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Higher Education Quality Requirements in the Context of Industrial Management Digitalization: A Literature Review

Radu Aurelia-Georgiana[1], Loghin Raluca[2]*, Fleacă Elena[3]
[1]PhD student, National University of Science and Technology POLITEHNICA Bucharest, Faculty of Entrepreneurship, Engineering and Business Management, Departamentul Antreprenoriat și Management, aurelia.radu@stud.faima.upb.ro
[2]PhD student, National University of Science and Technology POLITEHNICA Bucharest, Faculty of Entrepreneurship, Engineering and Business Management, Departamentul Antreprenoriat și Management, raluca.loghin@upb.ro
[3]Professor, National University of Science and Technology POLITEHNICA Bucharest, Faculty of Entrepreneurship, Engineering and Business Management, Departamentul Antreprenoriat și Management, elena.fleaca@upb.ro
***raluca.loghin@upb.ro**

Abstract. In the current context of globalization, digitalization is a key strategic factor that involves the use of new technologies in organizations' internal processes to increase efficiency, improve the user experience, and transform business processes. This paper aims to analyze how industrial digitalization impacts quality requirements in higher education. Higher education institutions are in the process of adapting to the integration of technologies, while an increasing number of organizations are utilizing digital management systems, performance monitoring, and data-driven decision-making processes. Thus, the external environment imposes constraints on the adaptability of educational organizations to current dynamics. In this context, the quality of higher education could be defined in terms of its ability to align with industrial needs. The study is based on a review of the specialized literature, with articles focusing on the concepts of industrial management, digitalization, and quality in higher education institutions. The analysis shows that industrial management digitalization creates new quality requirements for higher education.
Keywords: Digitalization, Industrial management, Higher Education.

1. Introduction

The contemporary socio-economic landscape is marked by a progressive transition towards a digital economy that reshapes traditional organisational processes and forces organisations to find new equilibria in order to remain competitive (Poliakova et al., 2020). In this context, digitalization is not merely a buzzword but a central managerial concern for organisations that seek modernization and improved performance (Cazoni et al., 2023). The literature typically distinguishes between *digitization* as the technical conversion of analogue information into digital form, *digitalization* as the ensemble of socio technical manifestations and practices through which digital technologies are integrated at the level of individuals, organisations and society, and *digital transformation* as a broader strategic reconfiguration of business models through coordinated digitalization initiatives (Legner et al., 2017). Against this backdrop, companies increasingly implement digital management systems to optimise internal processes, monitor performance and support data driven decision making in order to remain

relevant in a dynamic and competitive environment (Emeh et al., 2024). Digital management, supported by technologies such as artificial intelligence, blockchain and the Internet of Things, now extends beyond industry to domains such as education (digital campuses), government (digital governance) and health (digital health), where it underpins core organisational functions (Han et al., 2024).

Higher education institutions (HEIs), as complex organisations embedded in this digital economy, are undergoing their own internal digital transformation of management processes, including academic administration, quality assurance, human resources and financial management (Carmo et al., 2025; Fernández et al., 2023). At the same time, the emergence of Industry 4.0 and Quality 4.0 has stimulated a growing body of research on how data-driven, analytics-intensive quality paradigms can be transferred and adapted to higher education contexts (Alzahrani et al., 2021; Kumar et al., 2025; Lodi et al., 2022). Recent contributions argue that integrating Industry 4.0 technologies and Quality 4.0 principles into university management can strengthen internal quality management systems and support the transition towards "Higher Education 4.0", characterised by personalised learning, efficiency and closer alignment with labour market needs (Abnoulgid et al., 2025; Kumar et al., 2025). However, many existing quality assurance frameworks in HEIs remain partially anchored in traditional, document-based and ex-post evaluation logics, which are not fully aligned with the continuous, data-driven quality approaches observed in digitalised industrial management (Alzahrani et al., 2021; Lodi et al., 2022). This situation creates an instability: while industrial management increasingly relies on integrated digital systems, real-time performance monitoring and Quality 4.0 practices, internal university management and quality systems often adapt more slowly and according to different logics, risking misalignment with the quality expectations emerging from a digitalised industrial environment (Abnoulgid et al., 2025; Lodi et al., 2022).

This situation creates an instability: while industrial management increasingly relies on integrated digital systems, real-time performance monitoring and Quality 4.0 practices, internal university management and quality systems often adapt more slowly and according to different institutional logics, as HEIs are still in the process of developing the organizational, technological and managerial capacities required for digital transformation and Quality 4.0 adoption (Alzahrani et al., 2021; Carmo et al., 2025; Fernández et al., 2023). This risks misalignment with the quality expectations emerging from a digitalised industrial environment, particularly as recent literature calls for the integration of Industry 4.0 technologies and Quality 4.0 principles into higher education quality management (Abnoulgid et al., 2025; Kumar et al., 2025; Lodi et al., 2022). Starting from this gap, the paper is guided by the following research question: What quality requirements for higher education institutions can be derived from the digitalization of industrial management?

The purpose of this paper is to analyse how the digitalization of industrial management reshapes expectations regarding quality and to identify the resulting quality requirements for higher education institutions, with a specific focus on the adaptation of internal university management processes. To this end, the study conducts a literature review on industrial management digitalization, digital management in universities and Quality 4.0 in higher education. Furthermore, it synthesizes previous findings to clarify the advantages and limitations of current approaches and to propose a set of quality requirements that can guide the digital transformation of internal management in HEIs

2. Materials and methods

The study is based on a structured narrative literature review supported by thematic analysis. This approach was selected because the aim of the paper is to identify and synthesize the main quality requirements for higher education institutions in the context of industrial management digitalization, rather than to quantify publication trends. The review focuses on the relationship between industrial management digitalization, Quality 4.0, digital transformation in higher education and the evolution of quality assurance practices in universities.

The research process involved the selection and analysis of scientific and professional sources relevant to the main concepts addressed in the paper: industrial management digitalization, Industry 4.0, Quality 4.0, quality assurance in higher education, digitalization of higher education institutions and

university-industry alignment. The literature search was conducted using academic databases and scientific search platforms relevant to management, education, digital transformation and quality assurance. The main keywords and keyword combinations used in the search included: “industrial management digitalization”, “Industry 4.0”, “Quality 4.0”, “higher education quality”, “quality assurance in higher education”, “digital transformation in higher education”, “University 4.0”, “Education 4.0”, “learning analytics”, “digital competencies” and “university-industry collaboration”.

The selected sources were analysed according to their thematic relevance to the objective of the paper. The inclusion criteria covered studies addressing industrial digitalization and managerial transformation, Quality 4.0 and digital quality management, existing quality frameworks in higher education, digital transformation in universities and the relationship between higher education institutions and digitally transformed industrial environments. Sources were excluded when they were not directly related to industrial digitalization, quality management, higher education quality or university-industry alignment.

The analysis was carried out thematically. The selected literature was grouped into five analytical directions corresponding to the structure of the results section: (i) industrial management digitalization and quality logic; (ii) quality in higher education, with emphasis on existing frameworks and limitations; (iii) digitalization in higher education institutions; (iv) transferable elements from industrial management digitalization to higher education; and (v) emerging quality requirements for higher education in the context of industrial management digitalization. This structure allowed the study to move from the broader transformation of industrial management towards the identification of specific quality requirements for higher education institutions operating in a digitally transformed environment.

3. Results and discussions

This section presents and interprets the results of the literature review on industrial management digitalization, Quality 4.0 and higher education. It is structured in five subsections that move from describing how Industry 4.0 reshapes quality logic in industrial organizations to analysing how HE quality frameworks and internal digitalization trajectories (LMS, SIS, analytics, University 4.0) respond to these changes, and, finally, to deriving a set of emerging quality requirements for HEIs.

3.1. Industrial management digitalization and quality logic

Industrial management digitalization can be defined as the systematic integration of digital technologies into the planning, coordination and control of organizational processes across value chains, encompassing both manufacturing and service activities (Matt et al., 2015). In the literature, this transformation is closely associated with the Industry 4.0 paradigm, which connects physical assets and organizational workflows with digital infrastructures such as the Industrial Internet of Things (IIoT), cyber physical systems, cloud platforms, big data analytics and artificial intelligence (Sisinni et al., 2018). Digitalization thus affects not only isolated production operations, but the broader management system, including how information is collected, shared and used to design processes, allocate resources and orchestrate inter organizational relationships along supply and service networks (Tronvoll et al., 2020).

A central implication repeatedly highlighted by recent studies is the shift towards data driven and real time management at strategic, tactical and operational levels (Nouinou et al., 2023; Rosin et al., 2022). Managers gain continuous access to performance indicators from multiple units (e.g. production lines, logistics, maintenance, customer service) which enables earlier detection of deviations, quicker responses to disruptions and more frequent adjustment of plans and priorities (Matt et al., 2023). Digital platforms and dashboards support cross functional coordination between operations, quality, IT and supply chain management, reducing information asymmetries and supporting more integrated decision making (Tronvoll et al., 2020). At the same time, the literature on Industry 4.0 implementation and organizational change shows that these benefits depend on organizational capabilities, including managerial roles that support digital transformation, the development of data-driven decision-making

capabilities, and deliberate strategies to manage employee resistance through communication, participation and training (Brodeur et al., 2022; Ito et al., 2021; Nayernia et al., 2022).

Within this broader transformation of management, the underlying logic of quality is also being reconfigured. The Quality 4.0 literature describes a transition from traditional inspection- and control-oriented approaches towards digitally enabled, proactive and predictive quality management, in which real-time data collection, advanced analytics and integrated information systems are used to detect abnormal patterns, prevent non-conformities, optimize processes and enhance customer value (Broday, 2022; Bousdekis et al., 2023; Dias et al., 2022; Liu et al., 2023). Conceptualizations of Quality 4.0 capture this evolution as the fusion of established quality philosophies (e.g. TQM, ISO-based systems, continuous improvement) with Industry 4.0 technologies, emphasizing connectivity, transparency, stakeholder orientation and the alignment of people, processes and technology in a digitally supported quality culture (Chiarini & Kumar, 2022; Liu et al., 2023). This digitally enabled quality logic in industrial management constitutes an important reference point for understanding which quality related expectations and management practices may migrate towards higher education institutions operating in increasingly data driven and interconnected environments.

3.2. Quality in higher education: existing frameworks and limitations

Quality in higher education has been conceptualized through several well-known perspectives - quality as excellence, as perfection or consistency, as fitness for purpose, as value for money and as transformative development - each linked to particular sets of stakeholders and policy priorities (Harvey & Green, 1993; Harvey, 1999). Building on these conceptualizations, quality assurance (QA) regimes in higher education typically combine internal mechanisms - such as institutional self-evaluation, programme review, staff appraisal, and student feedback - with external mechanisms of accreditation, audit and evaluation conducted by national or regional QA agencies (Kayyali, 2023; Kayyali, 2024). External quality assurance and accreditation processes are usually standards-based and evidence-based, involving the evaluation or audit of higher education institutions or programmes by specialised quality assurance or accreditation bodies (European Commission et al., 2024). In the European Higher Education Area, the ESG 2015 remain the common reference framework for both internal and external quality assurance, covering institutional policies, programme design and monitoring, student-centred learning, information management, public information and continuous improvement (ENQA et al., 2015). Although these evaluations are external, they also shape internal university management, because institutions must translate external standards into everyday governance arrangements, reporting routines, stakeholder feedback mechanisms and quality improvement practices. In this respect, internal quality assurance becomes a managerial mechanism through which universities maintain standards, coordinate institutional actors and adapt their processes to changing educational conditions, including digital and hybrid learning environments (ENQA et al., 2015; Loukkola & Zhang, 2010; Benson et al., 2024).

Despite this relatively dense architecture of internal and external QA, the literature points to a series of limitations that become particularly visible when these frameworks are compared with the digitally intensive, data-driven quality logic emerging in industrial management.

First, many QA systems remain largely document- and event-based, relying on self-evaluation reports, external reviews, site visits and retrospective evidence, which can reinforce compliance-oriented practices rather than continuous institutional learning and rapid improvement (Harvey & Newton, 2004; Krooi et al., 2024). This limitation becomes more visible in increasingly digital learning environments, where learning platforms and institutional information systems generate data that could support more continuous monitoring, earlier identification of problems and faster adjustment of educational processes through big data and business intelligence dashboards (Sorour & Atkins, 2024).

Second, responsibilities for quality are often mediated through formal QA structures and procedures rather than being fully embedded across everyday academic and managerial practices, which may encourage bureaucratic compliance rather than an integrated quality culture oriented towards iterative

improvement; recent literature therefore conceptualizes internal QA through the alignment of purpose, people and process, rather than as a separate administrative function (Krooi et al., 2024).

Third, although QA systems generate and collect substantial information on programmes, students, graduates and stakeholders, this information is often used mainly for formal reporting and accreditation documentation, rather than being systematically integrated into internal decision-making, resource allocation, programme management and strategic planning.

Collectively, these limitations point to a structural tension: higher education QA frameworks remain strongly anchored in periodic review, documentation and standardization, while industrial quality management increasingly operates with continuous, integrated, predictive and data-rich quality logics associated with Quality 4.0; in higher education, this raises the need to integrate Industry 4.0 technologies, data-driven decision-making and the alignment of people, processes and technology into quality management practices (Abnoulgid et al., 2025; Liu et al., 2023).

3.3. Digitalization in higher education institutions

The literature on Education 4.0, Higher Education 4.0 and University 4.0 shows that universities are undergoing a deep internal digital transformation, with digital technologies progressively embedded in both educational and managerial processes (Bonfield et al., 2020; Fernández et al., 2023). Learning Management Systems, Student Information Systems, CRM tools and institutional analytics platforms increasingly function as core digital infrastructures for organizing teaching, assessment, student support, communication and institutional services, enabling greater connectivity, flexibility and personalization of learning, as well as more data-informed institutional management (Carmo et al., 2025). At institutional level, this transformation emphasizes not only technology adoption, but also the reconfiguration of governance, organizational processes and decision-making towards more digitally supported and adaptive forms of university management (Fernández et al., 2023; Carmo et al., 2025).

Within this broader trajectory, several studies highlight four families of technologies as particularly prominent for the internal digitalization of higher education institutions: cloud computing, Internet of Things (IoT), big data and artificial intelligence (Carmo et al., 2025). Cloud infrastructures provide scalable and relatively low-cost technological backbones that support virtualized computing resources, remote access to systems and the integration of multiple institutional platforms, thereby sustaining operational continuity and facilitating collaboration among academic and administrative units (Carmo et al., 2025; Ülker, 2025). Concrete solutions such as Microsoft Education Cloud (Office 365 for education), IBM Cloud Academy and HP cloud platforms offer universities integrated services for communication, content creation and storage, student data management and knowledge management, directly underpinning internal management processes (Ülker, 2025). IoT applications extend from smart classrooms to student housing and campus infrastructures, enabling real time monitoring and control of energy, environmental conditions and security systems, while also supporting more individualized teaching through sensor-based information on student presence and engagement (Carmo et al., 2025). Big data and analytics tools (e.g. Tableau, Power BI) are used to monitor student performance, optimize resource allocation and manage risks, and predictive analytics help institutional leaders anticipate future needs, evaluate policy effects and support vulnerable groups, contributing to evidence based strategic and operational decision making (Abnoulgid et al., 2025; Veldkamp, 2021). Finally, artificial intelligence is increasingly deployed to digitalize internal processes such as staff performance monitoring, timetable and room scheduling, resource planning and automated responses to routine queries, while also offering analytical insights into labour market trends that can inform curricular adjustments (Vonitsanos et al., 2024).

At the same time, recent work on Quality 4.0 in higher education suggests that institutional quality models and QA practices are still in transition and only partially aligned with this accelerating internal digitalization. While universities collect large volumes of high frequency data through LMS, SIS and analytics tools, many QA frameworks remain structured around periodic self-evaluation, accreditation cycles and document-based compliance with external standards, making limited use of the continuous data streams now available for real time monitoring and improvement (Kayyali, 2023). Moreover,

responsibilities for quality are often concentrated in specialized units, which may not yet be fully integrated with digital transformation initiatives led by IT, teaching and learning centers or institutional research offices, thereby reinforcing the gap between data rich operational environments and relatively static quality regimes (Harvey, 1999; Lodi et al., 2022; Alzahrani et al., 2021). This coexistence of advanced digital infrastructures and only partially digitalized quality models creates precisely the kind of "instability" that opens a space for transferring principles and practices from industrial digital quality logics, such as Quality 4.0, into the internal quality management of higher education institutions, which will be explored in the following section.

3.4. Transferable elements from industrial management digitalization to higher education

The emerging literature on Quality 4.0 in industry suggests that, beneath sector-specific technologies, there is a set of management principles that can be meaningfully translated into the higher education context. In industrial settings, Quality 4.0 is described as the digitalization and extension of established quality management approaches, including TQM and quality assurance systems, through Industry 4.0 technologies such as connectivity, automation, artificial intelligence, big data and advanced analytics, with the aim of creating more agile, data-driven, predictive and customer-oriented quality processes (Chiarini & Kumar, 2022; Dias et al., 2022; Liu et al., 2023). The question for higher education is therefore not whether universities should mimic industrial tools, but which underlying principles of digital quality management can inform the redesign of internal quality systems in ways that respect the specific mission, values and governance of HEIs. Recent work on Quality 4.0 in higher education supports this transfer-oriented perspective by examining how Industry 4.0 technologies can be integrated into higher education quality management practices without reducing universities to industrial organizations (Abnoulgid et al., 2025).

A first transferable principle is data-driven and built-in quality. In industrial Quality 4.0, digital quality transformation shifts organizations from periodic, document-based control towards continuous, data-enabled monitoring, predictive analysis and proactive prevention of defects and non-conformities, embedding quality into everyday processes rather than treating it as an external inspection function (Bousdekis et al., 2023; Liu et al., 2023). This implies integrated digital quality management systems in which quality-relevant data flow across functions and decision-making levels, supporting both operational control and strategic quality improvement (Liu et al., 2023). Transposed to higher education, this principle suggests reorienting internal quality assurance from a focus on episodic self-evaluation reports and accreditation files towards the systematic use of data from LMS, SIS, institutional analytics and quality dashboards for continuous monitoring of student learning, progression, engagement and support services (Abnoulgid et al., 2025; Sorour & Atkins, 2024). In such a model, quality becomes increasingly "built in" to teaching, advising and administrative routines through dashboards, alerts and feedback loops, rather than being primarily documented after the fact for external review.

A second element concerns the use of maturity models and staged implementation frameworks. Industrial Quality 4.0 frameworks conceptualize digital quality transformation along multiple dimensions and use maturity assessment to diagnose the current state of implementation, identify gaps and define staged improvement priorities (Zulqarnain et al., 2022). Recent work has adapted this logic directly to higher education by proposing Quality 4.0 assurance frameworks and maturity scales for HEIs, in which practices related to data, analytics, connectivity, culture, leadership, compliance, people, processes and technology are assessed to locate institutions on multi-level maturity scales (Alzahrani et al., 2025; Lodi et al., 2022). This suggests that HE internal quality management can benefit from maturity-based approaches that diagnose the current state of digital quality practices, identify strengths and weaknesses across process–people–technology dimensions and provide staged roadmaps for integrating digital tools into QA in ways that are realistic for each institutional context and quality culture (Alzahrani et al., 2025; Verschueren et al., 2023).

A third transferable principle is continuous improvement supported by digital feedback loops. In industrial contexts, Quality 4.0 builds on traditional continuous improvement philosophies, but extends them through digital tools, analytics and connected information systems that support more systematic

monitoring, prediction and improvement of quality processes (Liu et al., 2023). For higher education, this points towards redesigning internal QA processes so that feedback from students, staff, digital traces of learning and external stakeholders is not only collected for periodic reviews, but integrated into shorter, iterative cycles of improvement at course, programme and institutional level. Such an adaptation requires dashboards, analytics, feedback loops and clearer responsibilities for interpreting digital evidence and translating it into pedagogical, administrative and organizational adjustments (Abnoulgid et al., 2025; Sorour & Atkins, 2024).

Finally, client or stakeholder orientation - a core principle of quality management - is directly transferable, with appropriate reinterpretation, to higher education. In higher education, stakeholders are multiple and contested, including students, academic staff, employers, alumni, professional bodies and society more broadly. The transferable principle is therefore not a narrow customer logic, but the systematic integration of stakeholder data and feedback into institutional decision-making. Examples include linking graduate tracking data and employer surveys to curriculum review, using granular student progression and engagement data to redesign support services, and involving external partners in programme development and micro-credentials aligned with emerging labour market needs (Loukkola & Zhang, 2010; Martin, 2018). In combination, these transferable elements (data-driven and built-in quality, maturity-based development, digitally supported continuous improvement and stakeholder-oriented design) provide a conceptual repertoire for rethinking internal quality management in higher education under the conditions of industrial management digitalization.

3.5. Emerging quality requirements for higher education in the context of industrial management digitalization

Taken together, the evidence on industrial management digitalization, existing quality frameworks in higher education, the internal digital transformation of universities and the transferable elements of Quality 4.0 points to a set of emerging quality requirements that higher education institutions must address in order to remain aligned with digitally transformed industrial environments. These requirements do not imply that universities should reproduce industrial quality management models. Rather, they suggest that the underlying principles of digital quality management (data-driven monitoring, built-in quality, maturity-based development, continuous improvement and stakeholder orientation) can inform the redesign of internal university quality systems in ways that respect the specific mission, values and governance structures of higher education institutions.

These requirements are synthesized in Figure 1, which presents a conceptual scheme of the main directions through which digital quality management principles can be translated into the higher education context. The figure shows that the emerging requirements are not separate or isolated elements, but interconnected dimensions of internal university organization. They concern the way universities govern quality, integrate data into QA systems, embed improvement into everyday processes, develop staff competencies and quality culture, and engage stakeholders in a responsible and evidence-based manner.

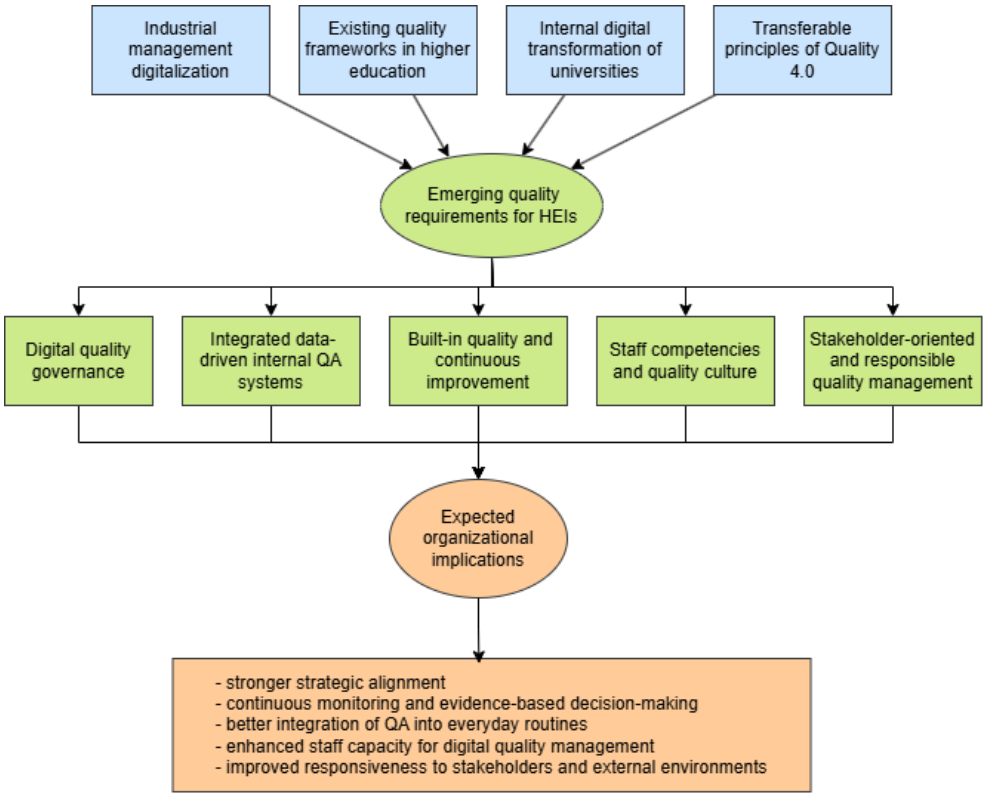

Figure 1. Conceptual scheme of emerging quality requirements for HEIs
Authors' own elaboration based on the synthesis of the literature reviewed in Sections 3.1–3.4.

As illustrated in Figure 1, the transition towards digitally informed quality management requires HEIs to move beyond periodic compliance and documentation towards a more continuous, integrated and data-informed model of internal quality management. Thus, quality becomes a shared institutional capability supported by digital infrastructures, clear responsibilities, iterative improvement routines and responsible stakeholder engagement.

At the governance level, a first requirement is the development of institutional capacity for digital quality governance. HEIs need explicit digital quality strategies that connect institutional missions with the logics of Industry 4.0, Higher Education 4.0 and Quality 4.0. This means linking digital transformation plans, quality policies, data governance arrangements and external engagement into a coherent institutional framework. In this perspective, quality is no longer treated only as a separate compliance function, but as an integral dimension of institutional strategy, with clear objectives regarding how digital infrastructures, analytics and Quality 4.0 principles will be used to enhance educational quality, institutional performance and responsiveness to external stakeholders (Abnoulgid et al., 2025; Fernández et al., 2023; Liu et al., 2023).

A second requirement concerns the development of integrated, data-driven internal quality assurance systems. Traditional QA in higher education has often relied on periodic self-evaluation reports, accreditation files and retrospective indicators. In contrast, the logic of Quality 4.0 points towards more continuous and data-enabled forms of quality management. For universities, this implies connecting learning management systems, student information systems, institutional analytics, student feedback mechanisms, graduate tracking data and administrative information systems. Such integration allows quality-related data to support continuous monitoring, early identification of problems and evidence-based improvement, rather than being used mainly for reporting and external review (Abnoulgid et al., 2025; Sorour & Atkins, 2024).

A third requirement is the redesign of QA around built-in quality and continuous improvement. Quality should not be documented only after the fact for accreditation purposes; it should be embedded into everyday academic and administrative routines. This requires dashboards, feedback loops, regular evidence-based discussions and clearly assigned responsibilities for acting on data at course, programme, faculty and institutional levels. In this way, internal QA becomes less dependent on episodic evaluation events and more closely connected to the ongoing management of teaching, advising, student support, programme review and administrative processes (Abnoulgid et al., 2025; Liu et al., 2023).

A fourth requirement is the development of staff competencies and quality culture. Digital quality systems cannot produce improvement if academic, administrative and managerial staff lack the capacity to interpret and use the data they generate. HEIs therefore need to strengthen digital competencies, data literacy and collaborative routines that enable staff to translate analytics, quality indicators and stakeholder feedback into pedagogical, administrative and strategic decisions (Abnoulgid et al., 2025; Fattah, 2024). This requirement also implies a cultural shift from quality as external control towards quality as shared responsibility and institutional learning, in line with broader understandings of internal quality assurance as an integrated alignment of purposes, people and processes (Krooi et al., 2024).

A fifth requirement concerns stakeholder-oriented and responsible quality management. In industrial Quality 4.0, customer orientation is central, but in higher education this principle must be reinterpreted through the multiplicity of stakeholders: students, academic staff, graduates, employers, professional bodies, public authorities and society. HEIs need digital mechanisms for collecting, analysing and using stakeholder feedback in programme review, support service redesign and strategic planning. At the same time, the increasing use of learning analytics, artificial intelligence, dashboards and integrated data systems requires safeguards related to privacy, cybersecurity, transparency, responsible data use and the prevention of algorithmic bias (Loukkola & Zhang, 2010; Martin, 2018).

Overall, these requirements indicate a shift from QA as periodic compliance towards quality as a continuous, data-informed and institution-wide management capability. In the context of industrial management digitalization, the relevance of Quality 4.0 for higher education lies not in the direct transfer of industrial tools, but in the adaptation of its underlying principles to the organizational, educational and societal mission of universities.

4. Conclusions

This study has shown that the digitalization of industrial management reshapes both managerial logics and quality expectations, creating direct implications for higher education institutions that seek to remain relevant in digitally transformed environments. The review indicates that the integration of technologies such as artificial intelligence, big data, cloud computing and analytics contributes not only to the transformation of organizational processes, but also to more informed, faster and more integrated decision-making. In this context, higher education institutions are increasingly required to adapt their internal quality management systems in response to the requirements generated by Industry 4.0, Higher Education 4.0 and the broader transition towards data-driven and continuously improved organizational models.

The study identifies five emerging quality requirements for higher education institutions. First, universities need to develop digital quality governance, by connecting institutional strategy, digital transformation plans, quality policies, data governance and external engagement into a coherent framework. Second, they need integrated data-driven internal quality assurance systems, able to combine information from learning management systems, student information systems, institutional analytics, feedback mechanisms and graduate tracking systems. Third, quality needs to become built into everyday academic and administrative routines, through continuous improvement mechanisms, feedback loops, dashboards and clearly assigned responsibilities for acting on evidence. Fourth, higher education institutions need to strengthen staff competencies and quality culture, especially digital skills, data literacy and the capacity to use quality-related evidence in pedagogical, administrative and strategic decisions. Fifth, universities need to develop stakeholder-oriented and responsible quality management,

integrating feedback from students, graduates, employers, professional bodies and other actors while ensuring ethical, secure and transparent use of data.

From an originality and value perspective, the study contributes to the literature by explicitly connecting industrial management digitalization with emerging quality requirements for higher education institutions, rather than treating these two fields as separate debates. While previous studies have examined Quality 4.0, university digitalization or higher education quality assurance independently, the present paper brings them together into a single analytical framework focused on the adaptation of internal university management. Its added value lies in showing that Quality 4.0 should not be transferred mechanically from industry to universities, but selectively translated into the higher education context through principles such as digital quality governance, data-driven QA, built-in quality, continuous improvement, staff data literacy and stakeholder-oriented quality management.

The findings also underline that digital transformation should not be reduced to technology adoption alone. Successful adaptation requires organizational and cultural change, including clearer responsibilities for data use, stronger analytical capabilities, better coordination between academic and administrative units, and more systematic integration of evidence into decision-making. In this sense, the future of quality in higher education depends increasingly on the capacity of universities to integrate digital infrastructures, managerial agility, ethical data governance and quality culture into a common internal governance logic.

The main limitation of the research lies in its theoretical character, as the study is based on a structured narrative review of the literature rather than on empirical investigation. As a result, the paper identifies and interprets emerging patterns, concepts and transferable requirements, but it does not empirically test how these requirements operate across different institutional contexts, national systems or university types. Another limitation is that the reviewed bodies of literature (industrial digitalization, Quality 4.0, higher education digitalization and higher education QA) do not evolve at the same pace or with the same conceptual consistency. Future research could address these limitations through empirical case studies, comparative multi-institutional analyses or mixed-method designs that validate the practical applicability of the proposed quality requirements in real university management settings.

The practical implications of the study are relevant for several categories of actors. For university leaders and quality managers, the results suggest the need to redesign internal quality systems around digital quality governance, integrated data architectures, continuous monitoring, iterative feedback loops and responsible data use. For academic and administrative units, the findings indicate that QA should become more embedded in everyday teaching, student support, programme management and institutional routines, rather than remaining concentrated in periodic accreditation exercises. For policymakers and quality assurance agencies, the study points to the importance of revising quality frameworks so that they better capture digitally enabled processes, stakeholder feedback integration, staff data literacy and the growing role of evidence-based governance in higher education.

Author contributions:

- Conceptualization: R.A.G. and L.R.;
- Methodology: R.A.G. and L.R.;
- Investigation: R.A.G and L.R..;
- Writing - original draft: R.A.G.;
- Writing - review and editing: R.A.G., L.R. and E.F.;
- Supervision: E.F.

The authors contributed equally to this work. R.A.G. and L.R. were involved in the conceptualization, methodology, investigation, and preparation of the original draft of the manuscript. All authors (R.A.G., L.R., and E.F.) contributed to the review and editing process. E.F. provided supervision throughout the research.

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