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Review

How Ready Is Higher Education for Quality 4.0 Transformation according to the LNS Research Framework?

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Abstract: The world is evolving, and it has transformed from the industrial age to the era of connected and intelligent products in both organizations and competition. The advances in technology in the last decade have led to the introduction of a new term called Industry 4.0 or the fourth industrial revolution and that has led to the emergence of the term Quality 4.0. Quality 4.0 is the digitalization of traditional quality approaches and the focus on the use of digital tools to improve an organization's ability to meet customers' requirements with high quality. The purpose of this paper is to assess the environments of higher education institutions (HEIs) against the 11 axes of LNS Research Quality 4.0 framework and provide insights about their readiness for Quality 4.0 transformation. The framework helps the organizations digitalize their traditional quality practices and transform to Quality 4.0 through exploring the traditional quality—Quality 4.0 continuum of tools and/or concepts related to each axis so they can assess their transformation efforts accordingly. This paper uses these continuums to identify the quality implementation efforts conducted by HEIs through analyzing the continuums' related practices adopted within their environments and find out what should be done to get to the full transformation to Quality 4.0 within the higher education field. The study shows the HEIs potential of adopting the Quality 4.0 tools and techniques of varies axes of the framework while revealing a limited adoption of most of them in the current times. This is due to several challenges the most impacting of which is having fragmented processes together with fragmented data systems and sources. The study is concluded with a proposed roadmap to assist HEIs to get the best out their efforts in the Quality 4.0 transformation process.

Keywords: quality 4.0; digital transformation; higher education institutions; HEIs; LNS research; 11 axes; big data analytics; cloud computing scalability; blockchain collaboration; app development; edge devises connectivity

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1. Introduction

Quality has evolved from concepts into practices, techniques, and articulated procedures [1]. Many researchers and practitioners agree that quality is important for long-term performance of institutes even though quality can be defined in multiple ways [2,3]. For instance, quality is defined as value [4], conformance to requirements [5], fitness for use [6], and meeting and/or exceeding customer expectations. According to Al-Tarawneh andand Mubaslat, [7], quality is a constant development process towards an anticipated degree of perseverance and consistency. Not only does quality signify the product/service quality, but also the quality management and the reputation of the organization. [8].

Implementing quality services in higher education institutions (HEIs) is key to distinguishing competitors as well as ensuring long-term sustainability [8]. A variety of quality tools, techniques, and models have been adopted to improve the quality of service and processes in higher education. These techniques include traditional quality methods such as Total Quality Management (TQM) [9], Quality Function Deployment (QFD) [10], and

more recently Lean Six Sigma (LSS) [11]. The implementation of these tools and techniques has brought about many benefits to HEIs such as reducing costs, improving productivity, streamlining processes, and increasing customer satisfaction [12]. However, in order to remain effective, such traditional quality practices are expected to be transformed. According to Elshennawy [13], quality professionals must adapt to a new world of high technology and innovation. Thus, such professionals and their organizations are expected to enhance quality related practices and processes by benefiting from the fourth industrial revolution, Industry 4.0, which incorporates new technologically advanced tools, devices, media, and approaches suitable be adopted in both manufacturing and service sectors.

Prior to Industry 4.0, three industrial revolutions occurred throughout history and impacted the world and its development. The first industrial revolution adopted coal in the year 1765. This original industrial revolution played a significant role in transforming the nation's economy from agriculture to industry. The production and exchange of goods were completely changed by the discovery of coal and the subsequent development of metal forging and steam engines [14,15]. The second industrial revolution was in the year 1870. This revolution involved the discovery of gas, oil, and electricity. Fuel sources supported the invention of the combustion engine. Developments were there in communication technology along with transportation growing considerably. Through the provision of mass production, there was a growth in mechanical production speed [16]. The third industrial revolution was in the year 1969. When nuclear energy and electronics entered the landscape, it was a praiseworthy change. While nuclear power began in Europe, it soon grew in the United States and Great Britain. With further developments, it also spread to Asia. As a result, people engaged more in innovative thinking and research [17].

As a result of these industrial revolutions, various business practices have evolved including those related to quality. Figure 1 summarizes the evolution of quality as described by [15]. Quality practices known today started with the work of Henri Fayol in France and Fredrick Winslow Taylor in the United States. They introduced the scientific management methods during the middle of the second industrial revolution to fulfill factories' need for ensuring assembly lines' smooth operation, production according to specifications, workers' engagement in the production process, and cost control. Those methods have expanded to cover designing processes to produce to specifications. The adoption of personal computing, in the 1980s and 1990s, has allowed organizations to rearrange quality efforts to be around the active engagement in quality and the value of culture. As a result, TQM, Lean, and Six Sigma (6σ) gained more popularity. With the increased adoption of connected, intelligent, and automated system, a renaissance is expected in quality methods and tools. Accordingly, progression in quality practices can be summarized in the following phases [15]:

- Quality as inspection: At this phase quality control related methods and tools, such as Shewhart's methods for statistical process control (SPC), were used to inspect bad quality of items produced.
- Quality as design: At this phase, by ceasing dependence on inspection as per Deming's recommendation, more holistic methods for designing quality into process emerged to prevent quality problems before their occurrence.
- Quality as empowerment: At this phase, total quality management and continuous improvement approaches, such as TQM and 6σ, emerged to provide empowerment to individuals and make continuous improvement as everyone's responsibility.
- Quality as discovery: As organizations move towards an adaptive intelligent environment, quality tools and methods will be of an increased dependence on the swift discovery and aggregation of new data sources, the effective discovery of root causes, and the ability to discover new insights about people, products, and organizations.

According to Sony et al. [18], Quality 4.0 can build and improve traditional quality methods, closely aligning quality management with Industry 4.0. In addition, as pointed out by Radziwill [15], organizations need to have Quality 4.0 strategies to realign quality management with corporates' strategies. A strong Quality 4.0 strategy would help orga-

nizations to overcome long-standing challenges and obstacles such as the lack of making data-driven quality decisions which led to the development of low-grade quality culture and inadequate functional visibility in various industries. In addition, the application of Quality 4.0 would enable organizations to achieve real values such as better market share, lower costs, enhanced product/service quality, improved efficiency, and broader brand recognition.

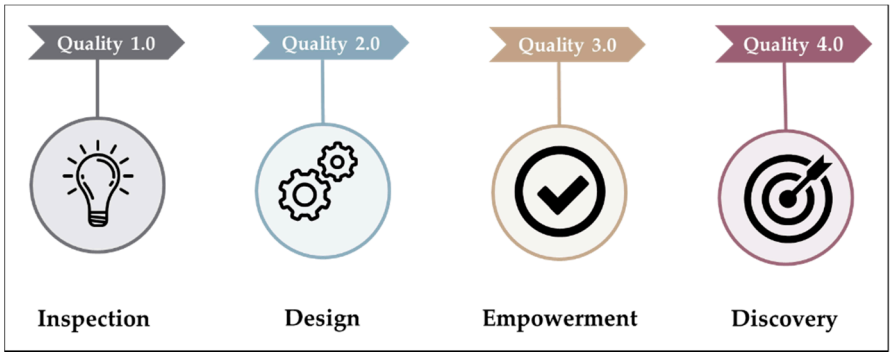

Figure 1. The evolution of quality.

According to Küpper et al. [19], Quality 4.0 is a development that helps to upgrade quality in the future since digital technologies help to improve quality in different ways. For example, the organization can monitor processes, collect real-time data, and apply analytics to predict quality problems and maintenance needs. The authors provided a better understanding of the role of technology in addressing the need to transform quality management through focusing on the opportunities and challenges arising from adopting Quality 4.0 through the application of Industry 4.0 advanced technologies. Thus, transforming from traditional quality to Quality 4.0 is important in today's evolving business world to meet and exceed customer expectations. Among the frameworks that help organizations to effectively pursue such transformation is the one developed by LNS Research, an advisory and research firm helping clients to innovate and bring about operational excellence [20]. The purpose of this paper is to assess the HEIs environments against the 11 axes of LNS Research Quality 4.0 framework and provide insights about their readiness for Quality 4.0 transformation. The framework is made of 11 axes that help the organizations digitalize their traditional quality practices and transform to Quality 4.0 through exploring the traditional quality—Quality 4.0 continuum of tools and/or concepts related to each axis so they can assess their transformation efforts accordingly. This paper uses these continuums to identify the quality implementation efforts conducted by HEIs through analyzing the continuums' related practices adopted within their environments and find out what should be done to get to the full transformation to Quality 4.0 within the higher education field.

An illustration of the 11 axes of the Quality 4.0 framework and their use in higher education is provided in the following sections, preceded by the description of the methodology applied.

2. Methodology

The authors followed in their literature review the PRISMA guidelines [21], as illustrated in Figure 2. Google Scholar, Web of Science, Scopus, Ebsco, and ProQuest databases were visited to identify literature related papers. The research has yielded (n = 1272) articles, and records after duplicates removed (n = 750) using Endnote X9. A total of 522 articles were excluded based on the exclusion criteria. Exclusion criteria are book chapters, papers that upon review were not related to the research questions, opinions, viewpoints, anecdotes, letters, and editorials. After excluding articles based on criteria, we included 110 articles that are studies in qualitative synthesis and studies in quantitative

synthesis. Inclusion criteria are written in English, peer-reviewed, and identify, describe, or use empirical and/or model graph.

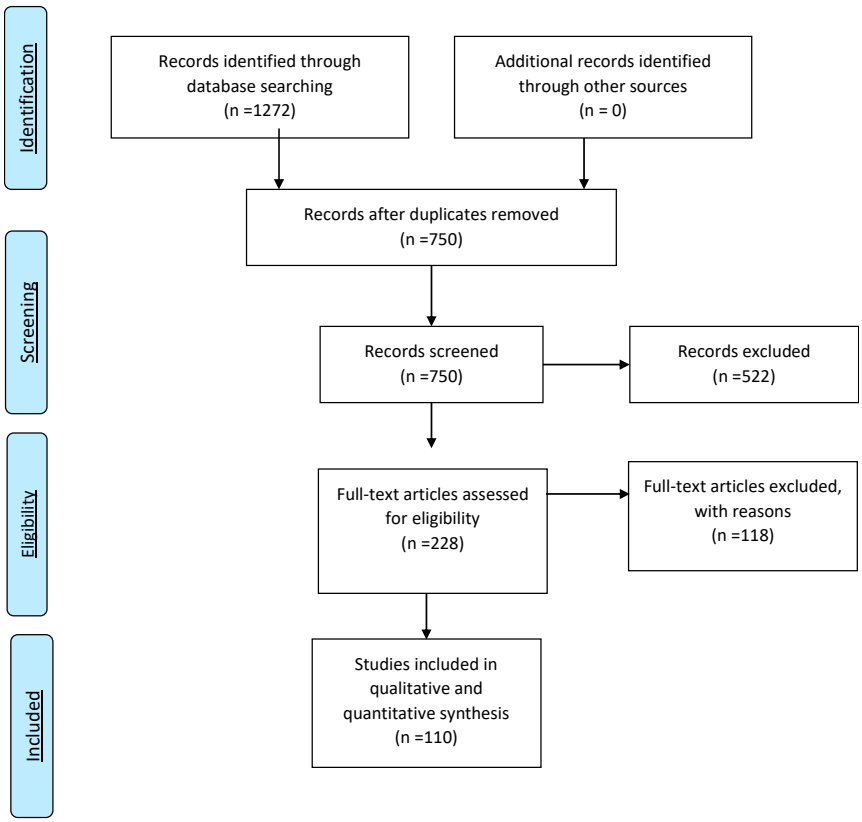

Figure 2. PRISMA literature review flowchart.

The analysis has been conducted for the selected papers of this study based on the keywords related to Quality 4.0 such as digital transformation, digitalization, disruptive technology, and enabling technology in HEIs. Considering the fact that various organizations, including HEIs, might desire to adopt Industry 4.0 technologies to improve the quality of their processes, products, and services [20], the authors considered analyzing HEIs' environments for practices related to the tools and concepts stated under the 11 axes of LNS Research Quality 4.0 framework instead of just being limited to quality related practices. Despite the fact that the level of implementing each of the 11 axes of the framework in HEIs deserves to be analyzed individually, this paper aims to explore their level of implementation collectively, by collecting sufficient axes' implementation evidence only. The literature review findings are presented in Section 3. The section is arranged according to the 11 axes to the LNS Research Quality 4.0 framework.

3. Quality 4.0 Axes

There are several frameworks in literature addressing the digital transformation required from organizations performing traditional quality practices to adopt Quality 4.0. For instance, Sader, Husti, and Daróczi [22] developed a framework to integrate Industry 4.0 new technologies with TQM best practices through reviewing the essential tools and features of Industry 4.0, analyzing TQM best practices, and exploring the opportunities of using Industry 4.0 in improving product quality and overall excellence of the organizations. The framework was based on the characteristics of quality control, quality assurance, and ISO seven principles of quality management (customer focus, leadership, engagement of people, process approach, improvement, evident-based decision making, and relationships management). However, the framework is general and lacks many detailed explanations, addressing model adoption challenges, and illustrating risk mitigation and data protection.

The second Quality 4.0 transformation framework available in literature focused on integrating information technology (IT) and operational technology (OT) through demonstrating the importance of connecting these technologies in enhancing the real-time use and analysis of Big Data [23]. However, in addition to lacking many definitions of many elements and methods required for IT–OT connection, the framework lacks the addressing of various essential aspects to adopting organizations such as compliance, leadership, and management systems.

The third Quality 4.0 transformation framework available in literature was developed by LNS Research [20] with the primary focus on enhancing the traditional quality methods and practices through having them digitalized to help organizations reach higher levels of efficiency. The framework helps organizations in their Quality 4.0 transformation journey assessing their digitization efforts in a set of defined axes while considering their impact on technology, processes, and people dimensions of the adopting organizations. Providing the traditional quality—Quality 4.0 spectrum of methods and practices applied in each axis while addressing the missing aspects of the previously illustrated frameworks makes the LNS Research framework more comprehensive and beneficial to organizations that seek the transformation.

Quality 4.0, as defined by Jacob [20], is the digitalization of quality management that impacts technology, processes, and people through the implementation of an 11-axes framework developed by LNS Research. The author states that Quality 4.0 provides technological advances in many fields that can be integrated with each other to give new insights, innovation, connectivity between individuals, and connectivity between machines and people. The emergence of highly capable and inexpensive sensors has ensured that people can capture more insights regarding the devices' performances. These devices might be manufacturing machinery, consumer goods, test equipment, transportation means, and wearable technologies.

The 11 axes forming the LNS Research Quality 4.0 framework, shown in Figure 3, are data, analytics, connectivity, collaboration, app development, scalability, management systems, compliance, culture, leadership, and competency. Each of the following subsections provides a description of one of the axes together with its traditional quality and Quality 4.0 related aspects while exploring their application within HEIs.

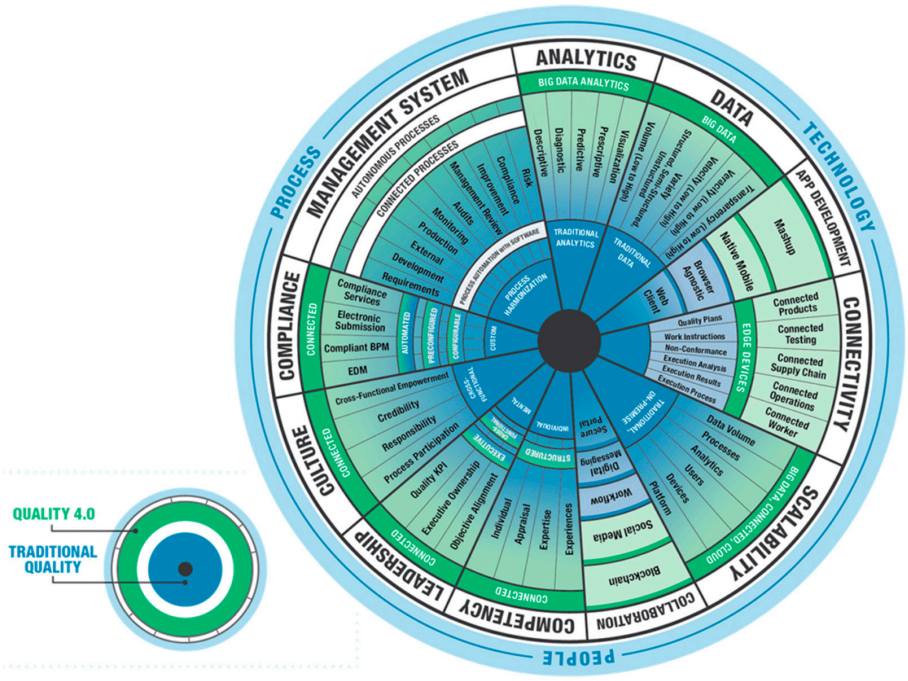

Figure 3. 11 axes of Quality 4.0. Reprint with permission from [20]. Copyright 2017 SAS.

3.1. Data

The availability of data is considered an essential element for an effective and accurate decision-making process in any organization. According to Jacob [20], data has five elements: volume, variety, velocity, veracity, and transparency. With the change in the characteristics of these elements, data is transformed from traditional data, used in traditional quality, to Big Data, used in Quality 4.0.

Data can come from a variety of sources depending on the nature and type of the organization, whether it be a manufacturing or service organization [24]. Until the last decade, the availability of data in some of the European HEIs remained a challenge. For instance, Bonaccorsi et al. [25] investigated the lack of data in 12 HEIs in 12 European countries and then provided strategies for collecting and validating data from different national sources. The investigation revealed data transparency related issues where individual higher institutions data were collected centrally by national statistical services in some of the studied countries while data were collected directly from individual universities in some of the other countries. In addition, the authors reported some issues concerning data quality and uniformity which affects the veracity element of data.

With the advancement of technology, Big Data has been used to solve many of the data related problems in HEIs. Big Data is defined as data that are too large to capture, process, and analyze using traditional computing techniques [26]. Initially, Big Data was described by three characteristics: volume (describing enormous quantities of data), velocity (created in real-time), and variety (consisting of structured, semi-structured, and unstructured data). Subsequently, other attributes were introduced to differentiate Big Data from small data. These attributes include volume, velocity, variety, exhaustivity, resolution and indexicality, relationality, extensionality, and scalability [27].

The applicability of Big Data in HEIs was examined by Chaurasia and Rosin [28]. By conducting semi-structured interviews with experts in information technology, administration, and academia in the higher education sector of India, the authors identified four main areas of Big Data applications. First, reporting and compliance which includes activities such as accreditation, transparency, and uniformity of information. Second, analysis and visualization, and it includes benchmarking and resource optimization. Third, security and risk mitigation, and it includes detecting network abuse and cyber regulation compliance. Fourth, predictive analytics which includes strategic planning and understanding student behavior. For transparency, the study stated that HEIs should consider data transparency by providing open and public access to data while maintaining data security and integrity.

Big Data has been investigated in HEIs for potential use in improving the teaching and learning process for students. Huda et al. [29] developed a model for implementing Big Data in HEIs using thematic analysis. The proposed model was based on a variety of data including structured data, such as students' records, and unstructured data, such as social networks interactions. The authors noted that the proposed model can be used to enhance decision makings, provide insights, explore knowledge, and optimize the learning process.

Moreover, a Big Data framework based on data elements of variety, veracity, and velocity was created for implementation in higher education [30]. The purpose of the proposed framework was to integrate data generation and acquisition (velocity), cleaning (veracity), storage management, analytics, visualization, and alerts. The data generation and acquisition included a variety of structured and unstructured data sources including student ID cards, social networks, and student information systems. The data storage and management system included a big database management system with capabilities such as real-time query optimization.

In addition, the implementation of Big Data with data warehouse to support the decision-making process in higher education was also explored [31]. In this study, the system was based on a combination of Hadoop (Big Data software) and RDMBS (Relational Database Management System). The proposed system facilitated disseminations of variety of data such as structured, semi-structed, and unstructured data (variety) across different devices and applications such as desktop applications, web, and smart phones. Moreover,

the proposed system was capable of dealing with various data quality issues (veracity) such as duplicated data, garbage data, and data inconsistency. Most of the respondents to the system applicability questionnaire reported that they had a good experience with the proposed system, and they stated that the proposed system had good customization and easy to use features.

The unstructured data collected through social media were also used by Agostino and Arnaboldi [32] to evaluate the performance of HEIs. The authors used data collected through Twitter to measure the effectiveness of higher education services in Italian universities. To collect the relevant data, interviews were conducted with general directors and staff responsible for managing social media in each university. Moreover, the Twitter database of each university was provided to the authors for further analysis. After that, the collected data were cleaned and classified to ensure the validity of the analysis. As a result, the authors developed four indicators of HEIs performance measures. First, a discriminant ratio for measuring the relative importance of a topic being discussed on Twitter non-official account. Second, a ratio for measuring the relative incidence of discussions raised by accounts that do not belong to the university. Third, a temporal distribution for measuring the distribution of tweets over a given period of time. Fourth, a polarity ratio for measuring user perception. This study showed how social media data can support top policymakers, staff, and faculty in planning and controlling the performance of universities.

According to Jacob [20], data has five elements: volume, variety, velocity, veracity, and transparency. Therefore, to transform into Quality 4.0 successfully, the HEIs need to adopt tools and techniques that advance the levels of the identified elements of the data axis which would lead to more availability and utilization of Big Data as compared to traditional data. As per the conducted literature review, variety, velocity, veracity, and transparency elements of data were investigated in HEIs. As most of the studies were using Big Data, it could be inferred that today's HEIs have a relatively large volume of data. However, many HEIs face significant challenges in making strategic decisions due to difficulty measuring and analyzing such volume of data [33]. In addition, the analyzed studies showed the availability of a variety of data (structured, semi-structured, and unstructured) and the existence of both veracity (duplicated data, garbage data, and data inconsistency) and transparency (by providing open and public access to data while maintaining data security and integrity) issues in today's HEIs. Moreover, the literature review revealed that HEIs used Big Data for the following applications, Figure 4:

- decision making,
- reporting and compliance,
- analysis and visualization,
- security and risk mitigation,
- predictive analysis,
- data generation and acquisition integration,
- data warehousing, and
- performance evaluation.

As a result, it can be inferred that the efforts exerted in adopting tools and techniques to advance the data axis elements of the Quality 4.0 transformation framework are assumed to be limited to individuals and specific processes instead of being adopted on an enterprise-level of today's HEIs. Although the reviewed studies discussed the data axis elements assuming the Big Data applicability as well as availability, the HEIs need the required physical and operational enablers to promote the level of data from traditional data to Big Data from both collection and properties perspectives.

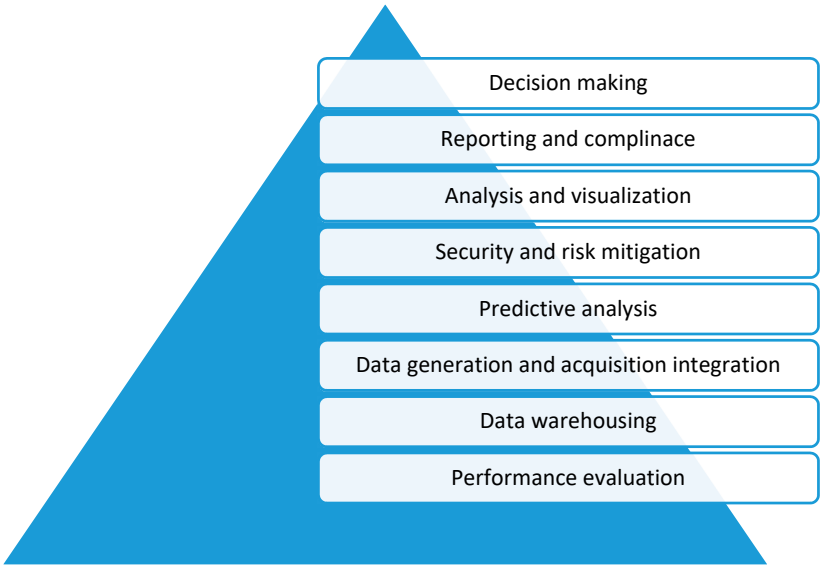

Figure 4. Applications of Big Data in HEIs.

3.2. Analytics

According to Jacob [20], data analytics are divided into four categories: descriptive, diagnostic, predictive, and prescriptive. Descriptive analytics include the most traditional measure of monitoring known or suspected correlations. Diagnostic analytics include metrics such as quality process cycle times to identify bottlenecks. Predictive analytics include metrics concerned with predicting the future, such as applying trend rules to SPC data and trend analysis. Prescriptive analytics are more advanced. They indicate failure and specify what should be done to address or change the outcome, and usually include some level of autonomous behavior. Analytics that are descriptive, diagnostic, and predictive in nature are performed in traditional quality settings using traditional data with possibilities of having more insights if machine learning and/or artificial intelligence (ML/AI) are applied. However, prescriptive analytics are exclusively conducted in ML/AI domain while considering the utilization of Big Data.

Many HEIs face significant challenges in making strategic decisions due to difficulty measuring and analyzing a large volume of data [33]. According to Nguyen, Gardner, and Sheridan [34], data analytics help HEIs understand the critical educational processes that help improve the performance of HEIs. The authors stated that there are three important ways to analyze data in HEIs:

- Learning Analytics: These analytics focus on the learning processes and the learners. This method collects learners' profiles and the teaching materials used and analyzes them using the descriptive analysis to improve the learning outcomes.
- Academic Analytics: This method helps faculty members know the most important factors that help improve students' levels and provide a clear insight into important practices for improving learning and teaching methods using descriptive and predictive analyses.
- Educational Data Mining: This method applies analytics to convert raw data into clear and useful knowledge to better understand students and educational systems.

According to Daniel [35], HEIs need data analytics to obtain results that help improve their performance. The author noted that there are opportunities to use advanced analytics types, such as predictive and prescriptive analytics, in HEIs. Predictive analytics help to identify future events and risks facing the organization through the results of descriptive analytics. Moreover, predictive analytics can enhance HEIs' ability to explore and uncover hidden data that are not clear in the descriptive analytics and identify the most important factors that affect students or employees, such as withdrawal from some courses or job dropout. As for the prescriptive analytics, these analyses help assess the institution's

current situation and choose the best way to face any risks based on predictive analytics. Prescriptive analytics combine descriptive and predictive analytics and build new strategies and methods to obtain the best solutions that improve the institution's performance. The author mentioned that despite the importance of these advanced analytics, there are many challenges facing HEIs when adopting them such as infrastructure, lack of scale and indicators for the quality of the data used in the analysis, lack of collaboration between departments, and a lack of transparency within HEIs.

The use of learning analytics (LA) has been widely investigated in HEIs. The main purpose of LA is to assess the behavior of the users in the teaching and learning domain to obtain new insights and provide relevant stakeholders with new techniques to assist with decision making and effective organizational processes and enhance the teaching and learning [36]. The authors Lias and Elias [37] defined LA as the process of measuring, collecting, analyzing, and reporting data related to the learning process to help understand and optimize the environment of the learning process. In this regard, Ifenthaler [38] used an LA benefits matrix to investigate the current capabilities of LA in HEIs and examined the importance of data sources to build an LA model. The study used an online survey to collect data about HEIs. The survey instrument consisted of many sections including staff capabilities for LA, barriers to implement LA, and benefits of LA to institutions among others. The study reported a lack of staff and technology to implement LA projects.

Among the techniques that have been widely used to analyze data is data mining. Data mining is considered as one of the descriptive analytics methods [39] and it refers to the techniques used to discover patterns and structures in large and complex data sets from data warehouse [40]. Popular data mining techniques in higher education include visualization, classification, clustering, and association analyses [41]. Data mining also can be used as a technique of predictive analytics. It was used to evaluate students' performance in a C++ course at one of the HEIs in the Middle East [42]. The study used predictive analytics employing: a classification tree, also known as decision tree, technique to study the main characteristics that may influence students' performance during the course. The occurrence of the developed model was measured, and the results indicated that the accuracy was not high because the collected sample was not sufficient to build a high-quality classification model.

Further, Natek and Zwilling [43] used predictive analytics to predict the success rate of students enrolled in one of the undergraduate courses using two data mining tools: Microsoft Excel and Weka. The data of 106 students were collected across three academic years, and then were validated, explored, cleaned, and transposed. The results showed a relatively high prediction success for both data mining tools and indicated that data mining techniques can be used for small data sets. Thus, the results obtained could benefit decision-makers in HEIs, such as professors and administrative staff, to predict the success of students, based on certain characteristics, and act accordingly.

The diagnostic aspect of analytics was also reviewed in the literature. For instance, data mining was used to assist decision-makers of the admission process at one of the HEIs in the Middle East [44]. In this study, a data mining model was developed using eight alternatives to filter students to satisfy the eligibility criteria. The proposed admission model consisted of five subsystems and was found to be a powerful technique in detecting the best admission method.

In summary, analytics are applied in many HEIs for a variety of reasons including:

- investigating LA capabilities in HEIs,
- examining the importance of data sources in building LA models,
- predicting students' performance, and
- discovering the best process operational methods (e.g., admission).

Nonetheless, when conducting various analytics, HEIs face many challenges related to infrastructure, scale and indicators of data quality, collaboration between departments, transparency within HEIs, and data volume required for selected analytics method. In addition, as stated by Jacob [20] for many organizations today, the literature has no suf-

ficient evidence of investigating the use of machine learning and artificial intelligence in HEIs as they are essential when performing prescriptive analytics and generating Big Data visualization. Consequently, it could be inferred that the HEIs use of analytics categories stated in Quality 4.0 LNS Research framework is limited to descriptive, diagnostic, and predicting ones.

3.3. Connectivity

According to Jacob [20], connectivity is the connection between IT and OT. Connecting business OT with business IT has been a common challenge for many organizations. According to the author, the IT includes the quality management (quality management system, quality processes, critical attributes/parameters, quality plan, and work instructions) while the OT includes operations management and quality execution (non-conformance, results and statistics, execution processes, and execution systems). The flow from IT to OT supports managing, planning, and improving operations management and quality execution activities while the flow from OT to IT supports executing, informing, and improving quality management activities. Therefore, not having an effective bridge between IT domain, where quality management resides, and OT domain, where quality execution resides, does not allow today's organizations to benefit from available data in design transfer and continuous improvement. Therefore, Quality 4.0 seeks through this axis to bridge this gap and ensure that people, data, and processes work together to reach effective connectivity. With Industry 4.0, the connectivity is transformed using inexpensive sensors to provide almost instantaneous feedback from connected people, processes, products, and edge devices.

Alexander [45] evaluated the contribution of IT in facilitating the learning process for students in Australia through analyzing communication and IT projects using questionnaires and case study approaches. The results revealed that most of the projects developed software related to one or more of the following: computer-based or aided learning, interactive multimedia, hypertext, or hypermedia. The results also indicated that staff IT enhances the quality of learning, improves the productivity and efficiency of learning and teaching, and facilitates access to learning. In addition, Alfahad [46] investigated the usefulness, efficiency, and efficacy of IT at a college level in HEIs of one of the Middle East countries. The students targeting questionnaire-based study indicated the students' use of electronic devices several times a week in addition to creating, reading, and sending email and instant messages.

In addition to IT, the implantation of enterprise resource planning (ERP) systems within the higher education context has been investigated. Soliman and Karia [47] reviewed the benefits of adopting ERP systems at universities in one of the Middle East countries. The authors stated that ERP systems help universities consolidate unrelated data and legacy systems. In addition, end-users have the ability to access data in real-time across different departments of an institution. ERP systems also improve internal communication, reduce or eliminate manual processes, and established a self-service environment for employees. Other benefits of adopting ERP systems in universities were also reported in the study. In another ERP systems related study, AlQashami and Heba [48] documented the critical success factors for implementing ERP systems in HEIs in one of the Middle East countries. These factors include:

- top management commitment and support,
- change management,
- project management,
- project leadership,
- implementation team,
- system customization,
- process reengineering,
- consultant selection and relationship,
- effective communication plan,

- active partnership with vendor,
- system selection,
- system integration, and
- post-implementation evaluation and management.

The enterprise quality management system (EQMS) has also been deployed in higher education. Kahveci and Taşkın [49] designed a model that integrated strategic management and process management to facilitate and support administrative tasks at one of the HEIs in Turkey. The developed model has three dimensions: strategic management, process management, and individual performance management. In addition, three phases were identified within each dimension. These phases are the target determination phase, the improvement planning phase, and the performance evaluation phase. The results showed that since the implementation of the model, the strategic performance indicators, such as the number of accredited programs, the rank of the university, and the level of satisfaction, have increased.

Based on this discussion, it can be realized that many HEIs have a potential set of benefits from using IT and OT including ERP systems and EQMS. Such benefits include consolidating unrelated data and legacy systems, ability to access data in real-time, establishing employees' self-service environment, and enhancing strategic performance indicators (e.g., number of accredited programs, university rank, and level of satisfaction). In addition, the reviewed literature showed evidence of IT contribution to learning processes through providing software solutions that helped enhancing quality of learning, improving productivity, facilitating access to learning, and efficiency of both teaching and learning. Moreover, IT has increased students' use of electronic devices for learning in addition to encouraging their use of communication means such as emails and instant messages. However, despite the benefits reported, the connectivity efforts within HEIs are assumed to be limited to connecting people and processes. Thus, products and edge devices connectivity need to be considered by HEIs to allow for adopting ML/AL related practices and ensure proper transformation to Quality 4.0.

3.4. Collaboration

According to Jacob [20], collaboration in performing quality management processes extends from being conducted through secure portals, digital messaging, and automated workflows to include social media and Blockchain as organizations transform from traditional quality to Quality 4.0. However, as the author stated, gains obtained from automated workflows and portals are not fully recognized yet since the number of organizations that adopt a core EQMS today is limited. The author also stated that the social media effect on collaboration is evident through the increased visibility of quality issues, which enabled direct customer assessment and improved competency and quality culture. The Blockchain has a potential collaboration role in quality practices in future especially in Supplier Quality Management (SQM) and traceability through providing visibility to both quality testing and product journey throughout the supply chain [20]. Through the profound transformation of collaboration by data, analytics, and connectivity, Jacob stated, leaders should consider its utilization to build a secure and reproducible data sharing strategies to satisfy such objectives as better competency, improved security, more streamlined oversight, and auditability.

Collaboration between employees at all levels within the organization is essential to achieve the quality gains and services [50]. This goes for any organization, and therefore, is just as important in HEIs to facilitate communication among faculty, staff, and students and improve educational processes. Digital means of communication such as emails, text messaging, social media apps, and Blockchain have been utilized to facilitate collaboration in higher education as well as in other industries.

Many studies explored the use of digital media in higher education. For instance, conducting a questionnaire-based study targeting faculty and staff, Jarvenpaa and Staples [51] explored the use of digital means of communication such as email and world

wide web for information sharing at a large university in Australia. The study investigated the factors that influence the adoption of electronic media as a means to share information across the university network. The factors considered in the study included information culture, organizational information ownership, propensity to share, task interdependence, computer comfort, and perceived characteristics of computer-based information. The results indicated that all the preceding factors have a significant influence on the use of electronic means of communication at the university. However, information culture and organizational information ownership negatively influenced the adoption of digital means of the communication while the remaining factors positively influenced the adoption of digital means of communication at the university.

In a similar study targeting graduate students of two courses in a public university in the South-Central USA, Gronseth and Hebert [52] investigated the use of a mobile instant messaging application (GroupMe) to facilitate course communications. The participants used many features of GroupMe such as tagging other users, liking posts and sharing photos. The study reported that GroupMe provided students with opportunities to engage in productive course activities and discussions.

Besides electronic media such as email and digital messages, social media has also been used by HEIs to collaborate and share information. Through conducting a survey-based study on colleges and universities in the USA, Canada, Australia and New Zealand, Reuben [53] documented social media platforms that are most widely used by HEIs. The investigated social media platforms included Facebook, Twitter, MySpace, YouTube, Flickr, Blogs, and del.icio.us. The results indicated that more than half of the participants reported that their college or university has an official Facebook page. Less than one third of the participants indicated that they have a presence on MySpace and two thirds stated that their college or university does not have a Twitter account. The majority of the participants stated that the marketing, communications, or public relations office are responsible for managing social media in their colleges or universities.

Tess [54] also reviewed the role of social media in HEIs. The study investigated the prevalence of social media platforms such as Facebook, Twitter, LinkedIn, and others in HEIs. The study reported that there is a lack of studies investigating the effectiveness of social media in terms of learning outcomes and student achievements. The study also reported that current research on the use of social media in higher education is limited to data reporting such as surveys, questionnaires and content analysis.

In addition to electronic communication means and social media, the potential adoption of Blockchain in higher education was also investigated. Blockchain is a decentralized transaction and data management technology that provides many features such as security, anonymity, and data integrity [55]. In Blockchain, goods, services, or transactions can be securely exchanged [56]. The application of Blockchain in higher education is still in its early stages, with most of the studies focused on the applicability of Blockchain in certain areas in HEIs. For example, Tapscott and Tapscott [57] investigated the potential application of Blockchain in HEIs. The study reported that Blockchain can be used in:

- transactions related to certificates, data, and money,
- increasing the security of students' records and profiles,
- human resources including students, staff, and other stakeholders,
- online access to libraries and copyright issues, and
- academic research publications.

The study also reported four recommendations for the successful use of Blockchain in the higher education context. These recommendations are defining the services and parties that will deal with and run the data, defining the key and method of crypto, building the smart contract process, and tracking proof-of-work.

According to Jacob [20], collaboration is one of the significant axes of Quality 4.0. Collaboration in recent years has changed within organizations and changed the way these organizations interact with their customers to gain their trust. Traditional collaboration tools such as text messaging, email, and world wide web have been used in HEIs for infor-

mation sharing and facilitating course communications. In addition, HEIs have started to use social media among students, faculty, and staff for collaboration and information sharing. Moreover, the effect of factors such as information culture, organizational information ownership, propensity to share, task interdependence, computer comfort, and perceived characteristics of computer-based information on digital means of communication was investigated while the effectiveness of social media in terms of learning outcomes and students' achievements is not yet fully investigated. Furthermore, the literature has explored areas where Blockchain can be applied in HEIs together with a set of recommendations for successful implementation. However, the observed usage of Blockchain in the explored areas are still in the early stages. Accordingly, the conducted literature review indicates that stakeholders in HEIs collaborate through using traditional collaboration means (secure portals, and digital messaging) in addition to using social media which represents a step forward towards transforming to Quality 4.0 level of collaboration. Nonetheless, current collaboration efforts lack research of automated workflows in HEIs and the adoption of Blockchain applications necessary for successful Quality 4.0 transformation.

3.5. App Development

The app development axis includes services provided via the web client, browser agnostic, mobile, native mobile, and mashup [20]. As organizations transform from traditional quality to Quality 4.0, they are expected to shift from using web-based apps to native mobile apps and mashups. Such shifts might go through the stage of optimizing web-based apps for large mobile devices prior to developing native mobile apps that operate in Android or iOS small devices (i.e., smartphones). The ability of organizations to develop their own mobile apps extends the shift even further especially for those apps that are developed to be used in a wide array of hardware other than smartphones. Having capabilities beyond merely being a simple web-based user interface, apps have a significant role in enhancing intelligence, participation, and adoption. They even become powerful enablers of efficiency, competency, and collaboration as they advance in providing the user with the suitable content, where needed, and in a form that suites his or her surroundings. These surroundings can even be properly sensed through wearable devices, transferred through augmented reality (AR), and simulated through virtual reality (VR).

Among the technologies that have been used in the early stages of app development is Web 2.0 technology. Web 2.0 is a process of utilizing the Web for social use to enable users to collaborate, participate in creating content, generate knowledge, and share information online [58]. Since the emergence of Web 2.0, research has reported its use in many universities. For instance, Bennett and his colleagues investigated the effect of using Web 2.0 on student engagement and learning outcomes in three Australian universities [59]. Six Web 2.0 implementation projects regarding different disciplines, class sizes, and year levels were conducted in the study. The projects included image sharing activities such as student-generated digital photo archiving and publishing/writing activities such as student reflective journal writing. The results showed that many students had little prior experience with Web 2.0, especially in the context of learning and teaching. However, students provided positive feedback about their participation in these projects and stated that these activities improved their knowledge sharing abilities.

With the advancement of technology and the development of operating systems, web browsers were developed to be agnostic. An agnostic browser of software is defined as being compatible with various operating systems [60]. An example of agnostic web-based applications currently used in the higher education context is Google Apps, which are compatible with various operating systems, namely Windows, Macintosh, UNIX, Linux, Solaris, and mobile devices [61]. The effectiveness of using Google Apps including Mail, Docs, Drive, Calendar, and Sites by IT staff in an academic institution was explored through a questionnaire [62]. The results indicated that two thirds of IT staff used Google Apps frequently. In addition, the study reported a significant difference between using Google Apps by IT staff alone and using Google Apps by IT staff and their students. Moreover,

the study reported many concerns regarding the use of Google Apps in higher education because of security breaches, data protection, and incomplete or insecure data deletion.

According to El-Senousy and Alquda [63], a variety of mashup tools such as Slide Share Flickr Photo, YouTube, etc. currently exist in HEIs environment within platforms such as Blackboard, a "virtual learning environment and course management system". These tools showed a positive impact in students' motivation of learning, faculty follow up of students, and improving learning methods. Blackboard is the most used platform in North America and Europe [64–66] and it has been investigated in several studies. For instance, a study on a large southwestern American university with students and instructors using Blackboard as a computer skill learning environment revealed that both instructors and students had positive experience using the platform since it accelerated learning, increased familiarity with technology, and enhanced course materials accessibility [64]. Another study in a Middle Eastern country showed less instructor familiarity with Blackboard despite their agreement with the significant impact of e-learning systems on the learning process [67]. A third study that compared students' perception about Blackboard and Moodle (an Australian Learning Management System) concluded that students see these platforms as a complement rather than a substitute for the face-to-face classes [68].

Evaluating the usage of smartphones and mobile apps in HEIs is witnessed through various studies in literature. For example, a study conducted at a Spanish distance education university, assessing the usefulness of utilizing smartphones and mobile apps for academic purposes, reported that are more students who feel them useful and satisfied than those who feel them useless and dissatisfied [69]. Another study reported the development of a mobile app to assist faculty, working at HEIs in a Middle Eastern country, in inserting and accessing sensitive data electronically [70]. The application was a dual language application designed for Android, iOS, and Windows operating systems. Users were satisfied with the app and were able to insert data such as students' grades in a secured environment. A third study investigated the effectiveness of using mobile apps in Indian HEIs revealed that mobile learning apps have a significant role in assessing students' learning, mobile apps were very useful when used in the higher education context, and students possess a high level of awareness regarding the use of mobile apps and the Internet for educational purposes [71].

In addition to mobile apps, VR has also been used by many universities to improve the learning experience. In Hong Kong, virtual reality (VR) and immersive virtual reality (IVR) were introduced in two undergraduate courses in a pharmacy college where students provided positive feedback about the experience [72].

In summary, it has been found that traditional tools, web client and browser agnostic applications, as well as advanced technological tools, mashups, native mobile apps, and VR, are adopted currently by HEIs in various ways. For instance, the use Web 2.0 for better students' engagement, improved learning outcomes, and enhanced knowledge sharing was reported, the effective use of such Google Apps as Mail, Docs, Drive, Calendar, and Sites was witnessed, the use of mashups to enhance students' motivation of learning, students' follow up, and learning methods was stated, the use of Blackboard and Moodle platforms was illustrated, mobile apps usage for inserting and accessing sensitive data and assisting students' learning was described, and the effect of VR in improving students' experience was demonstrated. Consequently, the presented mix of apps used in HEIs environment indicates a trend of adopting more mobile, native mobile, mashups, and VR for academic purposes. This trend is important for quality, which touches all aspects of management and operations, and will encompass data flows from multiple sources, an essential aspect for Quality 4.0 transformation.

3.6. Scalability

As per Jacob [20], scalability refers to the organization's ability to support data volume, devices, analytics, and users on a global scale. The author stated that more than one third of organizations consider having fragmented data sources and systems among the top

challenges in accomplishing quality targets. Therefore, any scalability level less than the global scale would hinder the effectiveness of both traditional quality and Quality 4.0 as well as the ability to synchronize processes, competencies, and best practices across the organization [20]. Among the technologies that have recently emerged and have the capabilities to achieve global scalability in organizations is cloud computing (CC). CC offers the organizations a wide range of service models such as Software as a Service (SaaS), Infrastructure as a Service (IaaS), and Platform as a Service (PaaS) [20]. Such services aid in upgrading the scalability level from being local, within organizations' premises, to being global, on the cloud, offering more processes and analytics capabilities in addition to more connectivity with organizations' partners [20].

Plummer and his colleagues defined CC as a technology that is capable of providing tremendously scalable IT services for external customers via Internet technologies [73]. CC is a new technology that has not been widely adopted in many organizations including HEIs. Most of the research on CC in higher education focuses on its benefits, risks and barriers, and roadmaps for potential implementation.

Al Rawajbeh and his colleagues highlighted the benefits of CC in higher education [74]. First, users such as students, faculty, and researchers can easily access services and other resources from any place and at any time with minimum effort and time. In addition, users are not required to download or install any software when using CC. Second, HEIs would recognize a large reduction in costs due to the optimal use of resources since CC users only pay for the resources they use. Third, since there is no software or hardware setup, the need for technical support staff would be limited as the occurrence of malfunctions and errors would be rare. Fourth, HEIs can use powerful and well-developed software with massive storage capacity, high-speed processing, and no complexity. As a result, students and faculty would be able to use virtual resources as needed. Finally, students and faculty can use the newest and most advanced software, applications, and methodologies to analyze and process Big Data and perform other education and research tasks.

The potential use of CC as an alternative to some IT services in HEIs has been explored. Mircea and Andreescu [75] developed a five-stage strategy for HEIs to adopt CC as an alternative to IT provision, management, and security. The first stage includes the development of a knowledge base awareness about CC. This can be accomplished through seminars, conferences, and discussions with suppliers and consulting subject matter experts. The second stage includes an evaluation of the current IT usage, structure, and needs as well as understanding the IT infrastructure of the university. The third stage involves the gradual transition to CC by testing a pilot project in the cloud, performing development and environment testing, and storing some data in the cloud. The fourth stage involves specifying the data, applications, functions, and processes of the university to use with CC. The final stage involves the implementation and management of the selected CC solution. The researchers in the study also created an architecture for adopting CC in a university.

As the most widely used by HEIs, Akande and Van Belle [76] investigated the use of SaaS in HEIs in South Africa. The authors reported many benefits of using SaaS in higher education including ease of access from any place and at any time; cost reduction; no software installation required by the institutions, ease of use, improved collaboration and knowledge sharing among different institutions, and scalability. The authors also reported some of the most widely used SaaS applications within the higher education sector including Microsoft Office 365, Salesforce.com, Google Big Query, New Relic, and Rackspace email. In addition, the authors stated that South African HEIs uses SaaS solutions to perform tasks such as admission, registration, enrollment, graduation, human resources, customer relationship management, supply chain, finances, payroll, asset management, and learning management system.

Given the benefits of CC and its wide range of applications, it is important to identify the factors that influence its adoption in HEIs. The cognitive factors that determine the adoption of CC among the faculty were investigated [77]. These factors include the attitude toward using CC, perceived privacy and security, perceived behavioral control,

the intention to use CC, and subjective norms. The results indicated that all factors have a significant positive influence on the faculty's adoption to use CC.

As per the conducted literature review, various aspects related to CC adoption in HEIs were studied. These aspects include CC benefits, CC potential use as an alternative of some IT services, CC adoption strategies, and factors determining CC adoption in HEIs. In addition, the literature showed that SaaS service model is the most widely used model among the three famous CC service models. Moreover, CC, through using SaaS model solutions, has been used to perform such tasks as admission, registration, enrollment, graduation, human resources, customer relationship management, supply chain, finances, payroll, asset management, and learning management system. As a result, it is evident that the use of CC in HEIs has been both considered and investigated which would have a positive impact on the organizations' capabilities regarding the scalability axis of Quality 4.0 framework and lead to have it exercised on a global scale.

3.7. Management System

The quality management System (QMS) is a group of procedures, policies, rules, and processes that are implemented to enhance organizations' productivity while providing products and services that meet or exceed customer expectations [78]. The QMS supports organizations to operate with stable processes and effective management activities to enhance the level of customer satisfaction [79]. The QMS consists of eight principles: system approach to management, mutually beneficial supplier relationships, customer focus, process management, leadership, factual approach to decision making, the involvement of people, and continuous improvement [80].

The management system of Quality 4.0 is required to be operated on an enterprise level instead of being operated as a standalone unintegrated system within the organization. This EQMS is considered the core of value chain creation within any organization since quality connects with all operational and managerial aspects of all processes in the value chain [20]. Therefore, as stated by Jacob [20], these processes should be harmonized and software automated before being connected to reach the autonomy level required to shift the high-value staff focus from mechanics of execution, in traditional quality practices, to innovation and improvement, in Quality 4.0. The author stated that despite the progress observed on the adoption, an integrated EQMS is only adopted by a little more than 10% of the adopting organizations. Such delay in adopting the quality technology that leads to systems' autonomy, a prerequisite for an integrated EQMS adoption, is due to having fragmented core processes in today's organizations. Thus, organizations should harmonize their quality processes in order to have them automated with software. Once such harmonization and automation take place on all quality processes of an organization, they can be connected to other systems and operations. Such connection would enhance collective analytics and learnings to improve system autonomy in a continuous manner.

Since the beginning of the twenty-first century, the QMS has become one of the essential systems applied in many organizations including some HEIs. Manatos et al. [81] state that the QMS represents an essential approach to dedicating the concept of quality throughout processes that exist at all levels of the organization. As the authors mentioned, by considering the integration of organizational level, processes level, and quality management level in the organization, the QMS helps an educational institution improves by linking organization's systems to quality management which results in aligning processes with requirements and standards and that leads to obtaining sustainable consistent results at all levels of the organization. O'Mahony and Garavan [82] found that senior leadership and sponsorship, stakeholder engagement, culture change management, and quality processes implementation (e.g., internal audit, benchmarking, etc.) are among the important factors that determine the effective implementation of QMS in HEIs. To lead the HEIs while implementing QMS within their premises, Spencer-Matthews [83] developed a framework for implementing QMS in an academic department in Australia. The study aimed to promote the cultural change and the awareness of continuous quality improve-

ment among the academic staff. The developed framework consisted of five steps: (1) reviewing the situation; (2) diagnosis; (3) planning a remedial action; (4) implementation; and (5) observation, reflection, and monitoring the change.

In addition to investigating QMS related aspects, the literature shows an evidence of investigating the implementation of ISO, TQM, 6σ, Lean, and LSS in HEIs. For instance, Kasperavičiūtė-Černiauskienė and Serafinas [84] investigated the ISO9001 standards accreditation in 25 HEIs of Lithuania. The authors found that the relative advantage, the adaptability, and the perceived compatibility of the ISO 9001 standard has a significant positive effect within HEIs. The authors stated that a correct understanding of the ISO 9001 standard is of great importance in its adoption. Kasperaviciute [85] analyzed the application of ISO9001 and the European Foundation for Quality Management Excellence Model (EFQM) in HEIS in various countries. The study aimed to understand HEIs' motivations for implementing ISO9001 and EFQM in addition to identifying the most important issues that HEIs face during implementation. The results indicated that main implementation drivers were stakeholder needs, increased competitiveness, and internal HEIs requirements. The issues that HEIs faced during implementation were weak support, difficulty interpreting the standard, and employee commitment.

The implementation of TQM in HEIs in the UK was investigated through a survey-based study about the TQM critical success factors influencing organizational performance and business excellence [86]. The results indicated the TQM implementation in a tiny number of the surveyed universities. In addition, the study indicated that the most important factor in promoting TQM in HEIs is the role of leadership. Moreover, the study showed that some of the barriers to implementing TQM include lack of commitment, insufficient knowledge, and fear of failure.

Moreover, a model for quality management consisting of three components: quality of design, quality of conformance, and quality of the performance was proposed for application in higher education [87]. These components were applied in three areas: operations, teaching, and research. In the operations area, the model was applied to improve the registration and student retention processes. In the teaching area, the model was applied to evaluate the teaching effectiveness and feedback by alumni and employers. In the research area, the model was used to assist creating a new pay system for research, manage the number of research publications, and satisfy the accreditation requirements.

Regrading 6σ implementation in HEIs, Bumjaid and Malik [88] assessed the implementation level and impact of 6σ in HEIs in one of the Middle Eastern countries. The results revealed that many of the analyzed institutions use 6σ for quality improvement to obtain such benefits as increasing the efficiency of processes, reducing costs, and reducing error rates.

According LeMahieu, Nordstrum, and Greco [89], Lean is related to the relationship between service providers and those who receive these services; both students and staff in the case of HEIs. Balzer, Francis, Krehbiel, and Shea [90] explored Lean implementation in HEIs through literature review. The study indicated that the application of Lean is of great value for improving administrative and academic processes. Despite the recognized Lean importance, the results indicated that there are still many HEIs planning to have it implemented in the future.

In another study, Kazancoglu and Ozkan-Ozen [91] examined the Lean philosophy to find the eight types of waste within HEIs. The study was conducted on a college level with five members of the Lean Transformation Committee. The results revealed that there are eight main wastes and 22 secondary wastes. Moreover, the study provided a model to guide the Lean transformation that helps improve various aspects of HEIs. Comm and Mathaisel [92] explored the level of application of Lean in 18 HEIs in the USA through a case study. The results revealed that Lean is practiced in HEIs, but at different levels. While some HEIs benefited from partial implementation of Lean related concepts, the success of applying Lean fully in other institutes was due to their leaders' consideration of full Lean implementation as a priority for their HEIs.

Fundamental challenges, barriers, and critical success factors (CSF) for introducing and developing LSS in HEIs context were investigated by Antony, Krishan, Cullen, and Kumar [93]. The study showed that solid top management support and commitment, horizontal and vertical effective communication, strategic and visionary leadership, organizational readiness development, implementation facilitation skills, and organizational culture are critical factors for LSS successful implementation in HEIs.

The literature also includes a model for deploying the EQMS in higher education [49]. The model is made of three dimensions that integrate strategic management and process management to facilitate and support the HEIs administrative tasks. The dimensions are strategic management, process management, and individual performance management. Each dimension includes phases of target determination, improvement planning, and performance evaluation. The model implementation resulted in increasing such HEIs strategic indicators as the university rank, level of satisfaction, and number of accredited programs.

The conducted literature review indicated the significant efforts of HEIs in managing quality within their premises. These efforts including implementing QMS, TQM, ISO, 6σ, Lean, LSS, and EQMS in HEIs where various benefits have been recognized. In addition, the importance of integrating HEIs organizational level, processes level, and quality management level to align processes with requirements and standards and enhance the HEIs' performance was recognized. Moreover, the critical success factors for effective QMS implementation in HEIs together with implementation framework were identified. Furthermore, a quality management model was proposed for application in operation, teaching, and research in HEIs. Despite all these stated efforts, the characteristics of the EQMS required in Quality 4.0 are still missing in HEIs and the integrated EQMs is not yet considered the core of value chain creation. In addition, the reviewed literature did not reflect the HEIs proper consideration of having connected harmonized processes automated with software required for system autonomy. Due to having fragmented core processes in today's HEIs, connection among various systems and operations and quality related processes is not yet achievable and that prevents enhancing collective analytics and learnings to improve system autonomous in a continuous manner.

3.8. Compliance

Compliance is among the important aspects that are assumed to be naturally addressed by quality practices conducted in organizations. This is because quality practices ensure that processes, products, and services comply with regulatory, industry, customer, and organizational requirements [20]. As stated by Jacob [20], technologies used to address requirements include custom, configurable, and pre-configurable code categories. The evolving scheme of these technologies considered increasing their flexibility in addressing requirements while reducing efforts and costs related to their deployments and upgrades. Quality 4.0 provides more opportunities to enhance compliance through automating and connecting related activities. Social collaboration, analytics, collaboration technologies, and integrated IT/OT data models are expected to play essential roles in enhancing compliance management and mitigating associated risks while transforming from traditional quality to Quality 4.0 compliance strategies.

Plummer et al. [73] studied HEIs regarding compliance with ISO 9000 in a questionnaire-based study on several HEIs. The study revealed that universities depend on two full-time employees, on average, to perform the annual assigned tasks required to maintain certification.

In Australia, a quality assurance framework was developed to assist Australian universities to comply with a set of standards [94]. The framework was based on the Tertiary Education Quality and Standards Agency (TEQSA), and it was created to accomplish a variety of tasks including registration of HEIs, course accreditation, assure quality against set standards, and decrease risks by overseeing the performance of the institutions against several measures. The framework consisted of three principles: the principle of regulatory necessity, the principle of reflecting risk, and the principle of proportionate regulation. Such framework motivates universities to adopt strong internal quality improvement processes

and prepare for the external compliance auditing visits as well as achieving the universities' educational objectives.

Amo, Alier, García-Peñalvo, Fonseca, and Casany [95] studied the learning management systems (LMSs) to understand aspects related to the personal data storage, processing, and security. The authors mentioned that recent years had witnessed many incidents of private data being used by HEIs service providers and sold to other organizations. These incidents caused distrust and fear among LMS users. The authors also mentioned that many HEIs still use custom code information system, which is challenging to update or add new rules due to the high cost and long time. Therefore, the author suggested that HEIs use automation technology or sophisticated systems to ensure compliance with laws and agreements.

As stated by Kumar and Van Hillegersberg [96], "ERP systems are configurable information systems packages that integrate information and information-based processes within and across functional areas in an organization." Soliman and Karia [97] mentioned that ERP systems help to raise the efficiency of service operations and competitiveness. The authors stated that despite the technological development and financial support that HEIs enjoy, they still poorly use these configurable information systems, especially in developing countries, due to facing significant challenges such as lack of end-user training, conflicts among users' departments, lack of top management commitment, and the attempt to link ERP systems to old systems.

In Vietnam, the QA system of HEIs and their compliance with the General Department of Educational Testing and Accreditation (GDETA) was explored [98]. The GDETA created a national accreditation system that includes regulations, standards, criteria, and procedures. Vietnamese QA instruments include auditing, accreditation, recognition, ranking, benchmarking, certification, licensing, program evaluation, student surveys, and verified data provision. The study found that the QA system is highly centralized, and compliance driven.

According to a conducted literature review, HEIs apply human-dependent methodologies to maintain compliance. In addition, HEIs utilize both custom code and configurable code information systems with update challenges related to the former one and poor utilization of the later one. In addition, challenges related to utilizing configurable information systems include lack of end-user training, conflicts among users' departments, lack of top management commitment, and the attempt to link the system to old systems. Moreover, there is a lack of research for the adoption of pre-configurations technologies and automated compliance in HEIs. Thus, today's HEIs are missing the Quality 4.0 level of automation and connectivity required to enhance compliance management through social collaboration, analytics, collaboration technologies, and integrated IT/OT models.

3.9. Culture

Culture refers to values, customs, beliefs, practices, and norms of the organization [99]. Many organizations suffer from not achieving their quality objectives due to lacking the appropriate culture of quality [20]. In addition, as quality is usually handled by a single department while other departments exercise limited participation and ownership, contribution of quality to strategic success of organizations is rarely observed by their cross-functional teams. Thus, as stated by Jacob [20], to foster the appropriate culture of quality, organizations need to promote a set of key elements on a cross-functional level. These elements are employees' participation, responsibility, credibility, and empowerment towards conducting tasks related to quality processes. However, due to having fragmented processes, fragmented data systems and sources, poor metrics and metric visibility, and regulatory burden, it is almost difficult, in traditional quality settings, to effectively promote these elements on cross-functional level. The effect of these aspects can be eliminated in Quality 4.0 and the proper culture of quality can be created through offering more connectivity, visibility, collaboration, and insights to quality processes as compared to traditional quality.

Many studies explored the role of culture in improving quality and workforce performance in HEIs. For example, the critical success factors of the business process reengineering in Malaysian HEIs were studied [100]. The study reported that quality culture was among the critical success factors to implement business process reengineering.

The relationship between quality, culture, and change following the introduction of QA systems in South Africa was investigated [101]. The study indicated that changing the organizational culture in HEIs is usually faced with individuals' resistance to change. The first form of resistance to change is habit which refers to the programmed responses that humans possess toward their environment. The second form of resistance to change is security, which refers to the fact that individuals resist any change that threatens their security. The third form of resistance to change is the economic factor that refers to the potential risk that may result from applying the change. The fourth form of resistance to change is the fear of the unknown which can be described by the replacement of known practices with uncertainty and ambiguity. The fifth form of resistance to change is selective information processing which refers to the fact that individuals filter and process only consistent information within their own belief system. Nonetheless, the study reported strategies to overcome the resistance to change and emphasized that changing the organizational culture is essential to developing an effective quality management system.

A framework of quality culture in higher education was developed [102]. The developed framework consisted of four significant elements, namely

- a structural element representing the quality system of an organization,
- enabling factors that assist organizations to adapt and incorporate quality practices into their culture,
- quality culture element which includes symbols, artifacts, and rituals of an organization, and
- transversal elements including communication, participation, and trust.

The study stressed the need for a quality culture to help HEIs improve quality of offered educational services.

The association between the quality culture and workforce performance HEIs was examined [103]. Specifically, the study examined the influence of quality culture on motivation, work performance, and job satisfaction of faculties in the Malaysian higher education sector. The results of this questionnaire-based study indicated that quality culture significantly influenced the motivation, work performance, and job satisfaction of the participants. The study showed a significant positive relationship between quality culture and workforce performance.

In another study, a review of the literature was conducted to determine the organizational elements that affect the development of quality culture in higher education and explore the working mechanisms of quality culture [104]. The study classified the organizational elements into three types: organizational structure elements, leadership elements, and communication elements. The organizational structure elements include managerial and psychological elements such as quality management systems and shared quality values. The leadership elements include leadership commitment and skills and resource allocation. The communication elements include sharing best practices across the organization and clear task requirements and responsibilities. In addition, the study reported the working mechanisms that may affect the behavior of the academic staff in adopting a quality culture. These working mechanisms include encouraging commitment and shared ownership of the academic staff and increasing the staff knowledge and empowerment.

As the literature includes several culture-change related studies, it is assumed that HEIs face significant challenges in developing the appropriate culture of quality. Several reported forms of individuals' resistance to change can be overcome through promoting employees' participation, responsibility, credibility, and empowerment towards conducting tasks related to quality processes on a cross-functional level throughout the organization. Although some of these elements are already identified as part of the working mechanisms to develop the appropriate culture of quality, there is no evidence of having them exercised

on a cross-functional level in today's HEIs due to the fact of having fragmented processes, fragmented data systems and sources, poor metrics and metric visibility, and regulatory burden. The effect of these aspects can be eliminated in Quality 4.0 and the proper culture of quality can be created through offering more connectivity, visibility, collaboration, and insights to quality processes as compared to traditional quality.

3.10. Leadership

Leaders play a significant role in any quality management and continuous improvement programs in facilitating the implementation of such programs and encouraging employees. Leadership is one of the most cited critical success factors for implementing TQM [105] and Six Sigma [106].

According to Jacob [20], as organizations transform from traditional quality to Quality 4.0, the leadership role of quality is shifting from being mental, handled by a single department in the organization, to being cross-functional, handled by several departments in the organization, to being on executive level, handled by quality leaders across organization. The author states that in the single department case, since the quality department is seen as a department acting as a quality police with unclear alignment to corporate success, there is a gap in both image and credibility between quality and quality function in many organizations. The author also states that quality is considered as a corporate value and many leaders today are intending to drive quality improvement using Industry 4.0 technology. In the meantime, leaders overlook the connection between corporate value and quality function as well as quality function and quality improvement by other functions and top management in the organization. Today's leadership of many organizations lacks considering quality as a priority, critical to customer satisfaction, and a function with clear and exciting role in delivering organizations' strategies [20]. To reduce the gap between quality as a function and quality as a corporate value in addition to establishing the connection between quality function and quality improvement intended through using Industry 4.0 technology, the author suggests that quality objectives should:

- be aligned with organizations' strategic objectives,
- guide initiatives' selection and resourcing process, and
- ensure that initiatives drive actions.

Quality team is expected to reset quality objectives to reposition its value proposition to other functions and top management. Quality 4.0 suggests the shift of quality ownership from quality-only to cross-functional to executive in order to enable effective corporate-wide quality built around a defined set of Key performance indicators (KPIs) to improve desired outcomes in a connected manner [20].

The higher education leadership role is investigated using the EFQM [107]. The EFQM consisted of three elements: people, policy and strategy, and partnerships and resources. The model identifies four criteria for the role of leadership in higher education as follows:

- Create the vision, mission, and values, and they are considered role models of cultural excellence,
- Participate in the development, continuous improvement, implementation, and organization management system,
- Communicate with customers, partners, and society representatives, and
- Motivate, support, and recognize the employees of the organization.

The critical success factors for effective leadership in HEIs in UK were explored in a questionnaire-based study [108]. The results indicated that only 7% of the participants strongly agree or agree that leadership practices are influenced by teaching quality assessment (TQA) and the research assessment exercise (RAE). Twelve percent of the participants strongly agree or agree that TQA and RAE influenced management and leadership practices concerning quality improvement policies and strategies. In addition, the participants ranked the importance of leadership second to policy, strategy, and processes.

Leadership may also contribute to the quality of services in higher education. The authors Trivellas and Dargenidou [109] investigated the influence of leadership on the quality of services provided at one of the HEIs in Greece. The results of this questionnaire-based study reported that different dimensions of service quality are associated with different leadership roles. For instance, the monitor leadership role is associated with ensuring compliance and the director leadership role is associated with identifying both objectives and expectations.

In Zimbabwe, the influence of institutional leadership on the quality of services in HEIs was examined [110]. The questionnaire-based study reported six main areas that need the attention of the university vice-chancellors to improve the quality of educational services. These areas include maintaining the quality of institutions, recruiting and retaining talented and experienced staff, implementing quality assurance methods to comply with regulatory requirements, financially supporting the university business and operations, improving university facilities, and providing effective leadership.

Kanji, Malek, and Tambi [86] examined the ability to assess TQM in HEIs in the UK. The study revealed that many HEIs leaders resist implementing quality plans due to their belief that quality increases bureaucracy.

In Quality 4.0, Jacob [20] emphasized that it is the role of quality leaders to lead quality across the organization, starting by redefining objectives and matching them with strategic objectives, extending the ownership of quality from a departmental level to cross-sectional level to the executive level, and utilizing quality Key Performance Indicators (KPI). Although many studies investigated leadership roles in higher education, this role as defined in Quality 4.0 is yet to be discussed and reported.

3.11. Competency

Enhancing employees' competencies takes various means as organizations transform from traditional quality to Quality 4.0. In either setting, as Jacob states [20], it is not wise for organizations to depend on employees to share knowledge among themselves. Thus, organizations should adopt proper means to enhance employees' competencies in structured approaches. In traditional quality, structured competency development approaches include LMSs to train competencies, training management to assess competency through certification, and Centers of Practice/ Centers of Excellence, to scale experience and develop expertise. The author also states that these structured approaches can further be enhanced by the following Quality 4.0 approaches:

- Experience: sharing experiences and lessons learned using social media,
- Expertise: developing new expertise through using ML/AI and benefiting from mashup apps and AR/VR,
- Appraisal: deploying connected worker schemes for detecting actions and guaranteeing compliance, competency, safety, and efficiency, and
- Management: encapsulating obtained learnings in LMSs and improving training delivery through providing VR-based experiences.

The training of academic staff in UK universities and colleges was investigated by developing a survey to identify the training courses and workshops that were conducted for three years period [111]. The questionnaire included questions on budgets, time allocation for training, course organization, advice on staff training, and strategies for enhancing motivation. The results indicated that all institutions provided some training during the study period specifically for new staff. The training topics included small group teaching, computer-based learning, personal tutoring, assessment, and examination.

Training of employees has a variety of effects in the higher education context. For instance, the effect of employee training along with employee empowerment and teamwork on organizational commitment was investigated [112]. The author designed a questionnaire sent to administrative and academic employees of public universities in Malaysia. The questionnaire training section included training opportunities to meet the changing needs, the applicability of on-the-job training, and training satisfaction. The results indicated

that employee training has a significant positive effect on organizational commitment, specifically job satisfaction. The study also revealed that employee empowerment and teamwork have significant positive effects on organizational commitment.

In addition to the role of training and empowerment, human resources management (HRM) strategies' effect on organizational engagement among HEI employees was also investigated. [113]. The organizational commitment was described in terms of three concepts: affective organizational commitment referring to the employee emotional attachment to the organization, continuance organizational commitment referring to the perceived cost associated with leaving the organization, and normative commitment referring to the employee feeling of obligation to remain with the organization. The study included variables such as employee participation, general training, job enrichment, wages, etc. The results indicated that significant and positive correlations were found between job enrichment and normative commitment and between wages and affective commitment. Moreover, a significant negative correlation between general training and normative commitment was observed.

In a similar study, the influence of HRM practices on employee retention in HEIs was investigated [114]. HRM practices selected in this study include employee empowerment, training and development, employee compensation, and appraisal system on employee retention. A questionnaire was designed, and a sample of academic staff including lecturers and tutors of a university was selected to collect relevant data. The results showed that training and development, appraisal system, and employee compensation have a significant influence on employee retention.

According to conducted literature review, today's HEIs use traditional activities such as training programs managed by the human resource department and reliance on individuals to share and exchange knowledge to improve employee competence. Therefore, competency approaches in Quality 4.0 can be useful in improving upon the traditional quality approaches. However, there is no evidence that any of these approaches have be adopted by HEIs so far.

4. Conclusions

4.1. Insights about HEIs Readiness for Quality 4.0 Transformation

Assessing the HEIs environments against the 11 axes of LNS Research Quality 4.0 has provided numerous insights about their readiness for Quality 4.0 transformation. The HEIs' efforts to adopt tools and techniques related to data axis elements are assumed to be limited to individuals and specific processes instead of being adopted on an enterprise level. In addition, it is necessary for HEIs to acquire both the physical and operational enablers needed to collect sets of data that satisfy Big Data characteristics of the five identified data elements of Quality 4.0. Such enablers include having the appropriate infrastructure, scale and indicators of data quality, collaboration among departments, and transparency within HEIs. Having data with stated characteristics together with enablers mentioned would assist the HEIs to generate data appropriate for conducting advanced analytics methods that are prescriptive in nature. Moreover, expanding the HEIs' connectivity efforts beyond people and processes to cover products and edge devices would provide almost real-time IT—OT connectivity and allow for deploying ML/AI related practices and ensure proper transformation to Quality 4.0.

Regarding the collaboration axis, HEIs are suggested to benefit from Blockchain applications together with the combination of tools currently adopted (secured portals, digital messaging, and social media) and with the consideration of extending their use to manage quality in addition to their operational practices of enhancing the student's learning process. For the app development axis, the conducted literature review showed that both traditional tools (web client and agnostic applications) and Quality 4.0 tools (mashups, native mobile, and VR) are currently adopted by HEIs with an increasing trend of adopting the latter tools for academic purposes in favor of the former ones. This trend is significant

for quality, which touches all aspects of management and operations, and will encompass data flows from multiple sources, an essential aspect for Quality 4.0 transformation.

The potential use of CC models (SaaS, IaaS, and PaaS) in performing various HEIs' tasks is evident in literature, which positively impacts their capabilities regarding the scalability axis of the Quality 4.0 framework and possibility exercised on a global scale soon. Regarding the quality management axis, despite the efforts conducted, the characteristics of the EQMS required in Quality 4.0 are still missing in HEIs. In addition, connection among various systems and operations and quality related processes is not yet achievable due to having fragmented core processes, which prevents the enhancing of collective analytics and learnings to improve system autonomous in a continuous manner.

For compliance axis, HEIs' utilization of custom code and configurable information systems in addition to human-dependent methodologies make the institutions miss the Quality 4.0 level of automation and connectivity required to enhance compliance management through social collaboration, analytics, collaboration technologies, and integrated IT/OT models. The literature review related to the culture axis of Quality 4.0 framework indicates significant challenges facing HEIs in developing the appropriate culture of quality. Thus, in order to have it developed, HEIs are required to promote staff participation, responsibility, credibility, and empowerment towards conducting tasks related to quality processes on a cross-functional level throughout the organization. However, as a prerequisite for these aspects' promotion, HEIs are required to overcome the challenges related to having fragmented processes, fragmented data systems and sources, poor metrics and metric visibility, and regulatory related issues. With Quality 4.0 offering more connectivity, visibility, collaboration, and insights, such challenges can be overcome, and the proper culture of quality can be created.

As HEIs, as well as other organization, might desire to adopt Industry 4.0 applications to improve the quality of their processes, the ownership of quality needs to be extended from a departmental level to cross-sectional level to the executive level while aligning quality related strategies and practices to HEIs' organizational strategies and operations. As a result, the leadership role required for Quality 4.0 needs to be exercised on an executive level with proper consideration of utilizing the appropriate set of KPIs that ensure the business-quality alignment. Finally, regarding the competency axis of the Quality 4.0 framework, the conducted literature review indicated that HEIs are missing all Quality 4.0 stated approaches related to this axis as they use the traditional ones. Thus, Quality 4.0 competency related approaches provide an opportunity for HEIs to enrich both skills and knowledge of their staff while benefitting from Industry 4.0 related applications.

4.2. The Transformation Roadmap to Quality 4.0 in HEIs

Should they desire to adopt the related tools and concepts, the transformation to Quality 4.0 in HEIs is better accomplished through the proposed roadmap of Assess, Recognize, Structure and Validate, as shown below in Figure 5. As presented in the figure, the transformation journey starts with assessing the maturity level of quality practices, currently adopted by HEIs, against the 11 axes of the LNS Research Quality 4.0 framework. The assessment results will form the basis for the next step of the proposed roadmap, Recognize, where HIEs will identify the potential areas to start Quality 4.0 transformation together with the transformation impact on their organizational performance. As the Recognize step might reveal the necessity of enhancing some traditional quality practices adopted currently in addition to adopting new Quality 4.0 related ones, the following step of the roadmap will include the structuring of the transformation initiatives required to improve traditional quality practices and deploy Quality 4.0 ones. Finally, HEIs' leaders need to validate the alignment of the structured quality initiatives with the institution's Quality 4.0 strategy, which aligns quality practices with institution's strategies.

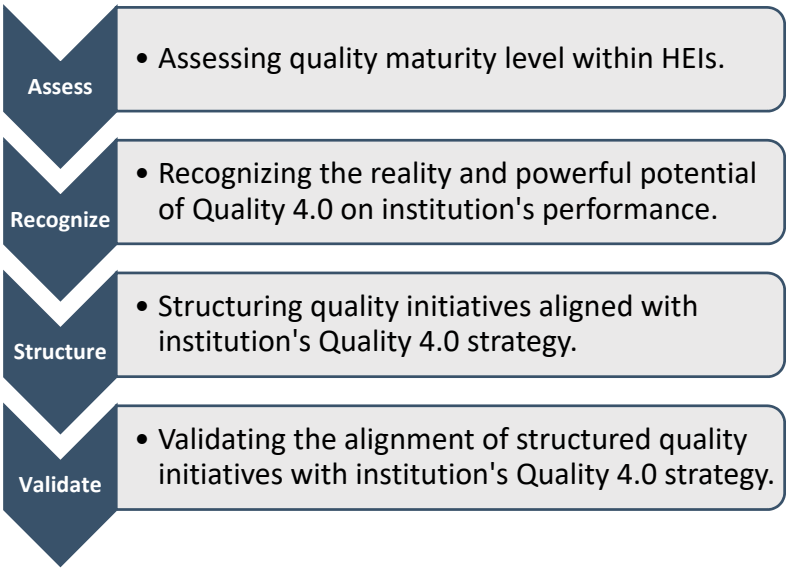

Figure 5. The transformation roadmap to Quality 4.0 in HEIs.

4.3. Limitations and Future Work

Authors were challenged to find studies that address the implications of adopting Industry 4.0 technology on specific quality practices in HEIs. Thus, the efforts performed in this study were directed towards analyzing HEIs environments for practices related to the tools and concepts stated under the 11 axes of LNS Research Quality 4.0 framework even if they are not in quality practices related setting. Such approach is justified with the assumption that many organizations are intending to drive quality improvement using Industry 4.0 technology at various processes performed within their premises. The useful insights obtained from the study encourages for further individual studies investigating the reasons behind the observed level of HEIs adoption of tools and concepts of each axis of the framework. Such individual studies will provide the foundation for developing a framework for assessing the maturity level of adopting quality with HEIs, the first step of the proposed transformation roadmap presented in Figure 5. This assessment framework will allow HEIs proceed with the remaining steps of the proposed roadmap and get the best out their efforts in the Quality 4.0 transformation process.

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