Institutional Readiness for Digital Transformation in Engineering Education: A Systematic Literature Review

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ABSTRACT

Digital transformation has become a strategic priority in higher education, particularly in engineering education, where technological innovation, Industry 4.0, and digital competencies are essential for preparing future professionals. However, the successful implementation of digital transformation initiatives depends largely on an institution's readiness to adapt organizationally, technologically, and strategically. This systematic literature review (SLR) aimed to examine institutional readiness for digital transformation in engineering education by identifying the factors that influence readiness, the challenges and barriers encountered, and the strategies, frameworks, and best practices proposed to enhance readiness. Guided by the PRISMA 2020 framework and Kitchenham Guidelines, the review employed a systematic search using Lens.org, with studies screened and managed through Zotero and Rayyan.ai. From an initial pool of 5,636 records, a rigorous screening, eligibility assessment, and quality evaluation process resulted in 19 studies being included in the final qualitative synthesis. Data were analyzed using thematic analysis, narrative synthesis, and bibliometric analysis. The findings revealed that institutional readiness is primarily influenced by leadership and governance, technological infrastructure, faculty competencies and digital literacy, organizational culture, and institutional support. The review also identified key barriers, including infrastructure limitations, digital competency gaps, resistance to change, resource constraints, and organizational challenges. Furthermore, effective strategies for enhancing readiness include digital leadership and strategic planning, faculty development and capacity building, readiness assessment frameworks, technology integration, and stakeholder collaboration. Overall, the findings suggest that institutional readiness for digital transformation is a multidimensional construct that requires the alignment of technological, organizational, human, and strategic dimensions. This review contributes to the growing body of knowledge on digital transformation in engineering education and provides evidence-based insights for policymakers, institutional leaders, educators, and researchers seeking to strengthen institutional preparedness and support sustainable digital transformation initiatives.

Keywords: institutional readiness, digital transformation, engineering education, organizational readiness, technology integration, education 4.0, higher education institutions

INTRODUCTION

The rapid advancement of digital technologies has significantly transformed the landscape of higher education, reshaping how institutions deliver instruction, conduct research, manage operations, and engage with stakeholders. Digital transformation extends beyond the mere adoption of technological tools; it represents a comprehensive organizational change that integrates digital technologies into institutional processes, culture, governance, and strategic decision-making. In the context of higher education, digital transformation has become a critical component in enhancing educational quality, institutional competitiveness, operational efficiency, and

the development of future-ready graduates. For engineering education in particular, digital transformation is increasingly important as engineering disciplines are closely associated with technological innovation, Industry 4.0, automation, artificial intelligence, data analytics, and smart systems. Consequently, higher education institutions offering engineering programs are expected to continuously adapt their structures, policies, resources, and pedagogical approaches to meet the evolving demands of the digital era.

Although digital transformation initiatives had already been gradually implemented in many educational institutions prior to 2020, their adoption accelerated dramatically during the COVID-19 pandemic. The global health crisis forced universities and colleges to rapidly transition from traditional face-to-face instruction to various forms of technology-mediated learning. Educational institutions that previously viewed digital technologies as supplementary tools suddenly relied on them as the primary means of sustaining academic operations. This unprecedented disruption highlighted the importance of institutional readiness in responding to technological change. Institutions with established digital infrastructures, supportive leadership, strategic planning mechanisms, and adequate technological resources were generally better positioned to adapt to the challenges brought about by the pandemic. Conversely, institutions with limited digital capabilities encountered significant difficulties related to infrastructure, faculty preparedness, student accessibility, policy implementation, and organizational coordination. As a result, the pandemic served as a catalyst that exposed both the strengths and weaknesses of higher education institutions regarding their readiness for digital transformation.

Within engineering education, the challenges associated with digital transformation are particularly complex. Engineering programs traditionally rely on laboratory activities, hands-on experimentation, collaborative design projects, technical simulations, and industry-based experiences that are often difficult to replicate in virtual environments. As institutions increasingly integrate digital technologies into engineering curricula, the need for organizational readiness becomes more critical. Institutional readiness encompasses various dimensions, including leadership commitment, governance structures, technological infrastructure, organizational culture, strategic vision, faculty competencies, financial resources, change management practices, and stakeholder engagement. These factors collectively influence an institution's capacity to successfully implement and sustain digital transformation initiatives. Without adequate readiness, digital transformation efforts may face resistance, inefficiencies, resource constraints, and implementation failures that can negatively affect educational outcomes and institutional performance.

Recent scholarly discussions have emphasized that digital transformation is not solely a technological issue but also an organizational and strategic concern. Successful transformation requires institutions to align their technological investments with organizational goals, human resource capabilities, and long-term development plans. Moreover, engineering education institutions must address numerous challenges and barriers, including limited funding, resistance to change, insufficient digital competencies, cybersecurity concerns, infrastructure limitations, and disparities in access to technology. At the same time, various strategies, frameworks, and best practices have been proposed in the literature to strengthen institutional readiness and facilitate sustainable digital transformation. These include the development of digital leadership capacities, strategic planning frameworks, faculty development programs, institutional support mechanisms, technology governance models, and continuous quality improvement systems.

Despite the growing body of research on digital transformation in higher education, the literature remains fragmented regarding the specific organizational factors that influence institutional readiness within engineering education. Existing studies often focus on individual technological interventions, teaching strategies, or student outcomes, while relatively fewer studies provide a comprehensive examination of the organizational dimensions that enable successful digital transformation. Consequently, there is a need to systematically synthesize existing evidence to better understand the factors, challenges, and strategies associated with institutional readiness for digital transformation in engineering education.

This systematic literature review seeks to address this gap by examining the existing body of knowledge related to institutional readiness for digital transformation in engineering education. Specifically, the review aims to answer the following research questions:

RQ1:What factors influence institutional readiness for digital transformation in engineering education?

RQ2: What challenges and barriers are reported in the literature regarding institutional readiness for digital transformation in engineering education?

RQ3: What strategies, frameworks, and best practices have been proposed to enhance institutional readiness for digital transformation in engineering education?

By addressing these research questions, this review aims to provide a comprehensive understanding of the critical determinants of institutional readiness, synthesize evidence on the barriers encountered during digital transformation initiatives, and identify effective strategies and frameworks that can support engineering education institutions in navigating the complexities of digital change. The findings of this review are expected to contribute to both theory and practice by informing policymakers, institutional leaders, educators, and researchers seeking to strengthen the digital transformation capabilities of engineering education institutions.

METHODOLOGY

Review Protocol

This study adopts a Systematic Literature Review (SLR) as its research design to systematically identify, evaluate, and synthesize existing literature on institutional readiness for digital transformation in engineering education. The review is guided by the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework and the Kitchenham Guidelines, which provide a structured and rigorous methodology for conducting and reporting the review. PRISMA 2020 ensures transparency and reproducibility through the stages of identification, screening, eligibility, and inclusion of studies, while the Kitchenham Guidelines support the planning, conducting, and reporting phases of the review. The integration of these frameworks ensures a comprehensive, systematic, and reliable synthesis of evidence related to the factors, challenges, and strategies associated with institutional readiness for digital transformation in engineering education.

Research Questions

The research questions for this systematic literature review were formulated based on the identified gap in the literature concerning institutional readiness for digital transformation in engineering education. While previous studies have extensively examined digital technologies, online learning, and technology adoption in higher education, the existing body of knowledge remains fragmented regarding the organizational factors that enable engineering education institutions to successfully undertake and sustain digital transformation initiatives.

To address this gap, the study sought to develop research questions that would provide a comprehensive understanding of the current state of research and generate insights that can support future institutional practices and policy development.

To ensure a systematic and focused formulation process, the research questions were developed using the PICOC (Population, Intervention, Comparison, Outcome, and Context) framework. Table 1 presents the PICOC framework used to guide the formulation of the research questions for this systematic literature review.

The framework defines the scope of the study by identifying the target population, the phenomenon of interest, the expected outcomes, and the contextual setting of the review. By clearly specifying these elements, the PICOC framework ensures that the research questions remain focused, relevant, and aligned with the objective of synthesizing evidence on institutional readiness for digital transformation in engineering education.

Table 1 PICOC Framework Used for the Formulation of Research Questions

PICOC Element	Specification
Population (P)	Engineering education institutions, engineering programs, engineering faculties, engineering departments, higher education institutions offering engineering education
Intervention (I)	Institutional readiness for digital transformation, digital transformation initiatives, digital technologies adoption, digitalization strategies, technology integration in education
Comparison (C)	Not mandatory for this review; may include comparisons between institutions with varying levels of digital readiness, digital maturity, or transformation implementation
Outcome (O)	Readiness factors, organizational factors, technological factors, human resource factors, barriers, challenges, success factors, frameworks, models, assessment tools, and best practices for digital transformation
Context (C)	Engineering education in higher education institutions, universities, colleges, and technical institutions undergoing or planning digital transformation

Guided by these PICOC elements, the following research questions were formulated:

RQ1: What factors influence institutional readiness for digital transformation in engineering education?

RQ2: What challenges and barriers are reported in the literature regarding institutional readiness for digital transformation in engineering education?

RQ3: What strategies, frameworks, and best practices have been proposed to enhance institutional readiness for digital transformation in engineering education?

These research questions provide a structured foundation for systematically exploring and synthesizing the existing literature. The findings derived from these questions are expected to contribute to a deeper understanding of the determinants of institutional readiness, the obstacles encountered during digital transformation, and the effective approaches that can support engineering education institutions in achieving sustainable digital transformation.

To ensure that the research questions are aligned with the scope and objectives of the study, each question was mapped to the corresponding elements of the PICOC framework. This alignment establishes a clear connection between the target population, the phenomenon of interest, the expected outcomes, and the contextual setting of the review. Table 2 presents the alignment of the research questions with the PICOC framework, demonstrating how each question contributes to the systematic investigation of institutional readiness for digital transformation in engineering education.

Table 2 Alignment of Research Questions with the PICOC Framework

Research Question	Population	Intervention	Outcome	Context
RQ1: What factors influence institutional readiness for digital transformation in engineering education?	Engineering education institutions	Institutional readiness for digital transformation	Readiness factors (organizational, technological, human resource)	Higher education engineering programs
RQ2: What challenges and barriers are reported in the literature regarding institutional	Engineering education institutions	Institutional readiness for	Challenges and barriers	Higher education

readiness for digital transformation in engineering education?		digital transformation		engineering programs
RQ3: What strategies, frameworks, and best practices have been proposed to enhance institutional readiness for digital transformation in engineering education?	Engineering education institutions	Institutional readiness for digital transformation	Strategies, frameworks, models, assessment tools, and best practices	Higher education engineering programs

Search Strategy

The literature search was conducted using Lens.org, an open-access scholarly discovery platform that provides extensive coverage of academic publications and related research outputs. Lens.org was selected because it aggregates and harmonizes scholarly records from major sources such as ScienceDirect, Springer Nature Link, Crossref, PubMed, OpenAlex, and other scholarly repositories, enabling comprehensive literature retrieval from a single platform. The database includes various types of scholarly works relevant to systematic literature reviews, including peer-reviewed journal articles, conference proceedings, books, book chapters, review articles, and other academic publications. Furthermore, Lens.org offers advanced search capabilities, citation analysis, filtering options, and structured search functions that support the systematic identification and evaluation of relevant studies. These features make Lens.org a suitable and reliable source for conducting a systematic literature review on institutional readiness for digital transformation in engineering education.

The search strategy was developed based on the PICOC framework and the key concepts derived from the research questions, namely institutional readiness, digital transformation, and engineering education. Boolean operators (AND, OR) were used to combine keywords and related terms to ensure a comprehensive and focused retrieval of relevant literature. The search was conducted in two stages using a main search string and an expanded search string. The main search string was designed to retrieve studies directly related to institutional readiness for digital transformation in engineering education, while the expanded search string incorporated additional synonymous and related terms, such as organizational readiness, digital readiness, technology integration, Industry 4.0, Education 4.0, barriers, determinants, frameworks, and best practices. This approach broadened the search coverage and minimized the possibility of overlooking relevant studies that used alternative terminologies. The main and expanded search strings used in this study are presented in Table 3.

To support the review process, Zoter**o** was used for reference management, organization of retrieved records, and duplicate removal. The resulting records were subsequently imported into Rayyan.ai to facilitate the title, abstract, and full-text screening processes based on the predefined inclusion and exclusion criteria. The combined use of Lens.org, Zotero, and Rayyan.ai provided a systematic and transparent workflow for literature retrieval, study management, screening, and final study selection.

Table 3 Main and Expanded Search Strings Used in the Literature Search

Search Type	Search String
Main Search String	("institutional readiness" OR "organizational readiness") AND ("digital transformation" OR "digitalization") AND ("engineering education" OR "engineering programs") AND (factors OR challenges OR barriers OR strategies OR frameworks OR "best practices")
Expanded Search String	("institutional readiness" OR "organizational readiness" OR "readiness for change" OR "digital readiness" OR "technology readiness" OR "institutional capacity" OR "organizational capacity" OR "organizational preparedness") AND ("digital transformation" OR digitalization OR digitization OR "educational transformation" OR "technology integration" OR "digital innovation" OR "Industry 4.0" OR "Education 4.0" OR "digital adoption") AND

	("engineering education" OR "engineering programs" OR "engineering curriculum" OR "engineering students" OR "engineering instruction" OR STEM OR "technology education" OR "engineering and technology education") AND (factors OR determinants OR drivers OR enablers OR influences OR challenges OR barriers OR obstacles OR constraints OR issues OR strategies OR frameworks OR models OR interventions OR "best practices" OR recommendations)

Inclusion and Exclusion Criteria

The establishment of inclusion and exclusion criteria is a critical stage in conducting a systematic literature review, as it ensures that the study selection process is transparent, consistent, and aligned with the objectives of the review. In accordance with the Kitchenham Guidelines and the PRISMA 2020 framework, predefined criteria were developed prior to the screening process to guide the identification and selection of relevant studies. These criteria were derived from the research questions and the PICOC framework to ensure that the retrieved literature adequately addressed the factors influencing institutional readiness, the challenges and barriers encountered, and the strategies and frameworks proposed for digital transformation in engineering education.

The inclusion criteria were designed to identify studies that provide relevant evidence on institutional readiness for digital transformation within engineering and technology-related higher education contexts. Conversely, the exclusion criteria were established to eliminate studies that fall outside the scope of the review, lack sufficient methodological rigor, or do not contribute directly to answering the research questions. The application of these criteria helps reduce selection bias, improve the quality of the evidence base, and ensure that the final set of studies is both relevant and reliable. Furthermore, the criteria facilitate a systematic screening process during the title, abstract, and full-text review stages, thereby enhancing the validity and reproducibility of the review findings. Table 4 presents the inclusion and exclusion criteria used in the study selection process.

Table 4 Inclusion and Exclusion Criteria for Study Selection

Category	Inclusion Criteria	Exclusion Criteria
Study Context	Studies involving engineering education institutions, engineering programs, faculties, departments, or schools within higher education institutions.	Studies focusing exclusively on non-engineering disciplines or conducted in non-educational contexts without relevance to higher education.
Research Focus	Studies discussing institutional readiness, organizational readiness, digital readiness, digital maturity, or preparedness for digital transformation.	Studies addressing only the technical development or implementation of digital technologies without discussing institutional readiness or organizational factors.
Digital Transformation Scope	Studies focusing on digital transformation, digitalization, technology integration, educational technology adoption, Industry 4.0, smart education, or related initiatives.	Studies focusing exclusively on general digital learning initiatives without a clear connection to digital transformation and institutional readiness.
Educational Setting	Studies conducted in higher education settings, including universities, colleges, and technical institutions.	Studies conducted exclusively in primary, secondary, or K–12 educational settings.
Factors, Barriers, and Strategies	Studies examining readiness factors, challenges, barriers, strategies, frameworks, models, assessment tools, and best practices for digital transformation.	Studies that do not address factors, barriers, challenges, frameworks, strategies, or best practices related to

		institutional readiness for digital transformation.
Outcome Focus	Studies examining organizational, technological, human resource, leadership, governance, infrastructure, financial, cultural, and policy-related aspects of readiness.	Studies focused solely on student learning outcomes, student satisfaction, or academic performance without examining institutional readiness.
Publication Type	Peer-reviewed journal articles, conference proceedings, review papers, and other scholarly publications.	Editorials, opinion papers, book reviews, magazine articles, newsletters, dissertations, theses, and other non-peer-reviewed publications.
Language	Studies published in English.	Studies published in languages other than English.
Publication Period	Studies published between 2021 and 2026.	Studies published outside the specified review period.
Accessibility	Studies with full-text availability.	Studies for which the full text is unavailable.
Methodological Quality	Qualitative, quantitative, mixed-methods, case studies, surveys, systematic reviews, and conceptual framework studies with sufficient methodological information.	Studies with insufficient methodological information or inadequate relevance to the research questions.
Record Management	Unique records identified through the search process.	Duplicate records identified across databases and search results.

The inclusion and exclusion criteria served as the foundation for the study selection process and were systematically applied during the title screening, abstract screening, and full-text assessment stages. Through the consistent application of these criteria, the review ensured that only studies with direct relevance to institutional readiness for digital transformation in engineering education were retained for analysis and synthesis, thereby strengthening the credibility, reliability, and overall quality of the review findings.

Study Screening and Selection Process

The study screening and selection process followed the PRISMA 2020 framework, which provides a transparent and systematic approach for identifying, screening, assessing, and selecting studies for inclusion in a systematic literature review. Figure 1 presents the PRISMA 2020 flow diagram used in this study.

The identification stage began with a search conducted in Lens.org using the expanded search string, which initially retrieved 5,636 records. Several filtering procedures were subsequently applied to refine the search results. Limiting the publication period to 2021–2026 reduced the number of records to 2,513. Applying the filters for Open Access, Has Abstract, and Has Full Text further reduced the records to 2,361. Restricting the document types to journal articles and conference proceedings resulted in 1,828 records. Finally, applying filters based on subject matter (subject and field of study**)** and identifier type (DOI) reduced the dataset to 36 studies.

During the screening stage, the 36 records were exported for further review. Of these, 10 studies were excluded because full access required subscription and the complete texts were unavailable. The remaining 26 records were imported into Zotero for reference management and duplicate checking, where one record was identified as null and removed. Consequently, 25 studies were uploaded to Rayyan.ai for title and abstract screening based on the predefined inclusion and exclusion criteria.

In the eligibility stage, the abstracts of the 25 studies were assessed for relevance to the research questions and alignment with the study scope. As a result, 6 studies were excluded because they did not meet the inclusion criteria. The remaining 19 studies proceeded to full eligibility assessment and quality evaluation.

Following the application of the eligibility criteria and quality assessment procedures, 19 studies were retained for the final qualitative synthesis. These studies demonstrated sufficient methodological rigor and direct relevance to the objectives of the review. Through a series of sequential filtering, screening, eligibility assessment, and quality evaluation procedures, the initial pool of 5,636 records was systematically narrowed to 19 high-quality studies, which formed the evidence base for this systematic literature review.

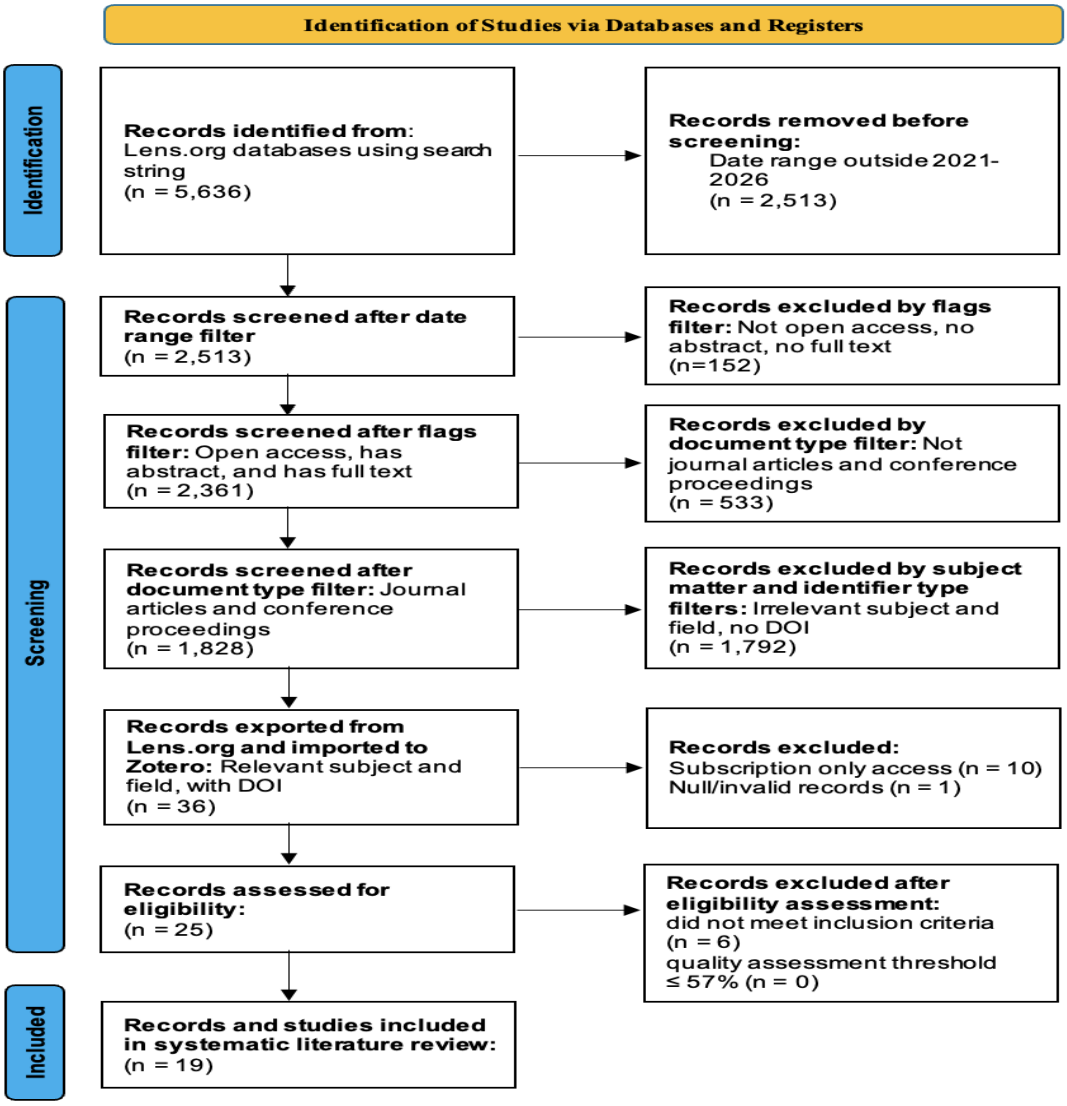

Figure 1. PRISMA 2020 Flow Diagram of the Study Screening and Selection Process

Quality Assessment

To ensure the credibility, reliability, and relevance of the studies included in the review, a quality assessment was conducted following the study selection process. Quality assessment is an essential component of a systematic literature review as it evaluates the methodological soundness and relevance of each study to the research objectives. Consistent with the Kitchenham Guidelines, the assessment aimed to identify studies that provide robust evidence regarding institutional readiness for digital transformation in engineering education while minimizing the inclusion of studies with methodological weaknesses or limited relevance.

The quality assessment focused on four key dimensions: research design, methodological rigor, data validity, and relevance to the research questions. Each study was evaluated using a set of quality assessment questions specifically developed based on the objectives of the review and the three research questions. The assessment ensured that the selected studies provided sufficient evidence regarding the factors influencing institutional readiness, the challenges and barriers encountered during digital transformation, and the strategies, frameworks, and best practices proposed to enhance readiness. Table 5 shows the quality assessment criteria used to evaluate the methodological quality and relevance of the selected studies.

Table 5 Quality Assessment Criteria

Code	Quality Assessment Question	Assessment Focus
QA1	Are the objectives and scope of the study clearly stated?	Research Design
QA2	Is the research methodology appropriate and adequately described?	Methodological Rigor
QA3	Are the data collection and analysis procedures clearly explained and justified?	Methodological Rigor
QA4	Are the findings supported by sufficient evidence and valid data?	Data Validity
QA5	Does the study address institutional readiness, organizational readiness, digital readiness, or related concepts?	Topic Relevance
QA6	Does the study identify factors influencing institutional readiness for digital transformation in engineering education?	RQ1 Relevance
QA7	Does the study discuss challenges, barriers, or obstacles related to institutional readiness for digital transformation?	RQ2 Relevance
QA8	Does the study propose or evaluate strategies, frameworks, models, assessment tools, or best practices for enhancing institutional readiness?	RQ3 Relevance
QA9	Are the conclusions logically derived from the results and analysis?	Data Validity
QA10	Does the study make a meaningful contribution to understanding digital transformation in engineering or higher education institutions?	Overall Relevance

Quality Assessment Results

A quality assessment was conducted to evaluate the methodological rigor, validity, credibility, and relevance of the selected studies to the objectives and research questions of this systematic literature review. Following the Kitchenham Guidelines, each of the 19 included studies was assessed using a predefined set of ten quality assessment criteria. A three-point scoring scale was adopted, where 2 = Yes (criterion fully satisfied), 1 = Partially Yes (criterion partially satisfied), and 0 = No (criterion not satisfied). To enhance the reliability of the assessment and minimize potential bias, the evaluation was independently conducted by three reviewers, and the results were compared and validated to ensure consistency in the scoring process.

As presented in Table 6, all three reviewers evaluated the same set of 19 studies, and all studies achieved quality scores above the predetermined inclusion threshold of 57%, resulting in a 100% agreement regarding their inclusion in the final review. The assessed studies obtained quality scores ranging from 65% to 100%, indicating that they possessed good to excellent methodological quality and sufficient relevance to the review topic. Studies receiving higher scores demonstrated strong research designs, clear methodologies, valid data collection and analysis procedures, and direct alignment with the research questions. Meanwhile, studies with relatively lower scores remained valuable sources of evidence despite having minor limitations in methodological detail or direct applicability to institutional readiness for digital transformation. Overall, the quality assessment confirms that the selected studies provide a robust and credible evidence base for examining the factors influencing

institutional readiness, the challenges and barriers encountered, and the strategies and best practices that support digital transformation in engineering education.

Table 6 Quality Assessment Results of Included Studies

Reviewer	Number of Studies Evaluated	Studies with Quality Score > 57%	Percentage (%)
Reviewer 1	19	19	100%
Reviewer 2	19	19	100%
Reviewer 3	19	19	100%

Data Extraction

Following the study selection and quality assessment processes, a systematic data extraction procedure was conducted to collect and organize relevant information from the selected studies. Data extraction is an essential step in a systematic literature review as it facilitates the consistent collection of evidence needed to address the research questions. A structured data extraction form was developed based on the objectives of the review, the PICOC framework, and the research questions concerning institutional readiness for digital transformation in engineering education.

The data extraction process focused on capturing key characteristics and findings of each study, including the author(s), publication year, country or geographical context, research methodology, sample or participants, key findings, and relevance to the research questions. Extracting these data elements enabled the systematic comparison of studies and supported the identification of recurring themes, patterns, and evidence across the literature. Furthermore, the extracted information served as the primary basis for the thematic and narrative synthesis conducted in the subsequent stages of the review.

To ensure consistency and accuracy, the data extraction process was independently performed and verified by the reviewers. The extracted data were then organized into a data extraction matrix to facilitate analysis and synthesis. Table 7 presents the data extraction template used in this study.

Table 7 Data Extraction Matrix

Author(s)	Year	Country	Methodology	Sample	Key Findings	Relevance to Research Questions
Author(s) of the study	Publication year	Country or region where the study was conducted	Research design (e.g., qualitative, quantitative, mixed methods, case study, systematic review)	Participants, institutions, documents, or datasets involved in the study	Major findings related to digital transformation and institutional readiness	Contribution to RQ1, RQ2, and/or RQ3

The extracted data were subsequently analyzed and synthesized to identify the factors influencing institutional readiness, the challenges and barriers encountered during digital transformation, and the strategies, frameworks, and best practices proposed to enhance readiness in engineering education institutions.

Data Synthesis

Data synthesis was conducted using thematic analysis, narrative synthesis, and bibliometric analysis to systematically analyze and interpret the findings of the selected studies. Thematic analysis was employed to identify and categorize recurring themes related to the research questions, including factors influencing institutional readiness, challenges and barriers, and strategies and best practices for digital transformation. Narrative synthesis was used to integrate and compare findings across studies with different research methodologies and contexts, while bibliometric analysis provided an overview of publication trends, countries of origin, and research methodologies represented in the reviewed literature. The combination of these methods enabled a comprehensive synthesis of the evidence related to institutional readiness for digital transformation in engineering education

RESULTS

This section presents the findings of the systematic literature review based on the 19 studies that met the inclusion criteria and quality assessment requirements. The results are organized to provide a comprehensive overview of the selected studies and to address the research questions systematically. First, the characteristics of the included studies are presented, including publication trends, geographical distribution, and research methodologies. Subsequently, the findings are synthesized according to the three research questions, focusing on the factors influencing institutional readiness for digital transformation in engineering education, the challenges and barriers associated with readiness, and the strategies, frameworks, and best practices proposed to enhance institutional readiness. The findings are presented using thematic categories and summary tables to facilitate comparison and interpretation across the reviewed studies.

Study Characteristics

A total of 19 studies were included in the final qualitative synthesis following the study selection and quality assessment processes. To facilitate systematic analysis and comparison, key information was extracted from each study, including the authors, publication year, country, methodology, sample, key findings, and relevance to the research questions. Table 8 presents the data extraction matrix of the selected studies and provides an overview of the characteristics of the evidence base used in this review.

Table 8 Data Extraction Matrix of Included Studies

Author(s)	Year	Country	Methodology	Sample	Key Findings	Relevance to RQs
Ahmed & Opoku	2022	Saudi Arabia	Mixed Methods	Engineering faculty and students	Technology-supported learning requires institutional support, faculty preparedness, and digital infrastructure for successful implementation.	RQ1, RQ2, RQ3
Anastasakis et al.	2023	Greece	Qualitative Survey	2,093 students	Identified technological, instructional, and communication barriers to online learning.	RQ2
Bond et al.	2021	Global Review	Systematic Mapping Review	282 studies	Identified trends in educational technology adoption and emergency remote teaching practices worldwide.	RQ1, RQ2, RQ3

Caprara & Caprara	2022	Italy	Quantitative	University students	Virtual learning effectiveness depends on technology readiness and institutional support.	RQ1, RQ2
Cobian et al.	2022	Philippines	Case Study	STEM education programs	Effective evaluation frameworks support institutional digital transformation initiatives.	RQ3
Elçi & Abubakar	2021	Turkey	Quantitative	Higher education students	Task-technology fit, motivation, and technology readiness influence digital learning adoption.	RQ1
Eppard et al.	2021	UAE	Qualitative	Faculty members	Culturally responsive technology integration supports digital transformation initiatives.	RQ3
Guppy et al.	2022	International	Quantitative Survey	3,806 students; 283 faculty	Digital capacity and technology usage influence institutional adaptation during crises.	RQ1, RQ2
Hasim et al.	2022	Malaysia	Quantitative	Higher education students	Digital readiness significantly influences e-learning adoption and effectiveness.	RQ1
Highman et al.	2023	United Kingdom	Qualitative	24 interviews	Strategic institutional partnerships support organizational capacity building and transformation.	RQ1, RQ3
Klusmann et al.	2022	Germany	Qualitative	Higher education instructors	Teacher support and training are essential for successful digital transformation.	RQ2, RQ3
Kovacs et al.	2023	Switzerland	Qualitative	10 university teachers	Organizational and pedagogical changes created challenges during digital transformation.	RQ2
Lai et al.	2022	Australia	Quantitative (CFA)	1,352 online learners	Developed a comprehensive technology evaluation framework incorporating institutional environment and technology dimensions.	RQ1, RQ3
Laufer et al.	2021	24 Countries	Mixed Methods	85 Higher Education Leaders	Leadership, governance, access, collaboration, and institutional support significantly influence digital transformation readiness.	RQ1, RQ2, RQ3

Pham et al.	2021	Vietnam	Case Study	Teacher education institutions	CDIO-based approaches support digital competency development and innovation.	RQ3
Purwandari et al.	2022	Indonesia	Mixed Methods	Engineering students	Community of Inquiry framework supports effective digital learning environments.	RQ3
Sum & Oancea	2022	Global Review	Systematic Review	32 studies	Faculty resilience, institutional support, and technology readiness shape technology adoption during emergency remote teaching.	RQ1, RQ2
Tang et al.	2021	China	Quantitative	University students	Student readiness and digital competencies affect online learning success.	RQ1, RQ2
Tran et al.	2023	Australia	Qualitative	International education stakeholders	Risk management, institutional resilience, and strategic coordination support sustainability.	RQ1, RQ3

Table 8 shows that the selected studies were conducted across diverse geographical contexts and employed a variety of research methodologies, including quantitative, qualitative, mixed-methods, case study, and systematic review approaches. The studies collectively provide evidence related to the factors influencing institutional readiness, the challenges and barriers encountered during digital transformation, and the strategies and frameworks proposed to enhance readiness in higher and engineering education institutions.

Findings by Research Question

RQ1: What factors influence institutional readiness for digital transformation in engineering education?

The analysis of the selected studies revealed that institutional readiness for digital transformation is influenced by multiple interrelated organizational, technological, human, and strategic factors. Five major themes emerged from the literature: leadership and governance, technological infrastructure, faculty competencies, organizational culture, and institutional support. These factors collectively determine an institution's capacity to plan, implement, and sustain digital transformation initiatives.

Effective leadership provides strategic direction, governance mechanisms, resource allocation, and organizational commitment necessary for successful digital transformation (Laufer et al., 2021; Highman et al., 2023). Likewise, robust technological infrastructure, including digital platforms, learning management systems, and reliable internet connectivity, serves as a fundamental foundation for technology-enabled educational processes (Lai et al., 2022; Guppy et al., 2022). The literature further emphasizes the importance of faculty competencies, particularly digital skills, pedagogical knowledge, and continuous professional development, in facilitating the adoption and effective use of digital technologies (Ahmed & Opoku, 2022; Sum & Oancea, 2022). Additionally, a supportive organizational culture characterized by innovation, collaboration, adaptability, and openness to change enhances institutional readiness, while adequate institutional support through funding, technical assistance, policies, and professional development opportunities strengthens the sustainability of digital transformation initiatives (Laufer et al., 2021; Kovacs et al., 2023; Lai et al., 2022).

These findings suggest that institutional readiness for digital transformation is a multidimensional construct requiring the alignment of leadership, technology, people, organizational culture, and institutional resources.

The thematic categories and corresponding factors identified across the reviewed studies are summarized in Table 9.

Table 9 Factors Influencing Institutional Readiness for Digital Transformation in Engineering Education

Thematic Category	**Factors Identified**	**Supporting Studies**
Leadership and Governance	Strategic vision, leadership commitment, digital governance, decision-making support, institutional direction	Laufer et al. (2021); Highman et al. (2023)
Technological Infrastructure	ICT facilities, internet connectivity, learning management systems, digital platforms, technology resources	Lai et al. (2022); Guppy et al. (2022); Ahmed and Opoku (2022)
Faculty Competencies	Digital literacy, technological skills, pedagogical competencies, professional development, technology adoption capability	Ahmed and Opoku (2022); Sum and Oancea (2022); Bond et al. (2021)
Organizational Culture	Innovation, collaboration, adaptability, openness to change, stakeholder engagement	Laufer et al. (2021); Kovacs et al. (2023)
Institutional Support	Funding, technical support, administrative support, institutional policies, professional development opportunities	Lai et al. (2022); Laufer et al. (2021); Highman et al. (2023)

RQ2: What challenges and barriers are reported in the literature regarding institutional readiness for digital transformation in engineering education?

The reviewed studies identified several challenges and barriers that hinder institutional readiness and the successful implementation of digital transformation initiatives. Five major themes emerged from the literature: infrastructure limitations, digital competency gaps, resistance to change, resource constraints, and organizational challenges. These barriers affect institutions' ability to effectively adopt, implement, and sustain digital transformation efforts.

Inadequate technological infrastructure, limited access to digital platforms, poor internet connectivity, and insufficient ICT facilities were found to negatively affect both instructional delivery and institutional operations (Anastasakis et al., 2023; Guppy et al., 2022). The literature also highlights deficiencies in digital literacy, technological skills, and professional development opportunities among faculty, students, and administrators, which reduce the effectiveness of digital transformation initiatives (Ahmed & Opoku, 2022; Sum & Oancea, 2022; Bond et al., 2021). Furthermore, resistance to change, limited funding, inadequate technological investments, and insufficient technical support were identified as significant obstacles to transformation efforts (Kovacs et al., 2023; Laufer et al., 2021; Lai et al., 2022). Organizational issues, including the absence of clear digital transformation strategies, weak governance structures, and inadequate institutional planning, further impede readiness and implementation success (Laufer et al., 2021; Sum & Oancea, 2022).

The findings indicate that barriers to institutional readiness extend beyond technological issues and also involve human, organizational, and strategic factors. Addressing these challenges requires a comprehensive institutional approach that supports both technological and organizational change. The thematic categories and corresponding challenges identified across the reviewed studies are summarized in Table 10.

Table 10 Challenges and Barriers to Institutional Readiness for Digital Transformation in Engineering Education

Thematic Category	Challenges and Barriers Identified	Supporting Studies
Infrastructure Limitations	Poor internet connectivity, inadequate ICT facilities, limited access to digital technologies and platforms	Anastasakis et al. (2023); Guppy et al. (2022)
Digital Competency Gaps	Insufficient digital literacy, inadequate training, limited technological proficiency	Ahmed & Opoku (2022); Sum & Oancea (2022); Bond et al. (2021)
Resistance to Change	Reluctance to adopt new technologies, organizational inertia, resistance to innovation	Kovacs et al. (2023); Laufer et al. (2021)
Resource Constraints	Limited funding, inadequate technological investments, insufficient technical support	Laufer et al. (2021); Lai et al. (2022)
Organizational Challenges	Lack of digital strategy, weak governance structures, policy limitations, inadequate planning	Laufer et al. (2021); Sum & Oancea (2022)

RQ3: What strategies, frameworks, and best practices have been proposed to enhance institutional readiness for digital transformation in engineering education?

The literature proposes a variety of strategies, frameworks, and best practices aimed at strengthening institutional readiness and supporting sustainable digital transformation. Five major themes emerged from the analysis: digital leadership and strategic planning, faculty development and capacity building, readiness assessment frameworks, technology integration, and stakeholder collaboration.

Establishing a clear digital vision, effective governance structures, and long-term strategic plans enables institutions to align digital initiatives with organizational goals and support sustainable transformation (Laufer et al., 2021; Highman et al., 2023). Additionally, faculty development through professional training, digital literacy programs, and continuous learning opportunities strengthens the competencies required for effective technology adoption and integration (Ahmed & Opoku, 2022; Sum & Oancea, 2022). The use of readiness assessment frameworks and evaluation models further assists institutions in monitoring progress and identifying areas for improvement (Lai et al., 2022; Cobian et al., 2022). Moreover, investments in technological infrastructure and digital learning environments enhance institutional capacity for innovation, while collaboration among institutional leaders, faculty, students, industry partners, and other stakeholders promotes knowledge sharing and collective commitment to transformation efforts (Bond et al., 2021; Laufer et al., 2021; Highman et al., 2023).

Overall, the findings highlight that enhancing institutional readiness for digital transformation requires more than simply investing in technology. Successful transformation depends on a balanced and coordinated effort involving strong leadership, continuous capacity building, effective technological integration, systematic readiness assessment, and active stakeholder participation. When these elements are aligned, engineering education institutions are better positioned to adapt to technological change, sustain digital initiatives, and achieve long-term transformation goals. The thematic categories and corresponding strategies identified across the reviewed studies are summarized in Table 11.

Table 11 Strategies, Frameworks, and Best Practices for Enhancing Institutional Readiness for Digital Transformation in Engineering Education

Thematic Category	Strategies, Frameworks, and Best Practices	Supporting Studies
Digital Leadership and Strategic Planning	Digital vision, governance frameworks, strategic planning, leadership development	Laufer et al. (2021); Highman et al. (2023)
Faculty Development and Capacity Building	Training programs, mentoring initiatives, digital literacy development, professional development	Ahmed & Opoku (2022); Sum & Oancea (2022)
Readiness Assessment Frameworks	Readiness models, maturity frameworks, institutional evaluation tools, assessment mechanisms	Lai et al. (2022); Cobian et al. (2022)
Technology Integration	Infrastructure enhancement, digital platforms, learning management systems, technology-supported learning	Lai et al. (2022); Bond et al. (2021)
Stakeholder Collaboration	Industry partnerships, stakeholder engagement, collaborative decision-making, cross-functional teams	Laufer et al. (2021); Highman et al. (2023)

DISCUSSION

The findings of this systematic literature review demonstrate that institutional readiness for digital transformation in engineering education is a multidimensional concept influenced by organizational, technological, human, and strategic factors. Across the reviewed studies, leadership and governance, technological infrastructure, faculty competencies, organizational culture, and institutional support consistently emerged as the primary determinants of readiness. These findings align with organizational change and digital transformation theories, which emphasize that successful transformation requires not only technological adoption but also leadership commitment, organizational capabilities, and stakeholder engagement (Laufer et al., 2021; Lai et al., 2022; Ahmed & Opoku, 2022).

A notable pattern observed across the studies is the interconnected nature of readiness factors and barriers. Institutions with strong leadership, adequate technological infrastructure, and supportive organizational cultures were generally better positioned to implement and sustain digital transformation initiatives. Conversely, institutions experiencing infrastructure limitations, digital competency gaps, resistance to change, and resource constraints often encountered difficulties in achieving transformation goals (Anastasakis et al., 2023; Guppy et al., 2022; Kovacs et al., 2023). These findings suggest that readiness is not determined by a single factor but rather by the alignment of technological, organizational, and human capabilities.

The review also highlights the growing emphasis on strategic approaches to digital transformation. Many studies proposed leadership-driven strategies, faculty development programs, readiness assessment frameworks, and stakeholder collaboration as effective mechanisms for enhancing institutional readiness (Laufer et al., 2021; Highman et al., 2023; Lai et al., 2022). This trend reflects a shift from viewing digital transformation as a purely technological initiative to recognizing it as a comprehensive organizational change process that requires long-term planning and continuous improvement.

Despite the increasing body of literature on digital transformation in higher education, several research gaps remain. Most studies focused on higher education broadly, with relatively limited attention given specifically to engineering education institutions. Furthermore, few studies proposed comprehensive readiness models tailored to the unique requirements of engineering programs, which often involve laboratory-based learning, technical training, and industry collaboration. Additional research is therefore needed to develop and validate context-specific frameworks that can better support digital transformation within engineering education.

The findings have important implications for policymakers, institutional leaders, and educators. Institutions seeking to enhance digital transformation readiness should adopt a holistic approach that integrates leadership, infrastructure development, faculty capacity building, organizational support, and stakeholder engagement. Moreover, readiness assessments should be conducted regularly to identify strengths, address weaknesses, and guide strategic decision-making. By addressing these dimensions collectively, engineering education institutions can improve their capacity to respond to technological change and achieve sustainable digital transformation outcomes.

LIMITATIONS OF THE REVIEW

This systematic literature review is subject to several limitations that should be considered when interpreting the findings. First, the literature search was conducted primarily using Lens.org, which, although comprehensive, may not include all relevant studies available in other academic databases. Second, the review included only English-language publications, potentially excluding relevant studies published in other languages. Third, the review was limited to studies published between 2021 and 2026, which may have resulted in the exclusion of earlier studies that could provide additional insights into institutional readiness and digital transformation. Finally, the review may be affected by publication bias, as studies with significant or positive findings are more likely to be published than those reporting negative or inconclusive results. Despite these limitations, the use of a systematic review protocol, predefined inclusion and exclusion criteria, quality assessment procedures, and the PRISMA 2020 framework helped ensure the rigor, transparency, and reliability of the review findings.

CONCLUSION

This systematic literature review examined institutional readiness for digital transformation in engineering education through the analysis of 19 selected studies. Guided by the PRISMA 2020 framework and the Kitchenham Guidelines, the review employed a systematic process of literature identification, screening, quality assessment, data extraction, and synthesis. The findings were analyzed using **t**hematic analysis, narrative synthesis, and bibliometric analysis to provide a comprehensive understanding of the current state of research on institutional readiness for digital transformation in engineering education.

The review successfully addressed its objectives and research questions by identifying the key factors that influence institutional readiness, the challenges and barriers encountered during digital transformation, and the strategies, frameworks, and best practices proposed to enhance readiness. The findings revealed that institutional readiness is primarily influenced by leadership and governance, technological infrastructure, faculty competencies, organizational culture, and institutional support. Furthermore, the literature highlighted several barriers, including infrastructure limitations, digital competency gaps, resistance to change, resource constraints, and organizational challenges. To address these barriers, the reviewed studies emphasized the importance of digital leadership, strategic planning, faculty development, readiness assessment frameworks, technology integration, and stakeholder collaboration.

This review contributes to the growing body of knowledge on digital transformation in engineering education by providing a synthesized understanding of the factors, challenges, and strategies associated with institutional readiness. The findings have important implications for policymakers, institutional leaders, educators, and researchers by highlighting the need for a holistic and strategic approach to digital transformation that integrates technological, organizational, human, and governance dimensions. Based on the findings, engineering education institutions are encouraged to strengthen leadership capacity, invest in digital infrastructure, support continuous professional development, and implement systematic readiness assessment mechanisms to enhance their preparedness for sustainable digital transformation. Additionally, future research should focus on developing and validating context-specific readiness frameworks tailored to the unique needs and characteristics of engineering education institutions.

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