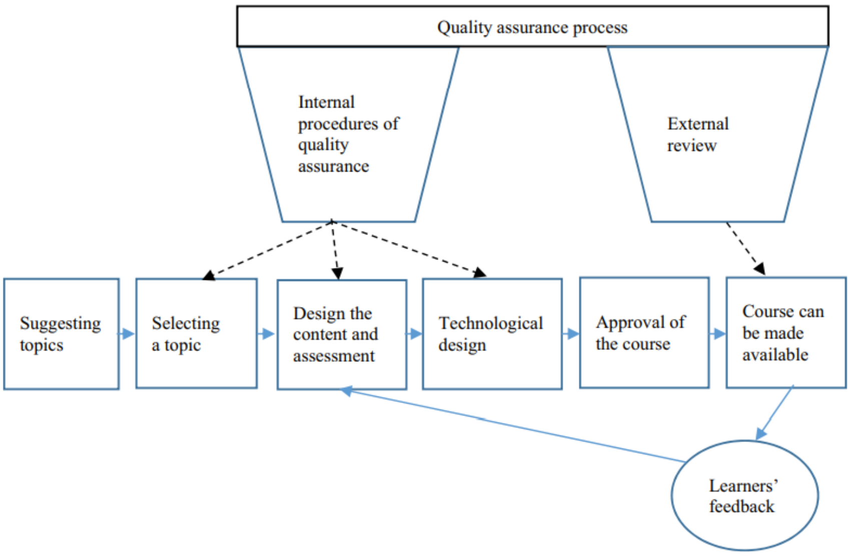

Figure 11 – The main steps in the MOOCs design process [45]

Digital education platforms are in the scope of many research works. For instance, in [46] authors propose a model to support blended and active learning taking into consideration underlying didactical strategies and processes. They indicate different levels of maturity depending on the skills and the needs of the educators, which require certain path and the resources involved that can be either simple or elaborate (Table 1). The maturity levels vary from the most basic level A to the most advanced level H, depending on the objectives and confidence in digital skills.

Table 1 – Maturity Model in Digital Education [46]

Level	Activities and Resources	Objectives and Achievements
A	In-Person or Online Training Modules (for Educators)	Developing Digital Skills
B	Orchestrating and Using Digital Learning Resources (Learners using Computers or Tablets without Network Access)	Implementing Enriched Traditional Learning Scenarios (and Summative Assessment)
C	Orchestrating and Using Online Learning Resources (Learners using Computers or Tablets with Network Access)	Implementing Blended Learning Scenarios
D	Personalizing, Creating or Co-creating Digital or Online Learning Resources	Collaborating with Colleagues and Implementing Blended Learning Scenarios
E	Designing Rich Educational Resources for Individual or	Implementing Active Learning Scenarios (and Formative

	Collaborative Activities	Assessment)
F	Implementing Learning Analytics Apps and Dashboards	Supporting Awareness and Reflection for Both Educators and Learners
G	Sharing Rich and Open Educational Resources	Providing Digital Education and Resources with all Stakeholders
H	Collecting and (Pseudo-) Anonymizing Digital Traces and Learning Outputs	Promoting Open Educational Science for Research and Impact Assessments

To achieve the mentioned maturity levels in design of digital education platforms mentioned above, the authors propose the Quadriptych Techno-Pedagogical Model (Figure 12). As the name suggests the model contains four elements, namely:

- Builder. This element enables the integration, personalization, the creation or the co-creation of learning resources, and their orchestration in learning activities by educators. It covers the orchestration and production features The "Builder" is for interactive online learning resources what the PowerPoint presentation editor is for slides. The "Builder" service should be so intuitive that it does not require the intervention of software or educational specialists in the design process, as it is known to impair spontaneity and creativity.

- Player. This element enables the usage of learning resources by educators (for presentation purposes) or by learners (for interaction purposes). The "Player" also enables learners to discover, explore, and experience rich educational content, as well as consolidate and construct or co-construct their own knowledge, while also developing transversal skills. The "Player" service is to interactive online learning resources what the PowerPoint presentation is to slides, with the additional features of having components being stateful and able to hold contributions from learners between sessions.

- Explorer. This element is an open library enabling the sharing and the discovery of open educational resources to cope with the scarcity of relevant digital content available to educators and proposed to learners or other stakeholders. Before arriving at that point, resources can be used independently. Then at some point, educators can start sharing them with trusted colleagues and even adapt them collaboratively. When educators believe that their resources have reached a good level of quality, they can decide to share them openly.

Most domain-specific libraries for educational resources currently enforce a complex validation process or commercial scheme before publishing a resource. This is not only impairing free and large access to knowledge, but it also explains why most educational resources are currently shared through YouTube, alongside a plethora of useless content (from an educational point of view). Libraries for educational resources should be well referenced to facilitate search. Moreover, popularity and quality should be elicited from the users following appropriate enforcement schemes, requiring less top-down moderation.

Builder Creating and Personalizing *Educators* Educational Resources and Learning Activities	**Player** Presenting and Interacting *Learners* Activity Traces and Learning Outputs
Explorer Sharing and Discovering *Providers* Open Library with Resource Collections	**Analyzer** Reflecting and Assessing *Stakeholders* Dashboards with Learning Analytics

Figure 12 – Quadriptych Techno-Pedagogical Model [46]

- Analyzer. This element enables learning analytics (LA), exploiting traces and learning outputs produced by contextual activities. Taking into account the GDPR – which states that personal data cannot be shared with third parties without explicit consent – a trusted platform should have such a LA service built-in. With learning analytics based on activity traces and learning outputs, educators can refine their resources and activities from usage patterns and learners' achievements. Learners can reflect on their own learning, as well as compare (if relevant) their progress against that of their peers. Only averaged and anonymized analytics of peers should be provided. Learning analytics can be shown in contextual dashboards (i.e., dashboards related to specific activities) or integrated directly into components of the learning resources.

In the next research work [47], the author demonstrates the architecture of the deployed Learning Management System (LMS). The platform (see Figure 13) is designed considering the following requirements:

- The system should be based on cloud technologies to provide simultaneous access for a large number of users.
- The system needs to be cross-platform and support mobile apps.
- The system should be universal enough for educational services both in higher education institutions and in companies.
- All data, including learning materials, tests, correct answers, etc., are stored on the server. Access is provided exclusively in secure mode.
- Each user has a unique personal account with the implementation of different levels of access rights depending on the role in the system.
- The administrator can add authorized agents of educational institutions or companies and provides the correctness of system's work.

- The authorized agent of the organization can change information about the company (for example, its name, list of subjects, schedule, etc.), add teachers (lecturers), subjects and groups, delegate access rights, etc.

- Teachers can create and edit learning and test materials, track the completion of homework. Tests can be created on the basis of the course sections, in particular without reference to any particular topic. There should be an option of "random" formation of questions from the given sections and the order of the withdrawal of possible answers for them.

- Students should be able to find educational materials on any accessible subject, perform homework, pass tests, have a feedback from teachers and other students within the system in their personal account.

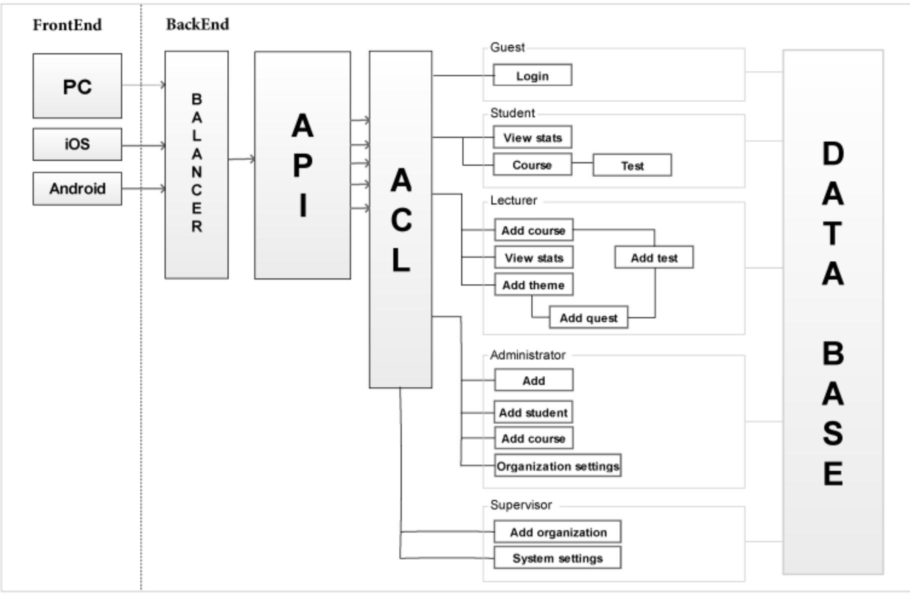

Figure 13 – The architecture of LMS [47]

The architecture (Figure 4) separates the platform on the back- and frontend parts. The frontend should be available from various platforms both desktop and mobile. Backend has the load balancer with corresponding APIs and the Access-control List (ACL) containing a set of permissions associated with corresponding objects/resources. Every user has a certain role, which enables him to perform a set of defined operations with ability to store the changes in the Database available.

In the research [48], the authors performed the questionnaire of the professors who has experience in working with various educational platforms for MOOC. The goal was to identify the advantages and disadvantages related to the platform/ecosystem itself, as well as related to the users' groups from the professor's perspective. The results are summarized in the Figure 14.

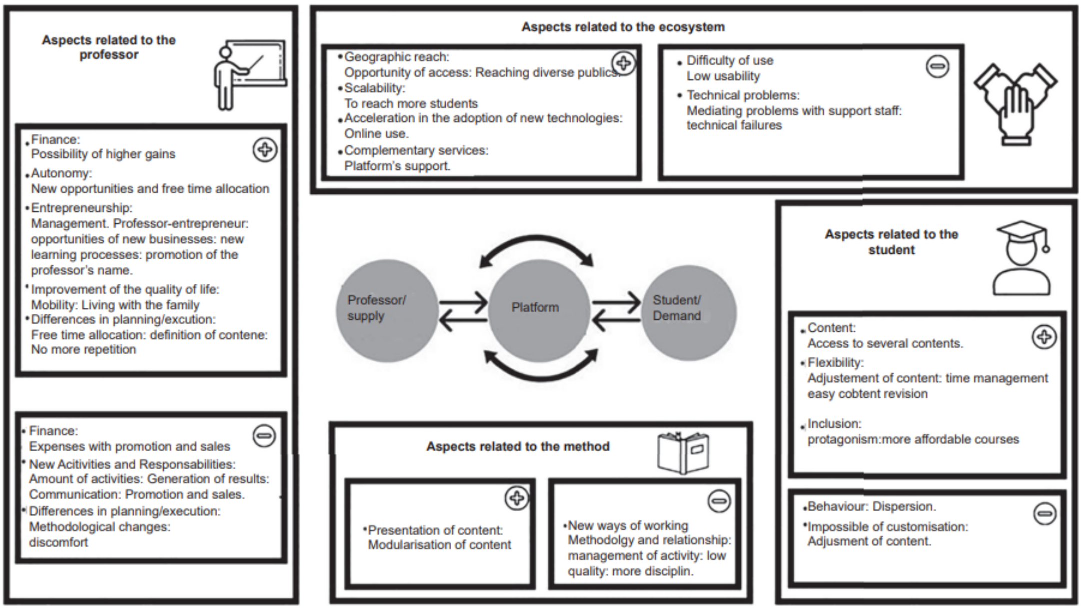

Figure 14 – advantages and disadvantages of digital platforms for MOOC [48]

2.3 Blockchain based Platforms in the area of Education

Blockchain technology was firstly introduced in 2008 for digital payment [22]. Since then, its application has been applied to different branches of business and research, organizations, and universities worldwide. The goal of blockchain is to solve the "trust" problem of central authority mediating transactions among parties. According to Butterin [23], in blockchain technology systems improve trust among parties. Furthermore, it excludes the interventions of third parties to perform transactions. Smart contracts run on blockchain platform, for instance as executable code blocks. In education, Blockchain provides benefits to a variety of stakeholders in online learning systems, such as students, teachers, and administrative staff [24]. Aspects of the blockchain that can be considered as useful for the area of educational systems [25]: (i) immutability; (ii) reliability; (iii) transparency of information; (iv) availability; (v) trust. All of those features might directly or indirectly be implied in the blockchain-based services.

Blcokchain based services are used in a variety of branches. In the context of supply chain management Yang et al. [26] proposes a quality management platform based on edge-cloud blockchain and Internet of Everything. The platform concept is developed to achieve low delay and rapid response to sensor data acquisition, authentication, consistency, transparency in the supply chain. The system is composed of three main entities: blockchain network, patient/users; medical institutions/research centers. The major phases are: data registration, data addition/update, and data retrieval from blockchain. Specifically, the proposed architecture encloses a data validator to check the quality and authenticity of data uploaded by users.

Most of the recent blockchain-based platforms in education address the academic degree management process and evaluation of learning results [1]. For instance, all the data about research experience, grades, and professional competencies can be securely managed and stored using blockchain environments. One example of an educational entity that is successfully applying the blockchain to manage, process and store student certificates is the

University of Nicosia. Moreover, it is claimed [2] that Nicosia University is the first institution issuing academic certificates with Pitocin-based blockchain verification. Another vivid example can be derived from MIT Media Learning Initiative [3] that has co-developed an ecosystem for creating, sharing and verifying educational certificates. The certificate reveals some basic information such as recipient, issuer, date, etc.

The main idea of blockchain application in education is the verification of the event, but not the trustworthiness of each party. In other words, blockchain can be used to verify the fact of exam happening and its results, but not necessarily the skills and knowledge, as the student still is able to cheat during the exam and university can issue a “bogus” certificate [2]. Another possible application point includes the connection between the employer and student or alumni, who can be assured of the validity of the certificate or in other word that the certificate was given to a particular person and issued by a particular institution [4]. Following paper [5] presents a solution able to do both store the academic achievements and provide a courses completion prove. The solution is based on the European Credit Transfer and Accumulation System (ECTS). Assumed that every student has a blockchain wallet to collect ECTS tokens assigned by the institution for completing courses, so that every time a student successfully finished the course she/he receives the defined amount of ECTS tokens (corresponding to the course of completion) to her/his wallet.

Moreover, blockchain in education can be also used for the sake of contributing to the national and international student exchange programs (EU Erasmus). In general, application of blockchain has the aim of increasing assessment transparency and contributes to curriculum personalization [6]. To summarise the importance of blockchain from education institution perspective, following points can be derived from the literature: (i) contribution to collaboration among institutions, (ii) reliable storage for life-time education and achievement records, (iii) no need to coordinate with multiple entities and to pay extra for educational record verification, (iv) data aggregation from multiple sources, (v) no need in trusted third party [6, 7].

In smart campus, blockchain co-exist with other applications, such as robotics and IoT (*Figure 15*). Among advantages ensured by it are: transparency, privacy, security, and data immutability. Moreover, it might be used to improve the quality of smart applications for higher education institutions.

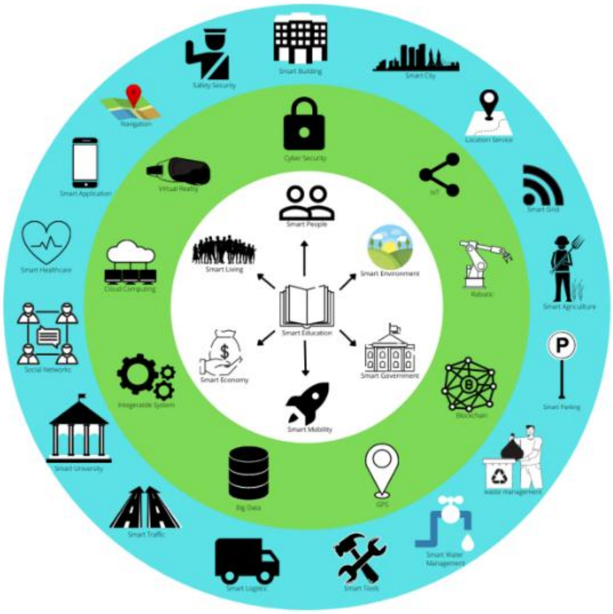

Figure 15 – Field and technologies of smart campus [12]

Another work [27] recognizes technology as a concept bringing significant improvements into the quality of educational process, and a task of strategy in educational community. Learning skills development might be seen as dichotomic task to evaluate quality and education level of students [28]. Study provided in [29] proposes a student focused E-Learning platform (Sci-B) with E-Portfolio supported by Blockchain technology (*Figure 16*). The study aims at requirements meeting of universities and improving cooperative education and improving skills.

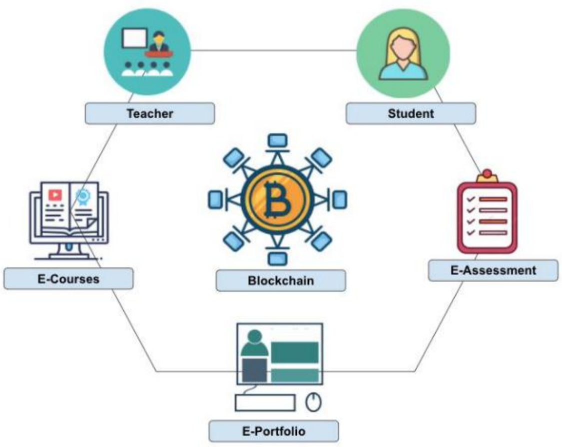

Figure 16 – Student-Centred iLearning Blockchain (Sci-B)

According to [30], blockchain technology might bring innovation to education. One of the options is the simplified and secure access to high-quality materials. One of those topics is the quality, for instance the blockchain allows controlling online user records to improve the quality of content. A research study [28] focuses on smart education and digital university. Blockchain technology plays an important role in technology accreditation. Furthermore, the authors discuss digital education strategy claiming: "high-tech strategy represents the pathways to universities to adopt the latest technologies of today's society with education quality".

Li et al. [31] proposed a blockchain-based security and sharing scheme for (Massive Open Online Course) MOOCs learning system, in which the following contributions were presented:

a) Blockchain-based structure (*Figure 17*) storage for ERLs.

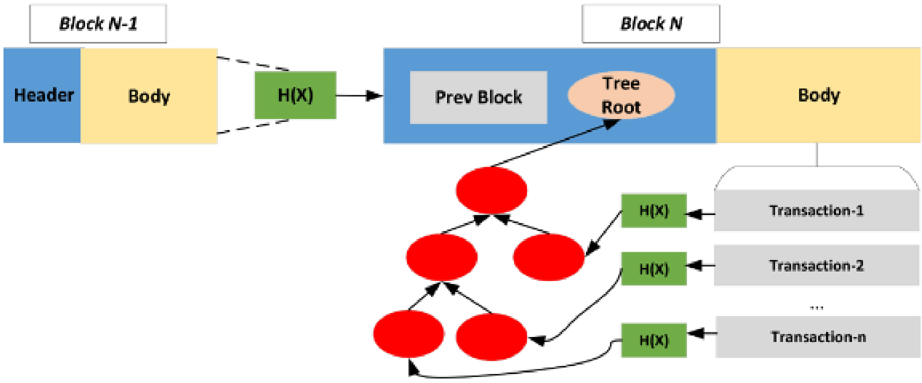

Figure 17 – Structure of a blockchain

b) Blockchain-assisted architecture implementing conditional anonymity and conditional traceability, and revocability; c) MOOCChain conduct several experiments. The system encloses the following principal components: trusted registration authority, MOOCs providers, end-user, blockchain, and data storage servers. A contribution, to ensure the quality of the processes, is exemplified as follows: MOOCs providers deal with punishment, if it was verified that the quality of course was complained by learners or if has been published illegal information, then smart contracts interface will be invoked. Summarily, the system joins MOOCs and blockchain technologies to enable: authentication, security storage, sharing of electronic learning records.

Alshahrani [32] proposes unique encryption technique for implementing a blockchain system in an e-learning (EL) environment to promote transparency in assessment procedures. Specifically proposes a novel improved elliptic curve cryptography algorithm (IECCA) for data encryption and decryption, in order to improve the trust in the assessment. The system encloses three types of stakeholders: (i) lectures, teachers, assistants, instructors, and other educators; (ii) learners, both on-line and off-line; (iii) readers, members, and the public. The technique improves truth services in online educational systems, assessment processes (*Figure 18*), educational history and credentials.

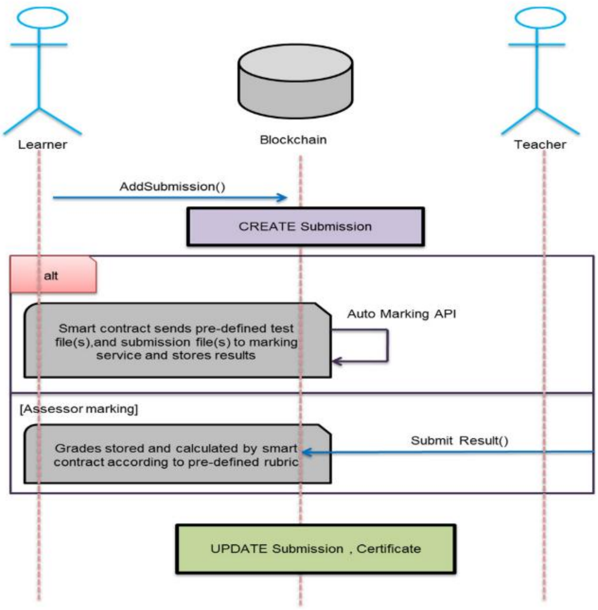

Figure 18 – Diagram of transactions for assessment [32]

The aforementioned system implements a rust-based blockchain system for student performance management, which core is the proposed encrypted method. It has been proved that the trust is improved through the proposed algorithm. Himeur et al. [33] proposed a blockchain-based recommender system. The more the blockchain recommender system (RS) knows about the past of a user, the better is the quality of its recommendations. The concept of quality trust improves the quality of the recommendations. The taxonomy of the system is represented in the (*Figure 19).*

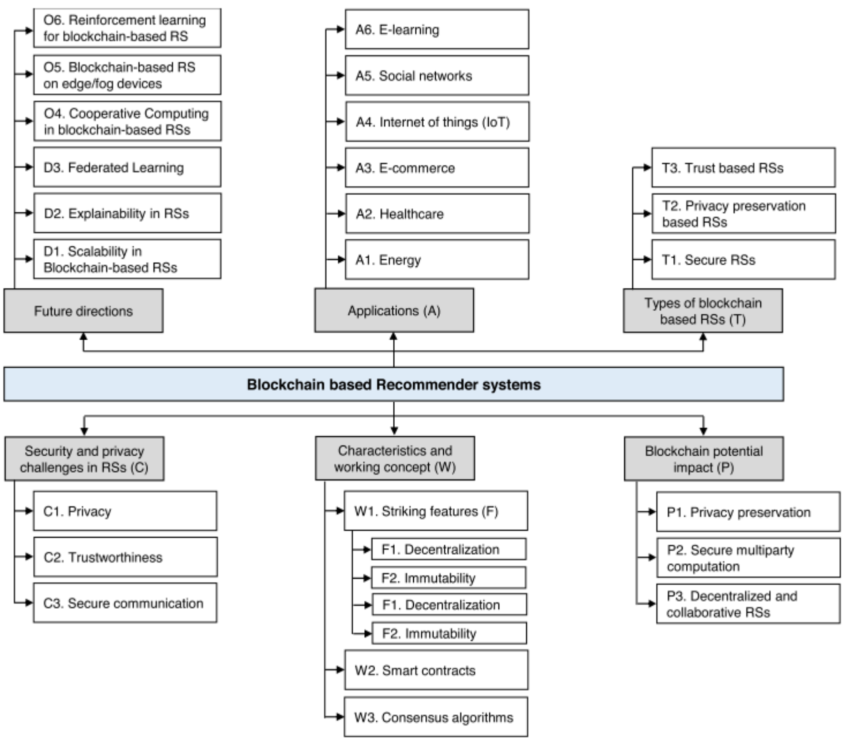

Figure 19 – Taxonomy of blockchain based RS [33]

The authors provide main requirements for the blockchain based RS, namely: adaptability, response time, scalability, performance, security, privacy. The solutions focus on centralized schemes. A recent study on student assessment and exams [34] demonstrates blockchain application in quality assurance for administrative processes and auditability. Seven design stages have been proposed: (i) initialisation, (ii) submission of draft documents, (iii) internal moderations, (iv) submission of moderated documents, (v) external examination, (vi) submission of final documents, and (vii) signing-off.

Most of the institutions generate and issue certificates in a relatively opaque way. To overcome this, Smart contracts that govern the whole process from course registration, assessment attempts, to credential generation, and offer a higher degree of transparency than existing tools, are of particular interest. A Smart contract based platform with high transparency level, which allows audit and quality control, has been proposed in [35]. It uses smart contracts in order to automate procedures for negotiation and personalization of curriculum, as well as credentials generation (Figure 20).

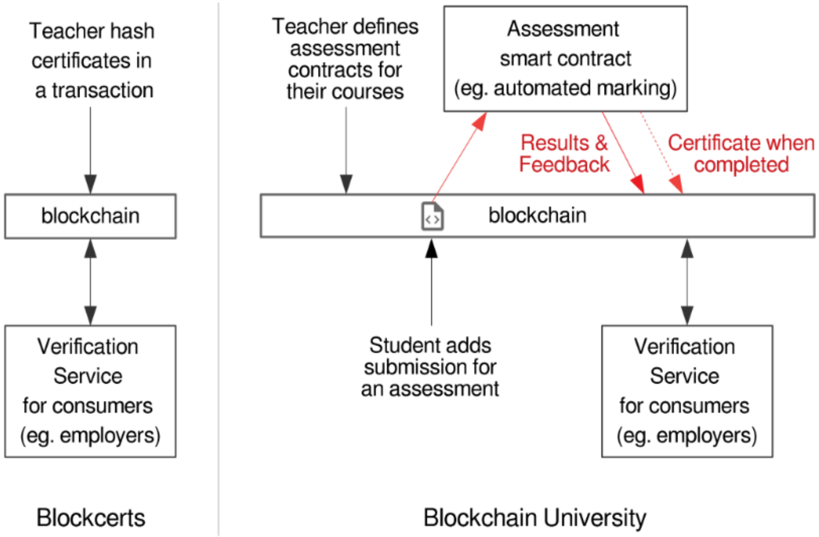

Figure 20 – Blockchain platform [35]

3 Current Technologies for Digitalisation in quality process

Digitalization of the quality process assurance in the higher education remains a big challenge. This chapter provides an overview over some technologies that can be used to support the digitization process.

3.1 BPMN Tools

There are several BPMN tools that can be of particular interest for the DIGITAQ project, such as Bonita Studio or Camunda. The Bonita Studio is the business process management and development platform. Besides the BPMN design process itself it allows creation of Graphical User Interfaces (GUI) that can be later utilized as the front end of the application report component. The GUI creation process is supported through a set of available widgets. Moreover, Bonita Studio enables requests that can be made using JAVA methods that can be of use during the process deployment stage. The typical procedure of creating the BPMN process consists of the following steps:

- Defining business data model that includes establishment of an object with a set of attributes. An example could be the curriculum object with an attribute “number of hours” of a specific type.
- On the next stage the process designer defines the organisations and actors. An example of an organisation could be the higher education institution and of an actor could be the “professor”. Afterwards the organisation entity is deployed.
- The BPMN model is designed during the next stage. The designer defines the BMPN lanes (Figure 21), assigns actors and develops the BPM process itself by dragging and dropping the necessary elements/components such as tasks, activities, gateways, events, etc. onto the canvas. Moreover, during this stage the designer defines the relations among the elements/components to complete the process flow.

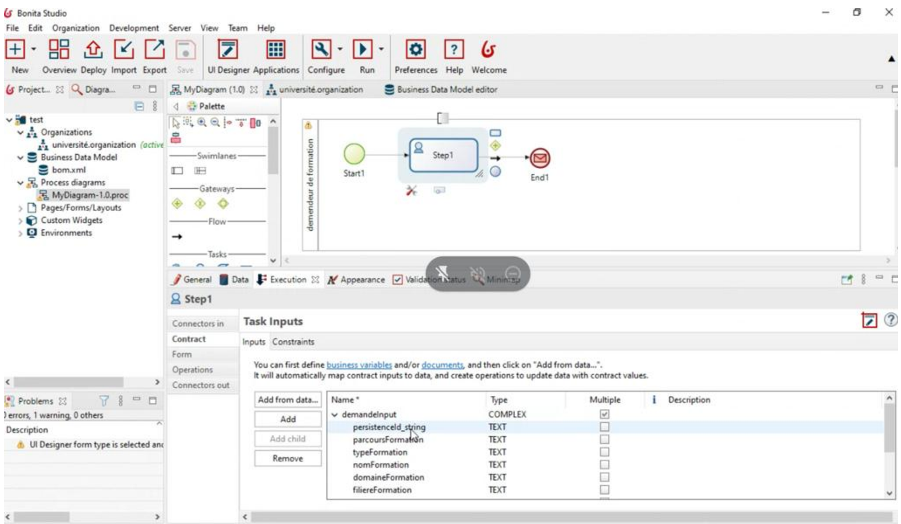

Figure 21 – BPMN flow design process example

- After the main elements are on the canvas and connected, the designer performs the instantiation and uses the Form Editor to create forms reflecting the process flow (Figure 22). An example of the form could be the initial form with an activation button that launches the whole process and some standard form to fill the curriculum attributes, such as the "number of hours" attribute.

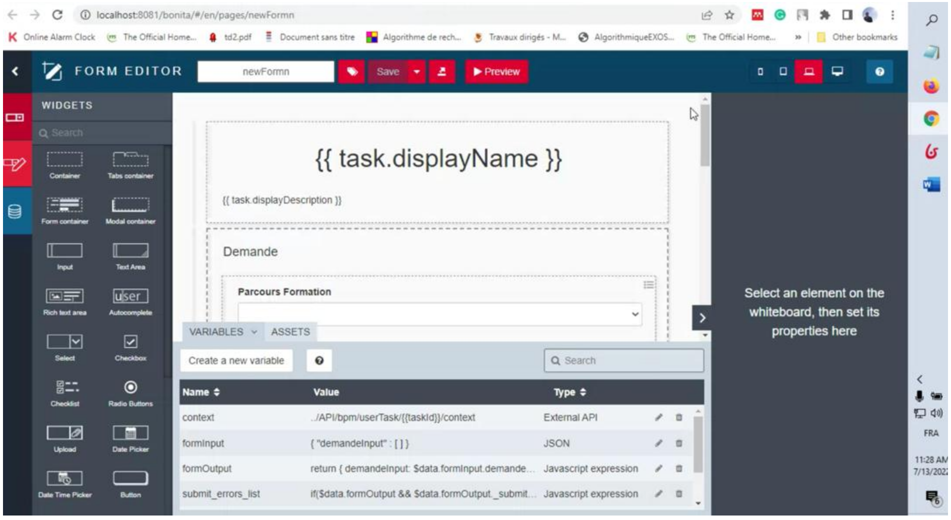

Figure 22 – Bonita Form Editor

- When the process is ready, it is executed at the run-time. And the forms previously created and assigned to certain process stages will appear in the pre-defined order. An example here is, for instance, a professor who prepares the curriculum filling the curriculum attributes. After the curriculum is submitted another actor, for instance, a governance organisation checks the curriculum if it fulfils the requirements.

3.2 Distributed systems

Many modern software platforms are relying on horizontal scaling instead of vertical [61]. This means that the platform is deployed and runs on multiple machines/nodes connected over the network and acting as a single logical entity. In fact, any client-server application is a distributed system. Same logic is applied to the storage systems, as the time when database (DB) systems were mainly running on a single node is gone. Most of the modern DBs have multiple nodes combined into a cluster to improve performance and enhance availability. Every distributed system has several participants called nodes or replicas that have their own states. They communicate with each other by exchanging messages. The synchronisation is accomplished using the clocks, which can be logical or physical. The communication links can be slow and unreliable, which poses one of the main challenges of distributed systems that nothing is entirely reliable. The difficulties related to the distributed nature of the systems are managed by usage of specialised distributed algorithms, which have notions of local and remote state and execution and work despite unreliable networks and component failures.

3.2.1 Distributed Ledger Technologies

Distributed Ledger Technology (DLT) is generating significant interest in applicability by a wide range of enterprises, interested in security processes, approve or validate monetary transactions and other types of data exchange. This technology is similar to a spread sheet where a record of transactions and other account information is accessible and transcribed. This information is owned by every node of a Peer to Peer (P2P) network, where their users have available a consensus mechanism to guarantee the integrity of the stored information [8]. The authors in [9] describe and analyse the main consensus protocols used in DLT.

According to the authors [10] [8], the most useful properties a DLT are the following:

- Shared record-keeping: multiple entities are allowed to collectively create, maintain, update and make accessible for those who need a shared set of records (ledger).
- Multi-party consensus: a group of parties of the DLT contribute to reach an agreement on the records to be stored and shared on the ledger.
- Independent validation: each participant is allowed to independently verify their transactions as well as the integrity of the system.
- Tamper evidence: data should not be modified, and each participant can perceive if non-consensual changes occurred.
- Tamper resistance: as a distributed system, the higher the number of the nodes, the more difficult it is to change past records, increasing the integrity of the data stored on the ledger.
- Scalability: In some IoT systems, the number of transactions tends to increase, taking into consideration that there is an expansion on the devices and their data. Thus, the infrastructure must be able to manage such an amount of operations.
- Energy costs: The energy cost to maintain consistent and safe infrastructure from attacks has to be kept at a reasonable level. As an example, the bitcoin energy cost is already approaching absurd levels of energy consumption and allocated memory.
- Fees: Transactions should be free of transaction costs. In the IoT system, a high number of devices are constantly making transactions to the surrounding parties. This fact would eventually deplete the coin value, hindering its ability to be used for regulating the veracity of the ledger.

3.2.1.1 Categories of DLT

There are different categories of DLTs, according to data availability, transparency of information and what users can do with the ledger data. A DLT can be classified as public, private or consortium DLT [11].

Public DLT: Anyone can use and see the ledger and contribute to the integrity, via trust-less consensus, of the distributed ledger, without the approval of third- parties, acting as a simple node or as a miner/validator [12]. According to the authors [12][13], this DLT type is an example of a fully decentralised system, while the other types come in the category of partially decentralised systems. Public blockchains have some major disadvantages. The first being the high energy consumption the applied consensus uses. They suffer from transaction speed, since it takes time to validate blocks and then complete the transaction.

Private DLT: is a permissioned DLT, where only those who are given access by a moderator can participate and join the network. This type is the most restricted and centralised DLT type. Private blockchains have fewer nodes, making the transactions faster than public ones. In contrast, as there are fewer nodes it can lack security.

Consortium: The owner of the ledger restricts their access for a selected group of users. Since the participants are whitelisted, costly consensus mechanisms, as the example of Proof of Work consensus, are not needed, as there is no threat of a Sybil attack [14]. Their users must be authenticated before accessing the DLT network and only limited users have the privilege to accept and verify transactions [12].

3.2.1.2 Smart contracts

Within the DLT context, a group of Programmatically Executed Transactions (Smart contracts) are computer scripts that, when triggered, are executed by the system. They are triggered by addressing a transaction to them and they run in a stipulated pattern, automatically and autonomously, in every node in the network, according to the data that is included in the triggering transaction. For example, a smart contract could be programmed for the following agreement: “If flight A is delayed for more than 3 hours, then all passengers from this flight receive a fixed monetary compensation”. Smart contract execution implies that every node is running a virtual machine (VM), and that the network acts as a distributed VM [15]. Deployed smart contracts are stored within the DLT and for this reason they are visible to all participants in the network [16].

When developing these scripts, it is necessary to take into consideration some programming challenges, e.g., access to external data sources within a contract [17]. The smart contracts are executed independently by each node of the chain. Thus, if the smart contract uses an external service to get information, there are no guarantees that all nodes retrieve the same information because the information can change between requests from the different nodes or the server can become overloaded and create inconsistencies between responses. As an example, a triggered smart contract that uses the real-time value of the product stock from a factory can get different outcomes from each node execution. This can happen since all nodes run the smart contract and they will not run at the exact time (as example, due to network delays or low resources), and the result for each script will be different, causing honest nodes to have different content. To overcome this issue, smart contracts use “Oracle services”. Oracles are used as sources of information and either sign a transaction containing a fact, by specifying if it is true or false, or can themselves provide factual data [18]. An example, Oraclize is a tool used by smart contracts to access the Internet in order to get data.

Although smart contracts bring the advantage of automating processes, they lack privacy as they are accessible by all participant nodes within the network, which may not be acceptable to use in some scenarios. For this reason, the authors in [46] propose the use of cryptographic algorithms to encrypt the stored data to ensure that only the users who have legitimate permissions to access the data can decrypt it, thereby improving the data security and privacy.

The authors in [14] suggest the use of smart contracts as they allow to automate complex multi-step processes. In [19], the authors suggest using a skeleton contract, as a general contract which contains all methods and points to the remaining contracts.

3.2.1.3 Types of DLT

DLT is a general term that refers to the technological infrastructure and protocols that have been accepted by their users, that allows a validation, access and insertion of data in an immutable manner across a distributed network, within multiple entities and locations. The most popular DLT is **Blockchain**, in which each new transaction makes up a new block that joins the previous one in order to create a chain of immutable blocks. Figure 1 shows a visual representation of the first three blocks of a Blockchain.

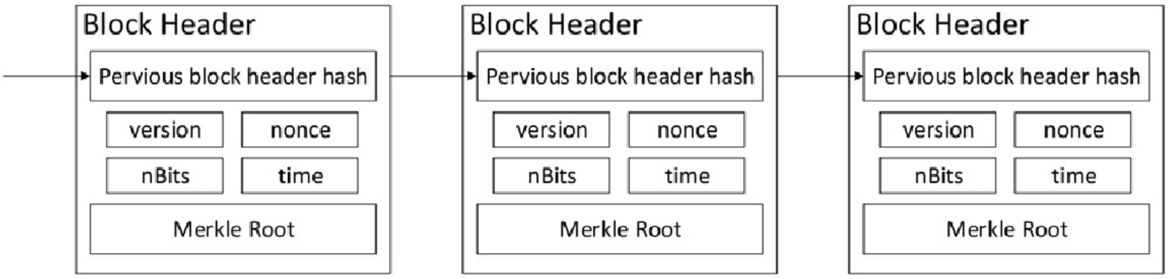

Figure 23 – Blockchain data structure. Image from [18]

Figure 23 shows a visual representation of the first three blocks of a Blockchain. A block is solely a group of transactions bundled together and logically organised, committed to the ledger. Each one of these transactions is digitally signed by the entity that emits the blocks. The first block is called Genesis Block. Each block has a header that contains a hash that references the previous block. Thus, the blockchain generates an immutable time-ordered history of transactions to other parties. Changing one block would result in inconsistency. Examples of blockchains are Bitcoin, Ethereum and Hyperledger Fabric.

Another type of DLT uses a Directed acyclic graph (DAG) structure. A graph is a diagram containing points called nodes that are connected with edges. In directed graphs, the edges are connected through arrows and indicate the direction from one node to the other, in such a way that those directions will never form a closed loop [20]. An example of a DAG is depicted in Figure 24.

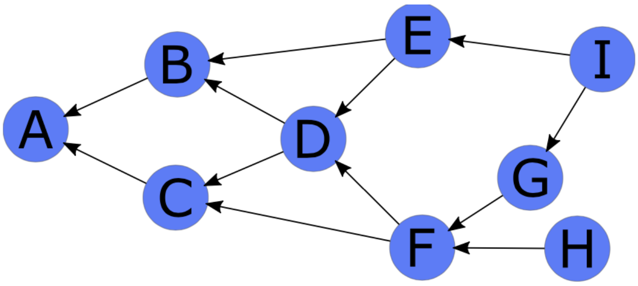

Figure 24 – Example of a DAG

For instance, a particular instance of a DAG is the IOTA Tangle. IOTA is the first open-source distributed ledger that enables fee-less micro transactions for IoT [21]. IOTA developed an IoT-inspired DAG [8] to store transactions, called Tangle [21], which has the following characteristics:

- Each vertex in Tangle is a transaction and the (directed) edge is its approval.
- Every new transaction has to approve at least 2 new transactions.
- The last edges are transactions to be validated.

IOTA platform removed the need for miners and associated transaction fees through the requirement of new transactions validate two existing transactions.

Other types of DLT are Hashgraphs or Holochain, however, they are very recent and there are few documentation and technologies that use this type of structures.

3.2.2 Distributed Database Management Solutions

DIGITAQ plans to adopt the distributed approach for database deployment. Distributed database can be defined as a collection of multiple, logically interrelated databases located at the nodes of a distributed system [62]. The two important characteristics of the distributed database are logically interrelated data and deployment on a distributed system. In its turn, the distributed computing system can be regarded as a number of interconnected autonomous processing elements, which can be heterogeneous. However, an important aspect is that they do not have access to each other's state, which they discover by exchanging messages imposing communication costs. Therefore, for the distributed data management and access there is a need for a specific Database Management System (DBMS).

In the case of relational data, different relations or their partitions might be stored at different sites, requiring join or union operations to reply to typical SQL queries. One possibility is to define a schema of the distributed data. On the other hand, data in NoSQL systems, as, for instance, in the graph DBs, the vertices of a graph might be stored at different sites. In other words, data in distributed DBs are logically integrated, but physically distributed. The specific DBMS provides the user the view of a unified database, while the underlying data are distributed. In the literature [62], the one considers two types of distributed DBMSs: geographically distributed and single location. Single location distributed DBMSs are typically associated with computer clusters in the same data centre.

3.3 Security Features

The security of any. system is an important part of their development and it comes with its set of challenges. Anyway, the security aspects of a system can be tackled by using multiple methods [37] that may integrate the most important security aspects associated to [38]:

- Authentication: This is a process that ensures that an object has the ability to identify and prove the identification of another object (and sometimes its own identification).
- Authorization: This is the process that defines the permissions of an identity inside a network.
- Integrity: Integrity is crucial in any network. It is responsible for checking if data that has been transmitted has been corrupted or tampered with.

- Confidentiality: This process is responsible for guaranteeing that data can only be read by those who do have permission to do it. This is usually assured using cryptography.
- Non-repudiation: non-repudiation is the assurance that a device cannot dispute its authorship, or the validation of a message sent by it.

Authentication as mentioned before is a security step towards establishing a secure communication session between an end-user and a server. Assigning an unique identifier for the devices and users is the basis for the authentication step and the consequent authorization phase. This fact is important because it allows confirming and insuring the identity of all parties within a system. As mentioned by the authors in [36], there are several types of authentication schemes, namely the identity-based authentication schemes which is the information presented by one party to another to authenticate itself. The party can use one (or a combination) of hash, symmetric or asymmetric cryptographic algorithms. Figure 25 and Figure 26 are examples of authentication procedures that can be appended to data in order to identify the creator of that data.

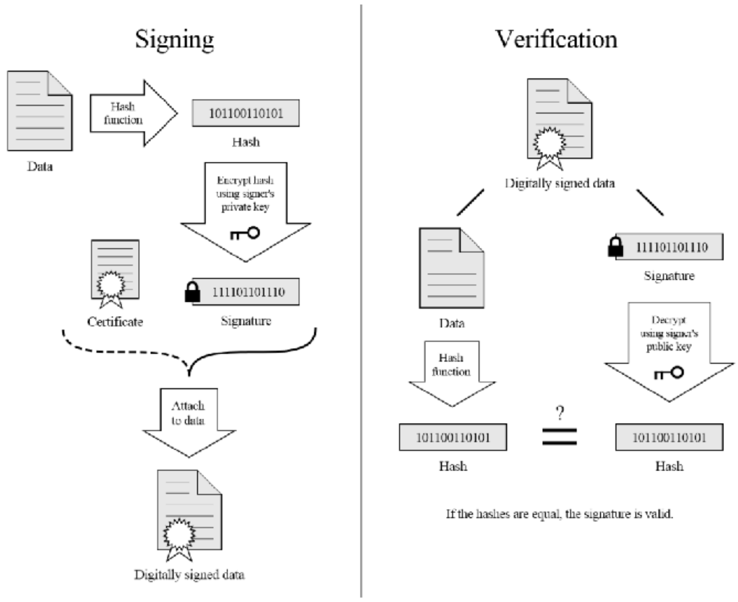

Figure 25 – Digital Signature mechanism [2]

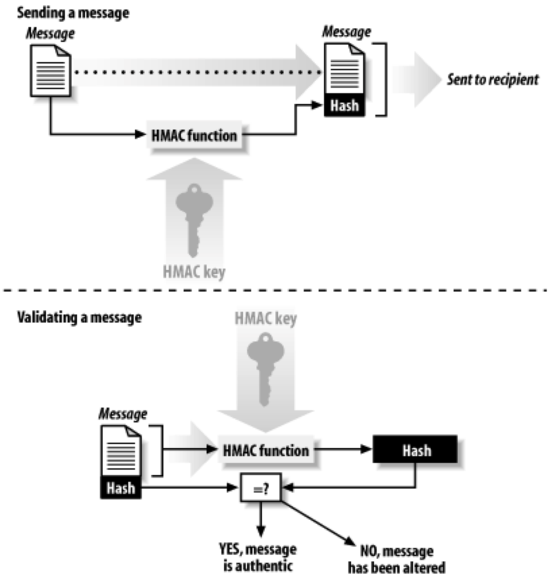

Figure 26 – HMAC [3]

Digital Signature Algorithm (DSA) is an example of Public-key cryptography or Asymmetric cryptography. This cryptography method encrypts and decrypts data by using a public key and private key pairs. The public key is a key that can be shared between any users of the system, whereas the private key is only known by its owner.

A Hash Message Authentication Code (HMAC) is an example of a private-key cryptography or symmetric cryptography. Symmetric-key algorithms make use of a single key (secret key) to encrypt and decrypt data that is only shared between data receiver and data sender. DSA and HMAC can be both used to simultaneously verify data integrity and authenticity of a message.

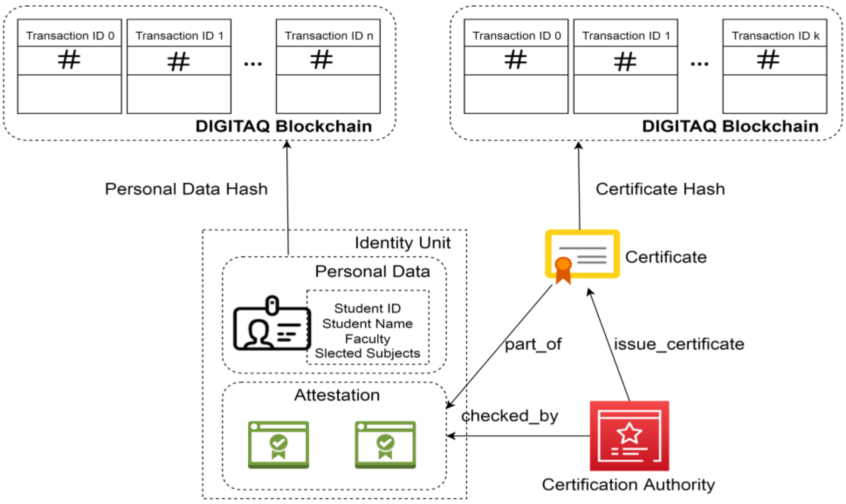

Figure 27 – Certificate issuing process

3.4 Final Discussion about Technologies to be used

Blockchain even being analysed as a prominent technology solution cannot be used within the DIGITAQ. After the set of discussion rounds with “Autorité Gouvernementale de Certification Électronique” authority, it has been found that the use of blockchain for certification and digital signature between public institution is prohibited by Algerian regulations, namely by the law 15-04 of 11 from 01/02/2015. And this is the only authority capable to grant this kind of certification within state institutions. By this fact, the use of blockchain in the DIGITAQ project is unfortunately cancelled due to regulatory reasons. However, the impossibility of a blockchain technology use is a real loss for the project, but the compliance with regulations is critical for the project’s success.

4 *The Proposed DIGITAQ Platform*

As one of the inspiration sources for the platform specification we are using the TOGAF previously defined in chapter 1.1. On this stage we define a set of building blocks, namely the ABBs that satisfy the required capabilities or fundamental functionalities previously identified. The corresponding SBBs defining the specific tools to deliver the required functionalities will be defined on the later stages. Moreover, the possibility to use artefacts to define the building blocks is considered. Below the specified ABBs with corresponding descriptions are listed:

- Certification / Ministry Viewer. This ABB serves the goal of certification of a BPMN to then be used by all universities. In this case, access to BPMN Process Repository *“adopted by ministry”*. Another point is to certify a Result (Performance Result) of a university. The future plans for SBB include the DIGITAQ Reporting DBs to assure the information integrity.
- Reporting Application. This ABB is responsible for reporting of each step (variables defined) of the quality process and integrate such reported data with particular information of their own university.
- BPMN Editor or DIGITAQ Lab. This ABB should deliver the capability of creating the new processes collaboratively, save and send them to the certification authority following metadata rules with ability to follow particularities to then assure the right recording.
- DashBoard Viewer. This ABB checks the performance of the entities/universities at both national and university levels and provides an option to save a view (report a result to DIGITAQ Reporting DB). The AI-Analytics block enables the data analysis to suggest possible improvements to the process design.

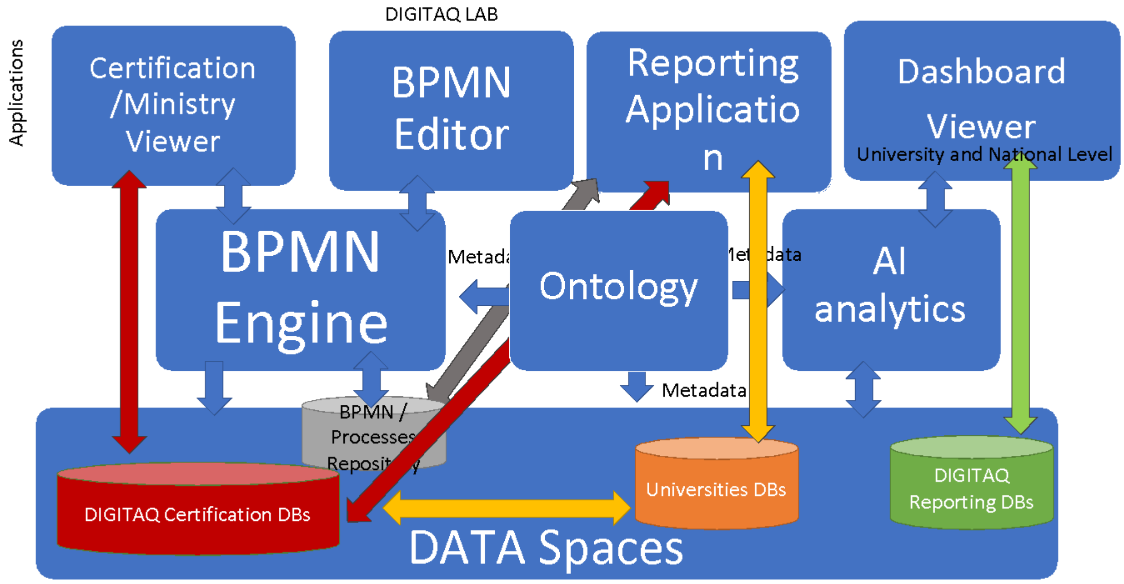

Figure 28 – The core components (ABBs) of the DIGITAQ model

The next stage covers the process of SBBs selection and/or development to satisfy the capabilities/functionalities defined by ABBs (see Table 1). Let's look at the example to give an insight: the Reporting Application can utilise, for instance, publish-subscribe messaging paradigm. Then we can employ one of the available message brokers. Thus, one of the SBB for this ABB will be a messaging broker, for instance, *Mosquitto*, and the optional one – EMQX. The Table presented below represents the defined ABBs with the corresponding SBBs delivering the functionality of ABBs, including the Explanation column for justification of a choice of specific SBB solutions.

In the tables below we have defined the ABB and SBB for one of the key components – BPMN Editor, the rest of the components will be addressed after the WP2.

Two BPMN engines were considered to be used by the DIGITAQ. Both provide quite similar functionalities allowing establishment of BPMN process flows. One advantage of Bonita is that it allows designing better sophisticated GUIs, while Camunda GUIs are simpler. Both solutions support REST APIs to access the data with HTTP requests. Even though the solutions are quite similar, the Bonita studio has been selected for the role of BPMN editor in DIGITAQ.

Table 2 – critical aspects of the BPMN ABB

Component	Functionality	Attributes	Interfaces	Constraints (functional dependencies)	Manageability
BPMN Editor	Create BPMN process flows	Set Actors	N/A	Storage	Define the actors involved in the process
		Deploy functional elements	JAVA API /RESTful	Storage	Set the functional elements and set corresponding connections among them
		Create GUI	N/A	Storage	Create the forms

					reflecting the stages of the designed process

Table 3 – Possible SBBs for the BPMN ABB

Solution	**ABB Component**	**Level**	**Functionality**	**Evaluation**
Bonita Studio	BPMN Engine and Editor	Generic	BPMN process design and deployment	Use (?)
Camunda	BPMN Engine and Editor	Generic	BPMN process design	Don't use

In the next phase of this work already under the WP2 work it will be analysed the other elements of the architecture. Thus, the following table (Table 4) will be fulfilled to accomplish the specification and further DIGITAQ platform implementation. As BONITA offer different outcomes it may be explored for different modules of the developed architecture.

Table 4 – The ABBs defined with corresponding SBBs

ABBs	Preferred SBBs	Optional SBBs	Explanation
Certification / Ministry Viewer			
Reporting Application			
BPMN Editor or Digitaq Lab			
DashBoard Viewer			

5 References

1. Chen, G., Xu, B., Lu, M. et al. Exploring blockchain technology and its potential applications for education. Smart Learn. Environ. 5, 1 (2018). https://doi.org/10.1186/s40561-017-0050-x
2. Sharples M., Domingue J. (2016) The Blockchain and Kudos: A Distributed System for Educational Record, Reputation and Reward. In: Verbert K., Sharples M., Klobučar T. (eds) Adaptive and Adaptable Learning. EC-TEL 2016. Lecture Notes in Computer Science, vol 9891. Springer, Cham. https://doi.org/10.1007/978-3-319-45153-4_48
3. Gräther, Wolfgang; Kolvenbach, Sabine; Ruland, Rudolf; Schütte, Julian; Torres, Christof; Wendland, Florian (2018): Blockchain for Education: Lifelong Learning Passport. In: W. Prinz & P. Hoschka (Eds.), Proceedings of the 1st ERCIM Blockchain Workshop 2018, Reports of the European Society for Socially Embedded Technologies (ISSN 2510-2591), DOI: 10.18420/blockchain2018_07
4. Wiebke S. Lévy, Jutta Stumpf-Wollersheim and Isabell M. Welpe. Disrupting education through blockchainbased education technology? Beiträge zur Hochschulforschung, 2019, https://www.ihf.bayern.de/fileadmin/user_upload/Publikationen/Beitraege_zur_Hochschulforschung/2019/3_2019_Gesamt.pdf#page=10
5. M. Turkanović, M. Hölbl, K. Košič, M. Heričko and A. Kamišalić, "EduCTX: A Blockchain-Based Higher Education Credit Platform," in IEEE Access, vol. 6, pp. 5112-5127, 2018, doi: 10.1109/ACCESS.2018.2789929.
6. Raimundo, R.; Rosário, A. Blockchain System in the Higher Education. Eur. J. Investig. Health Psychol. Educ. 2021, 11, 276-293. https://doi.org/10.3390/ejihpe11010021
7. Meng Han, Zhigang Li, Jing (Selena) He, Dalei Wu, Ying Xie, and Asif Baba. 2018. A Novel Blockchain-based Education Records Verification Solution. In Proceedings of the 19th Annual SIG Conference on Information Technology Education (SIGITE '18). Association for Computing Machinery, New York, NY, USA, 178–183. DOI:https://doi.org/10.1145/3241815.3241870
8. P. Ferraro, C. King, and R. Shorten, "Distributed Ledger Technology for Smart Cities, the Sharing Economy, and Social Compliance," IEEE Access, vol. 6, pp. 62728–62746, 2018, doi: 10.1109/ACCESS.2018.2876766.
9. S. Zhang and J. H. Lee, "Analysis of the main consensus protocols of blockchain," ICT Express, vol. 6, no. 2, pp. 93–97, 2020, doi: 10.1016/j.icte.2019.08.001.
10. M. Rauchs et al., "Distributed Ledger Technology Systems: A Conceptual Framework," 2018. doi: 10.2139/ssrn.3230013.
11. B. Farahani, F. Firouzi, and M. Luecking, "The convergence of IoT and distributed ledger technologies (DLT): Opportunities, challenges, and solutions," J. Netw. Comput. Appl., vol. 177, p. 102936, Mar. 2021, doi: 10.1016/j.jnca.2020.102936.
12. T. M. Fernandez-Carames and P. Fraga-Lamas, "A Review on the Use of Blockchain for the Internet of Things," IEEE Access, vol. 6, pp. 32979–33001, 2018, doi: 10.1109/ACCESS.2018.2842685.
13. G. G. Dagher, J. Mohler, M. Milojkovic, and P. B. Marella, "Ancile: Privacy-preserving framework for access control and interoperability of electronic health records using blockchain technology," Sustain. Cities Soc., vol. 39, no. August 2017, pp. 283–297, May 2018, doi: 10.1016/j.scs.2018.02.014.
14. K. Christidis and M. Devetsikiotis, "Blockchains and Smart Contracts for the Internet of Things," IEEE Access, vol. 4, pp. 2292–2303, 2016, doi: 10.1109/ACCESS.2016.2566339.
15. K. Yeow, A. Gani, R. W. Ahmad, J. J. P. C. Rodrigues, and K. Ko, "Decentralized Consensus for Edge-Centric Internet of Things: A Review, Taxonomy, and Research Issues," IEEE Access, vol. 6, pp. 1513–1524, 2018, doi: 10.1109/ACCESS.2017.2779263.
16. H. Pervez, M. Muneeb, M. U. Irfan, and I. U. Haq, "A Comparative Analysis of DAG-Based Blockchain Architectures," in 2018 12th International Conference on Open Source Systems and Technologies (ICOSST), Dec. 2018, no. December, pp. 27–34, doi: 10.1109/ICOSST.2018.8632193.
17. A. Taherkordi and P. Herrmann, "Pervasive Smart Contracts for Blockchains in IoT Systems," pp. 6–11, 2018, doi: 10.1145/3301403.3301405.
18. I. Bashir, Mastering Blockchain, Second. Birmingham: Packt Publishing, 2018.
19. N. Fotiou and G. C. Polyzos, "Smart Contracts for the Internet of Things: Opportunities and Challenges," 2018 Eur. Conf. Networks Commun. EuCNC 2018, pp. 256–260, 2018, doi: 10.1109/EuCNC.2018.8443212.
20. D. Burkhardt, M. Werling, and H. Lasi, "Distributed Ledger," in 2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC), Jun. 2018, pp. 1–9, doi: 10.1109/ICE.2018.8436299.
21. S. Popov, "IOTA Whitepaper," New Yorker, vol. 81, no. 8, pp. 1–28, 2018, [Online]. Available: https://assets.ctfassets.net/r1dr6vzfxhev/2t4uxvsIqk0EUau6g2sw0g/45eae33637ca92f85dd9f4a3a218e1ec/iota1_4_3.pdf.
22. 'Programming the Open Blockchain' (no date).
23. 'Next Generation Smart Contract & Decentralized Application Platform. Whitepaper'
24. 'Exploring blockchain technology and its potential applications for education' (no date).
25. Awaji, B., Solaiman, E. and Albshri, A. (2020) 'Blockchain-based applications in higher education: A systematic mapping study', PervasiveHealth: Pervasive Computing Technologies for Healthcare, pp. 96–104. doi: 10.1145/3411681.3411688.
26. Yang, C. et al. (2022) 'Edge-cloud Blockchain and IoE enabled Quality Management Platform for Perishable Supply Chain Logistics', IEEE Internet of Things Journal. IEEE, 4662(c), pp. 1–1. doi: 10.1109/jiot.2022.3142095.
27. Melnyk, Y. B. and Pypenko, I. S. (2020) 'How will Blockchain Technology Change Education Future?!', International Journal of Science Annals, 3(1), pp. 5–6. doi: 10.26697/ijsa.2020.1.1.

28. Nurovi, E. and Poturak, M. (2021) 'Rethinking the Concept of the Education through Digitalization of Higher Education Institutions and Blockchain', International Journal of Social Sciences & Educational Studies, 8(2), pp. 88–95. doi: 10.23918/ijsses.v8i2p88.
29. Purnama, S. et al. (2021) 'Design of Educational Learning Management Cloud Process with Blockchain 4.0 based E-Portfolio', Journal of Education Technology, 5(4), p. 628. doi: 10.23887/jet.v5i4.40557.
30. Raimundo, R., & Rosário, A. (2021) 'Blockchain System in the Higher Education', European Journal of Investigation in Health, Psychology and Education, 11(1), pp. 276–293.
31. Li, D., Han, D., Zheng, Z., Weng, T. H., Li, H., Liu, H., ... & Li, K. C. (2022) 'MOOCsChain: A blockchain-based secure storage and sharing scheme for MOOCs learning', Computer Standards & Interfaces, 81(103597).
32. Alshahrani, M. Y. (2022) 'Implementation of a Blockchain System Using Improved Elliptic Curve Cryptography Algorithm for the Performance Assessment of the Students in the E-Learning Platform'.
33. Himeur, Y. et al. (2022) 'Blockchain-based recommender systems: Applications, challenges and future opportunities', Computer Science Review. Elsevier Inc., 43, p. 100439. doi: 10.1016/j.cosrev.2021.100439.
34. Mitchell, I., Hara, S. and Sheriff, M. (2019) 'dAppER : D ecentralised Application for Examination Review', 2019 IEEE 12th International Conference on Global Security, Safety and Sustainability (ICGS3), pp. 1–14.
35. Lam, T. Y., & Dongol, B. (2020). A blockchain-enabled e-learning platform. Interactive Learning Environments, 1–23. doi:10.1080/10494820.2020.1716022.
36. M. El-hajj, A. Fadlallah, M. Chamoun, and A. Serhrouchni, "A Survey of Internet of Things (IoT) Authentication Schemes," Sensors, vol. 19, no. 5, p. 1141, Mar. 2019, doi: 10.3390/s19051141.
37. A. J. Martins De Oliveira, "IOT SECURITY ASSESSMENT IoT Security Assessment in an IoT Smart City Scenario," no. September, 2019.
38. S. Li, T. Tryfonas, and H. Li, "The Internet of Things: a security point of view," Internet Res., vol. 26, no. 2, pp. 337-359, 2016, doi: 10.1108/IntR-07-2014-0173.
39. N. R. Moşteanu, "Digital Campus - A future former investment in education for a sustainable society," *E3S Web Conf.*, vol. 234, pp. 1–5, 2021, doi: 10.1051/e3sconf/202123400029.
40. M. Sailer, F. Schultz-Pernice, and F. Fischer, "Contextual facilitators for learning activities involving technology in higher education: The C♭-model," *Comput. Human Behav.*, vol. 121, no. March, p. 106794, 2021, doi: 10.1016/j.chb.2021.106794.
41. F. J. García-Peñalvo, "Avoiding the dark side of digital transformation in teaching. an institutional reference framework for eLearning in higher education," *Sustain.*, vol. 13, no. 4, pp. 1–17, 2021, doi: 10.3390/su13042023.
42. V. Tsiligiris and C. Hill, "A prospective model for aligning educational quality and student experience in international higher education," *Stud. High. Educ.*, vol. 46, no. 2, pp. 228–244, 2021, doi: 10.1080/03075079.2019.1628203.
43. M. O. Lawal and P. T. A. Umoru, "Human and Infrastructural Resources for Quality Assurance in Polytechnic Office Technology and Management Program," vol. 8, no. 1, pp. 65–74, 2021.
44. A. Mondal, *Computational Intelligence in Digital Pedagogy*.
45. Ahmed A. Al-Imarah, Robin Shields & Richard Kamm (2021) Is quality assurance compatible with technological innovation? Case studies of massive open online courses (MOOCs) in United Kingdom higher education, Quality in Higher Education, 27:1, 4-19, DOI: 10.1080/13538322.2021.1830474
46. D. Gillet, I. Vonèche-Cardia, J. C. Farah, K. L. P. Hoang and M. J. Rodríguez-Triana, "Integrated Model for Comprehensive Digital Education Platforms," 2022 IEEE Global Engineering Education Conference (EDUCON), 2022, pp. 1587-1593, doi: 10.1109/EDUCON52537.2022.9766795.
47. A. Gorshenin, "Toward Modern Educational IT-ecosystems: from Learning Management Systems to Digital Platforms," 2018 10th International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT), 2018, pp. 1-5, doi: 10.1109/ICUMT.2018.8631229.
48. dos Santos, V.M., Cernev, A.K., Saraiva, G.M.M. and Bida, A.G. (2022), "Faculty experience and digital platforms in education", Revista de Gestão, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/REGE-05-2021-0090
49. Kaplan, A. M., & Haenlein, M. (2016). Higher education and the digital revolution: About MOOCs, SPOCs, social media, and the Cookie Monster. Business Horizons, 59(4), 441–450. doi:10.1016/j.bushor.2016.03.008
50. Angela Yung Chi Hou, Christopher Hill, Martin Ince, Fang Yu Lin & Emma Chen (2021): A preliminary exploration of crisis management approach on higher education and quality assurance in Taiwan under COVID-19 pandemic: relevancetoothercontexts?, Journal of Asian Public Policy, DOI: 10.1080/17516234.2021.1919390
51. Taudes, Alfred, Markus Feurstein, and Andreas Mild. "Options Analysis of Software Platform Decisions: A Case Study." *MIS Quarterly* 24, no. 2 (2000): 227–43. https://doi.org/10.2307/3250937.
52. Pablo, Bermejo.: Building Software Platforms: A Guide to SaaS Transition with AWS. Independently published, November 5, 2021.
53. Amrit, Tiwana.: Platform Ecosystems, Aligning Architecture, Governance, and Strategy 2014. DOI. https://doi.org/10.1016/C2012-0-06625-2
54. Bridgera. What is a Software Platform? 2022. Retrieved from: https://bridgera.com/what-is-a-software-platform/
55. Tolga, Şimşek., M, Atilla,Öner., Özlem, Kunday., Gökçen, Arkalı,Olcay.: A journey towards a digital platform business model: A case study in a global tech-company. Technological Forecasting and Social Change, Vol. 175, February 2022, 121372.
56. Erich, Gamma., Richard, Helm., Ralph, Johnson., John, Vlissides., Grady, Booch.: Design Patterns: Elements of Reusable Object-Oriented Software. Addison-Wesley Professional; 1st edition, November 10, 1994.

57. ARQA TECHNOLOGIES.: Software Platform Architecture. 2022. Retrieved from: https://arqatech.com/en/products/qort/tech-features/software-platform-architecture/#:~:text=The%20platform%20is%20created%20in,server%20components%20and%20client%20applications.
58. Information Systems vs. Information Technology. https://online.csp.edu/resources/article/information-systems-vs-information-technology/#:~:text=An%20information%20system%20is%20a,record%20is%20an%20information%20system.
59. J. A. Zachman, "A framework for information systems architecture," in IBM Systems Journal, vol. 26, no. 3, pp. 276-292, 1987, doi: 10.1147/sj.263.0276.
60. The Open Group, The TOGAF Standard, Version 9.2, 2018.
61. Alex Petrov. Database Internals A Deep Dive into How Distributed Data Systems Work, O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472
62. M. Tamer Ozsu, Patrick Valduriez. Principles of Distributed Database Systems. Fourth edition. Springer Science+Business Media, LLC 2011. https://doi.org/10.1007/978-3-030-26253-2

DIGITAQ

Création de Capacités Digitales pour le Pilotage de l'Assurance Qualité dans l'Enseignement Supérieur Algérien