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Review

Digital Transformation and Public Value Creation in Higher Education: A PRISMA-ScR Review and Evidence-Synthesized Framework of Digital Competencies, Institutional Readiness, and Governance Pathways

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Abstract

This study examines how digital transformation in higher education institutions (HEIs) contributes to public value creation, moving beyond efficiency-oriented narratives toward broader societal outcomes. Using a PRISMA-ScR approach, the study systematically reviews 47 peer-reviewed articles published between 2013 and 2025 across major academic databases. The review maps the evolution of scholarship and identifies the key mechanisms through which digital transformation influences public value. The findings reveal three interrelated dimensions shaping outcomes: digital competencies, institutional readiness, and governance alignment. Digital competencies enable the effective adoption and use of technologies, while institutional readiness—comprising digital infrastructure, leadership capacity, and organizational culture—acts as a mediating condition influencing implementation success. Governance alignment, including regulatory coherence, accountability mechanisms, and stakeholder engagement, plays a moderating role in determining whether digital transformation initiatives generate inclusive and socially beneficial outcomes. In addition to positive outcomes such as improved access, service quality, and transparency, the review identifies critical risks—including digital inequality, data governance challenges, and algorithmic bias—that may constrain public value creation, particularly in resource-constrained and Global South contexts. Building on these findings, the study develops the Global Digital Transformation—Public Value Creation (G-DTPVC) framework as an evidence-synthesized model derived from the reviewed literature. The framework specifies key constructs, causal relationships, and indicative measures to support future empirical research and policy application. By linking digital transformation processes in HEIs to broader public value outcomes and Sustainable Development Goals (SDGs 4, 9, and 16), this study advances theoretical understanding and provides actionable, context-sensitive guidance for policymakers and institutional leaders seeking to foster inclusive, accountable, and resilient higher education systems.

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1. Introduction

Digital transformation has become a defining feature of contemporary higher education systems, fundamentally reshaping how institutions design, deliver, and govern teaching, research, and administrative functions. Higher education institutions (HEIs) increasingly deploy digital technologies—including learning management systems, artificial intelligence, big data analytics, cloud computing, and e-governance platforms—to enhance operational efficiency, expand access, and improve service delivery [1–4]. While these developments have generated measurable improvements in institutional performance and responsiveness, the dominant discourse remains largely techno-centric, emphasizing efficiency gains and innovation outputs rather than broader societal impacts.

In contrast, the concept of public value shifts attention from internal organizational performance to outcomes that benefit society at large. In higher education, public value encompasses equitable access to education, transparency and accountability in governance, responsiveness to stakeholder needs, and contributions to social mobility and democratic development [5–7]. As public and quasi-public institutions, universities play a critical role in advancing inclusive development and knowledge-based economies. Consequently, digital transformation represents not only a technological shift but also a key mechanism through which public value can be created—or undermined.

Despite this relevance, the relationship between digital transformation and public value in HEIs remains conceptually fragmented and empirically underdeveloped. A significant body of literature adopts information systems and innovation perspectives, focusing on technology adoption, digital maturity, and institutional readiness [3,6,8,9]. While these approaches provide valuable insights into organizational capabilities and performance, they rarely connect digital transformation processes to explicit public value outcomes such as equity, legitimacy, transparency, or societal impact. Conversely, research on public value and digital governance has developed robust theoretical insights into value co-creation, accountability, and citizen-centric service delivery, yet these perspectives are only sporadically applied within higher education contexts [7,10,11]. This disconnect constrains a holistic understanding of how digital transformation can be aligned with the broader societal mission of universities.

The urgency of addressing this gap was further underscored by the COVID-19 pandemic, which accelerated the adoption of digital technologies across HEIs worldwide. While this rapid transition enabled continuity in teaching, learning, and administration, it also exposed structural inequalities in access to digital infrastructure, institutional capacity, and digital competencies—particularly in Global South contexts [12,13]. These disparities highlight that digital transformation is not merely a technical process but a complex socio-institutional phenomenon shaped by organizational readiness, governance arrangements, and contextual constraints.

Emerging scholarship increasingly conceptualizes digital transformation in higher education as an integrated process involving technological, organizational, and governance dimensions. Institutional readiness—comprising digital infrastructure, leadership capacity, and organizational culture—has been identified as a critical condition for successful implementation [3,9,14]. Similarly, digital competencies among academic staff, administrators, and students play a central role in shaping the effective use and sustainability of digital

initiatives [9,15–17]. At the same time, governance structures—including regulatory frameworks, accountability mechanisms, and stakeholder engagement processes—determine whether digital transformation efforts translate into inclusive and socially beneficial outcomes [5,8,11].

However, empirical evidence on these dynamics remains unevenly distributed across regions and institutional contexts. Much of the existing research is concentrated in high-income settings characterized by relatively advanced digital infrastructures and stable policy environments [1–3,6]. In contrast, studies from low- and middle-income contexts highlight persistent challenges, including limited resources, uneven digital competencies, and misalignment between national policies and institutional realities [9,10,15–18]. These asymmetries raise critical questions about whether digital transformation mitigates or reproduces existing inequalities in access, quality, and institutional outcomes.

Furthermore, existing studies often examine components of digital transformation in isolation. Research on teaching and learning emphasizes flexible delivery models, student engagement, and digital skills development, while other studies focus on administrative efficiency, smart campus systems, and data-driven management [2,3,6,8,11,19]. Parallel strands explore digital competencies, frequently revealing significant capability gaps that affect institutional performance [15–17]. However, few studies provide a systematic and comparative synthesis of how digital competencies, institutional readiness, and governance arrangements interact to shape public value outcomes across diverse contexts.

Addressing this gap requires a comprehensive and methodologically rigorous synthesis of existing scholarship. Scoping reviews guided by the PRISMA-ScR framework are particularly suited to mapping heterogeneous bodies of literature, identifying thematic patterns, and clarifying conceptual relationships in emerging fields. Accordingly, this study undertakes a PRISMA-ScR review of peer-reviewed literature published between 2013 and 2025 to examine how digital transformation in higher education contributes to public value creation.

This study advances the literature by developing an integrated, empirically grounded conceptual framework that systematically links digital competencies, institutional readiness, and governance alignment to public value creation in higher education. While extant research has examined these dimensions independently, a critical gap remains in understanding their interdependencies and cumulative effects on digital transformation outcomes. Addressing this limitation, the framework proposed in this study is inductively derived from a PRISMA-ScR synthesis of 47 peer-reviewed studies, thereby ensuring strong empirical traceability and analytical robustness. Rather than functioning as a purely abstract construct, the framework serves as a multi-level analytical lens that captures dynamic interactions between individual capabilities, organizational conditions, and institutional governance structures. The study further contributes to theory by integrating insights from public value theory, institutional theory, and the technology–organization–environment (TOE) framework into a coherent explanatory model. In doing so, it provides a structured basis for understanding how digital transformation processes can generate inclusive, efficient, and sustainable public value outcomes—particularly within resource-constrained and policy-fragmented higher education systems.

Specifically, the study aims to: (1) map the evolution of research on digital transformation in HEIs; (2) identify the key drivers and conditions shaping transformation outcomes, with particular attention to digital competencies, institutional readiness, and governance alignment; and (3) synthesize these insights into an evidence-based analytical framework that explains the pathways through which digital transformation generates public value. By integrating insights across technological, organizational, and governance dimensions, this study advances theoretical understanding of digital transformation in higher education

and its societal implications. It also provides policy-relevant insights for designing digital strategies that are inclusive, accountable, and context-sensitive. In doing so, the study aligns digital transformation in HEIs with broader sustainability priorities, particularly Sustainable Development Goals (SDGs 4, 9, and 16), emphasizing the role of universities in fostering equitable, innovative, and resilient societies.

2. Literature Review

The literature on digital transformation in higher education has expanded significantly over the past decade, reflecting growing scholarly and policy interest in how digital technologies reshape institutional processes and outcomes. Existing research can be broadly organized into four interrelated dimensions: (i) technology-driven transformation, (ii) institutional readiness, (iii) digital competencies and human capabilities, and (iv) governance and public value outcomes. Despite this expansion, the literature remains fragmented, with limited integration across these dimensions and insufficient attention to how governance mechanisms mediate the relationship between digital transformation and public value creation.

2.1. Technology-Driven Transformation in Higher Education

The first strand of research focuses on technology-driven change, emphasizing the adoption and integration of digital tools such as learning management systems, artificial intelligence, cloud computing, and data analytics [1,3,10,20]. These studies highlight improvements in teaching delivery, administrative efficiency, and data-driven decision-making. Digital platforms have enabled flexible and personalized learning models, expanded online and blended education, and supported institutional responsiveness to changing demands [3,10,18].

However, this body of work often adopts a functionalist and linear perspective, treating digital transformation primarily as a process of technology adoption and implementation. As a result, it tends to underemphasize the broader organizational, governance, and societal implications of digitalization. In particular, the focus on tools and systems frequently obscures how digital transformation interacts with institutional contexts and public value objectives.

2.2. Institutional Readiness and Organizational Capacity

A second strand of literature emphasizes institutional readiness as a critical condition for successful digital transformation. Institutional readiness encompasses digital infrastructure, leadership commitment, governance capacity, organizational culture, and strategic alignment [1,3,6,9,10].

Empirical studies and digital maturity models suggest that many HEIs remain at early or intermediate stages of transformation, characterized by fragmented initiatives and limited strategic coordination [3,9]. Robust infrastructure—comprising hardware, software, and network systems—is essential for enabling digital teaching, learning, and administrative functions, yet access to such infrastructure varies significantly across institutions and regions [1,10,20].

Leadership and governance capacity are equally important. Research consistently identifies strategic vision, institutional leadership, and clear accountability structures as key enablers of sustained digital transformation [6,9,10]. Organizational culture further shapes transformation outcomes: institutions characterized by openness to innovation, collaboration, and adaptability are more likely to embed digital initiatives effectively, while rigid structures and resistance to change can limit impact [1,6,7].

2.3. Digital Competencies and Human Capabilities

Alongside institutional conditions, a growing body of research highlights the role of digital competencies and human capabilities in shaping digital transformation outcomes. Access to digital resources—including connectivity, devices, and platforms—remains uneven, reinforcing socio-economic and geographic inequalities [1,10,12,18,20]. Evidence from the COVID-19 period shows that students from disadvantaged backgrounds faced significant barriers to participation despite rapid digitalization [10,18,21,22].

Digital competencies extend beyond technical skills to include information literacy, pedagogical application, and collaborative capabilities in digital environments [10,20,23]. Studies consistently find that gaps in competencies among staff and students can undermine the effectiveness of digital technologies and limit their contribution to learning outcomes and institutional performance [1,20,24].

Importantly, these capabilities are not solely individual attributes but are shaped by institutional support structures. Training programs, professional development, technical support systems, and organizational incentives play a crucial role in enabling sustained engagement with digital tools [10,24]. This highlights the interdependence between human capabilities and institutional environments in digital transformation processes.

2.4. Digital Governance and Transformation Processes

A critical but underdeveloped dimension in the literature is digital governance, which mediates how digital transformation unfolds within higher education institutions. Digital transformation processes span academic, administrative, and governance domains, including teaching and learning systems, administrative platforms, and decision-support tools [1,3,19].

Administrative digitalization—covering admissions, records, finance, and communication systems—has been shown to enhance efficiency and enable data-driven management. However, many institutions experience fragmentation across units, limiting interoperability and strategic use of data [3,7,9,25].

Governance digitalization involves the use of digital tools to enhance transparency, accountability, and stakeholder participation. Emerging studies highlight the role of dashboards, business intelligence systems, and online engagement platforms in reshaping institutional governance and public engagement [1,9,10]. At the same time, concerns regarding data ethics, surveillance, and algorithmic bias underscore the need for robust governance frameworks to guide digital transformation [20,26,27]. Despite these insights, governance is often treated as a secondary consideration rather than a central analytical dimension. This limits understanding of how regulatory alignment, accountability mechanisms, and stakeholder participation influence whether digital transformation generates inclusive and sustainable outcomes.

2.5. Public Value Outcomes of Digital Transformation

A growing strand of literature explicitly examines how digital transformation contributes to public value in higher education. Studies suggest that digitalization can expand access to education, enhance service quality, and support social innovation, thereby contributing to inclusive development and sustainability goals [10,12,21].

However, public value outcomes are uneven and context-dependent. While digital technologies enabled continuity of learning during the COVID-19 pandemic, they also exposed and, in some cases, intensified inequalities in access and participation [18,21,22]. Without targeted interventions—such as inclusive design, subsidized access, and context-sensitive policies—digital transformation may disproportionately benefit already advantaged groups [10,12].

Transparency, accountability, and trust are also central dimensions of public value. Digital governance tools can enhance openness and stakeholder engagement, but they also raise concerns regarding privacy, data protection, and ethical use of information [20,26,27]. Institutions that align digital strategies with public missions and ethical standards are more likely to strengthen legitimacy and trust, whereas poorly governed digitalization may erode confidence among stakeholders.

2.6. Contextual Moderators and Integrative Linkages

Across the literature, digital transformation in higher education is consistently shaped by a range of contextual moderators, including socio-economic conditions, regulatory environments, and cultural norms. These factors influence not only the feasibility of digital initiatives but also the extent to which they generate meaningful public value outcomes. Empirical studies from Latin America, Asia, Africa, and Eastern Europe highlight how funding constraints, uneven digital infrastructure, and policy instability can limit institutional readiness and exacerbate digital inequalities [1,6,10,19,21].

Regulatory frameworks play a particularly important role in shaping digital transformation trajectories. Policies related to data protection, quality assurance, accreditation, and digital governance determine whether technological innovations are effectively institutionalized or remain fragmented and peripheral [10]. At the same time, cultural norms—such as attitudes toward technology adoption, authority structures, and equity—affect organizational behavior, leadership approaches, and stakeholder engagement processes [6,10,18,20,24].

Beyond these contextual influences, the literature increasingly points to the need for integrative perspectives that connect technological, organizational, and societal dimensions of digital transformation. Existing studies suggest that institutional readiness and digital competencies interact to shape implementation processes, while governance mechanisms influence whether these processes translate into inclusive and sustainable public value outcomes [3,9,10,28]. In this regard, institutional readiness may function as a mediating condition between digital capabilities and outcomes, while governance alignment and contextual factors act as moderating influences.

Importantly, evidence also suggests the presence of feedback dynamics. Positive public value outcomes—such as improved access, transparency, and stakeholder trust—can reinforce institutional commitment, attract resources, and sustain digital transformation efforts. Conversely, negative outcomes, including digital exclusion, governance failures, or ethical concerns, may generate resistance, reduce trust, and trigger policy or organizational backlash [6,7,9,10].

Despite these insights, the literature lacks a coherent analytical framework that systematically integrates digital competencies, institutional readiness, governance alignment, and contextual moderators into a unified explanatory model. This gap limits the ability to understand how digital transformation processes translate into public value across diverse higher education systems. Accordingly, this study builds on the identified gaps to develop an evidence-based analytical framework that captures the interdependencies among these dimensions and clarifies the pathways through which digital transformation contributes to public value creation in higher education.

Table A1 (presented in Appendix A) summarizes the global mapping of studies included in the scoping review, highlighting patterns in digital competencies, institutional readiness, and public value outcomes across higher education systems.

Table A1 (Appendix A) provides a structured mapping of the 47 studies included in this PRISMA-ScR review, summarizing their geographical contexts, institutional settings, competency domains, institutional readiness dimensions, transformation processes, and

public value outcomes. In addition to descriptive synthesis, the table enables comparative analysis across regions, income levels, and institutional types. It also distinguishes between studies directly focused on higher education and those included for their transferable governance and digital transformation insights. This mapping forms the empirical basis for identifying the relationships between digital competencies, institutional readiness, governance alignment, and public value creation.

(The detailed mapping of the reviewed studies is presented in Appendix A).

3. Theoretical Framework

This study develops an integrated theoretical framework to explain how digital transformation in higher education institutions (HEIs) translates into public value outcomes. In line with the scoping review design, the framework is derived from the synthesis of the reviewed literature and integrates complementary perspectives from public administration, information systems, and organizational theory. Rather than advancing a standalone conceptual model, the framework provides a structured lens for interpreting the relationships identified across the 47 included studies.

At its core, the framework combines three primary theoretical anchors: the Technology–Organization–Environment (TOE) framework, public value theory, and institutional theory. These are further supported by complementary perspectives—including technology adoption models (TAM/UTAUT), diffusion of innovation, social cognitive theory, and digital capital theory—to capture micro-, meso-, and macro-level dynamics of digital transformation.

3.1. Public Value Theory as Normative Foundation

Public value theory provides the normative foundation of the framework by conceptualizing universities as public-serving institutions whose performance must be assessed not only in terms of efficiency but also in relation to equity, transparency, accountability, and societal impact [1,6,29,30]. In the context of digital transformation, value is created when technology-enabled changes enhance inclusive access to education, improve quality, strengthen governance accountability, and contribute to long-term human capital development [3,31].

Recent scholarship emphasizes that digital transformation in public institutions must move beyond service optimization toward broader value constellations that include citizen participation, data rights, and fair distribution of digital benefits [29,30,32]. This orientation aligns digital transformation in higher education with Sustainable Development Goals, particularly SDG 4 (quality education), SDG 9 (innovation and infrastructure), and SDG 16 (inclusive and accountable institutions) [1,6].

3.2. TOE Framework as Structural Backbone

The Technology–Organization–Environment (TOE) framework provides the structural backbone for analyzing digital transformation processes. TOE posits that innovation adoption and implementation are shaped by technological characteristics, organizational conditions, and environmental contexts [1–3,10]. In this study, these dimensions are operationalized as follows:

Technological dimension → digital competencies and capabilities (skills, tools, and digital resources)

Organizational dimension → institutional readiness (infrastructure, leadership, culture, and strategy)

Environmental dimension → governance alignment and contextual conditions (regulation, policy, and socio-economic context)

This mapping enables the framework to connect technological inputs with organizational processes and external constraints, thereby providing a coherent structure for synthesizing findings across diverse institutional settings.

3.3. Institutional Theory and Governance Alignment

Institutional theory complements the TOE framework by explaining how formal regulations, normative expectations, and cultural-cognitive structures shape organizational behavior. It is particularly relevant for understanding governance alignment, including policy coherence, accountability mechanisms, and stakeholder engagement processes that influence digital transformation outcomes [6,10].

Through this lens, governance is not treated as a passive environmental factor but as an active mechanism that conditions how digital initiatives are interpreted, implemented, and sustained. Institutional pressures—such as accreditation requirements, national digital policies, and societal expectations—shape both the direction and legitimacy of digital transformation in HEIs.

3.4. Micro- and Meso-Level Complementary Perspectives

To capture behavioral and capability-level dynamics, the framework incorporates insights from technology adoption and learning theories. Technology Acceptance Models (TAM/UTAUT) explain how perceived usefulness, ease of use, and social influence shape individual adoption of digital systems [33–36]. Social Cognitive Theory further emphasizes the role of self-efficacy, training, and social reinforcement in sustaining digital engagement [23,27].

Diffusion of Innovation theory extends this perspective by explaining how digital initiatives spread within and across institutions, highlighting the importance of innovation characteristics and institutional networks [1,3,37]. These perspectives collectively inform the analysis of digital competencies, user engagement, and the institutionalization of digital practices.

In addition, digital capital theory provides a critical lens on inequality, emphasizing disparities in access to devices, connectivity, and digital skills [6,10,27]. This perspective is particularly important for understanding why similar digital initiatives produce divergent outcomes across socio-economic and geographic contexts.

3.5. Integrated Framework and Causal Pathways

The integration of these theoretical perspectives enables a multi-level explanation of digital transformation and public value creation in higher education. Based on the synthesis of the reviewed literature, the framework specifies the following relationships:

Digital competencies (technological dimension) enable the adoption and effective use of digital systems

Institutional readiness (organizational dimension) acts as a mediating condition, shaping implementation effectiveness

Governance alignment (environmental/institutional dimension) functions as a moderating factor, influencing whether transformation processes generate inclusive and accountable public value outcomes

Contextual conditions (e.g., socio-economic context, regulatory environment) further moderate these relationships.

The framework also recognizes feedback dynamics, whereby positive public value outcomes (e.g., improved access, transparency, and trust) reinforce institutional commitment and resource mobilization, while negative outcomes (e.g., digital exclusion, ethical concerns) may undermine sustainability and legitimacy.

3.6. Conceptual Contribution

By explicitly articulating these complementary relationships, the framework addresses fragmentation in the existing literature and provides a coherent structure linking technological adoption, organizational capacity, governance processes, and societal outcomes. It advances existing scholarship by positioning digital transformation in higher education as a governance-driven and context-dependent process of public value creation, rather than a purely technical or managerial phenomenon.

Figure 1 presents the integrated Global Digital Transformation–Public Value Creation (G-DTPVC) framework, visually illustrating the relationships among digital competencies, institutional readiness, governance alignment, and public value outcomes.

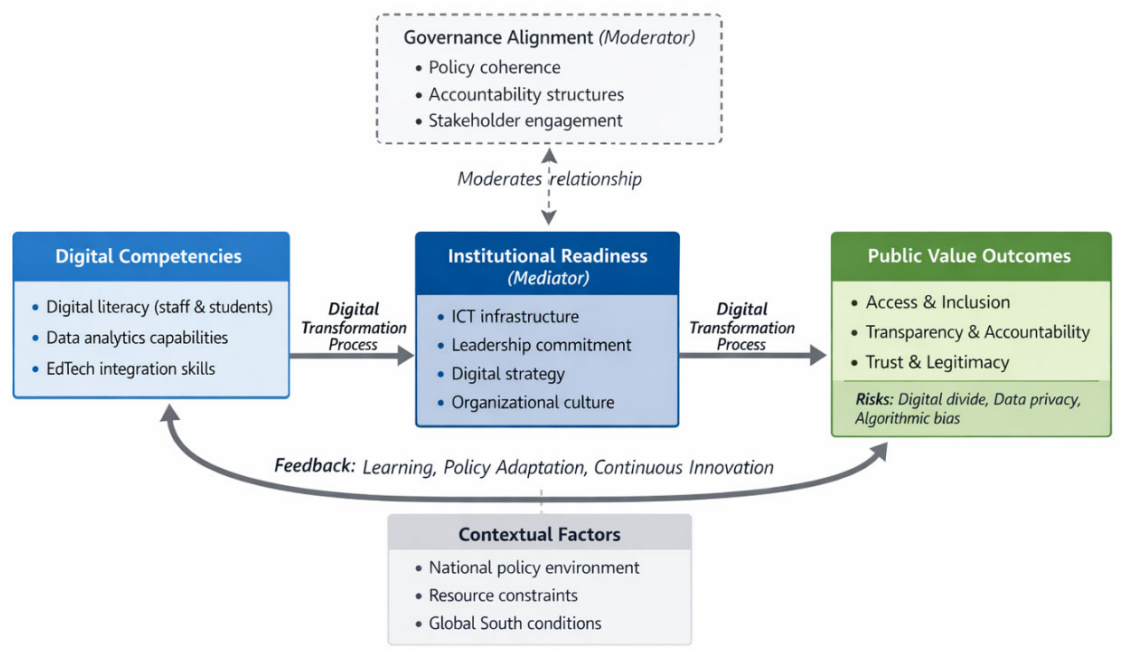


Figure 1. Global Digital Transformation–Public Value Creation (G-DTPVC) Model for Higher Education. Source: Authors analytical framework, 2025.

3.7. Integrative Theoretical Foundations

Research on digital transformation in higher education draws on multiple theoretical perspectives to explain how technologies are adopted, implemented, and institutionalized. At the micro level, technology adoption models such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) highlight the importance of perceived usefulness, ease of use, social influence, and facilitating conditions in shaping individual engagement with digital systems [35,38]. These models are particularly relevant for understanding faculty and student adoption of learning platforms and digital tools.

At the organizational level, Diffusion of Innovation (DOI) theory explains how digital initiatives spread within institutions, emphasizing the role of communication channels, organizational culture, and institutional support in scaling innovations across departments [27,35]. Complementing this perspective, the Technology–Organization–Environment (TOE) framework underscores the importance of organizational capabilities, leadership, and external environmental conditions in shaping institutional readiness for digital transformation [10,39].

Despite their analytical value, these models are often applied in isolation and primarily focus on adoption and implementation processes, with limited attention to broader societal outcomes. Public value theory addresses this limitation by providing a normative lens that

links digital transformation to outcomes such as equity, transparency, accountability, and social inclusion [21,40].

Building on this synthesis, the G-DTPVC framework integrates these complementary perspectives into a unified analytical structure. It links digital inputs (technologies, strategies, and capabilities), transformation processes (academic, administrative, and governance digitalization), and public value outcomes, while incorporating the mediating role of institutional readiness, the moderating influence of governance alignment, and the effects of contextual conditions.

This integrative foundation enables the study to move beyond descriptive accounts of digital transformation toward a structured and comparative understanding of how, and under what conditions, digital transformation in higher education contributes to sustainable and public-oriented outcomes.

Conceptual Framework Development

4. Evidence-Synthesized Conceptual Framework: G-DTPVC

The conceptual framework proposed in this study is grounded in the systematic synthesis of the reviewed literature and reflects recurrent patterns identified across empirical studies; it is not introduced as an abstract or purely theoretical construct, but as an evidence-based model that integrates key determinants of digital transformation in higher education. Specifically, the framework captures dynamic and interdependent relationships between digital competencies, institutional readiness, and governance alignment, positioning these elements as mutually reinforcing components that collectively shape public value outcomes. By consolidating insights from public value theory, institutional theory, and the technology–organization–environment framework, the model provides a structured and theoretically robust lens for analyzing complex transformation processes. Importantly, it addresses a critical gap in the literature by moving beyond fragmented analyses toward a holistic and relational perspective, thereby enhancing both explanatory power and practical relevance for policymakers and institutional leaders. Building on the thematic synthesis of the 47 included studies, this study further proposes the Governance–Digital Transformation–Public Value Creation (G-DTPVC) framework as an analytically grounded model explaining how digital transformation in higher education institutions (HEIs) generates public value under varying institutional and governance conditions; unlike purely conceptual models, the G-DTPVC framework is inductively derived from patterns identified across the reviewed literature, directly addressing the fragmentation between technology adoption, organizational capacity, and governance-oriented explanations of digital transformation, and therefore functions both as an evidence-based synthesis and a theory-building contribution that responds to gaps identified in prior scholarship.

4.1. Theoretical Integration and Analytical Positioning

The framework integrates complementary theoretical perspectives to explain the multi-level dynamics of digital transformation and public value creation.

Technology adoption theories—including the Technology Acceptance Model, Diffusion of Innovation, and the Technology–Organization–Environment (TOE) framework—emphasize factors such as perceived usefulness, organizational support, and environmental conditions as critical to digital uptake [27,41,42]. However, these models primarily focus on adoption processes and do not sufficiently explain how digital transformation translates into broader societal outcomes.

To address this limitation, the framework incorporates public value theory, as developed by Mark H. Moore and further elaborated by Colin Talbot, which emphasizes the role of public institutions in generating societal benefits such as equity, transparency, and

trust. In addition, governance perspectives are integrated to explain how institutional coordination, accountability structures, and policy alignment shape the translation of digital initiatives into public value.

These perspectives are analytically complementary:

- Technology adoption theories explain how transformation is initiated
- Institutional perspectives explain organizational capacity and readiness
- Governance theory explains alignment and coordination mechanisms
- Public value theory explains societal outcomes

4.2. Core Constructs of the G-DTPVC Framework

The G-DTPVC framework is structured around three interrelated enabling constructs digital competencies, institutional readiness, and governance alignment which collectively shape public value outcomes.

Digital Competencies:

Digital competencies refer to the technical, cognitive, and adaptive capabilities required to effectively adopt and utilize digital technologies within HEIs. These include digital literacy among staff and students, data analytics capabilities, and the ability to integrate emerging technologies into teaching, research, and administrative processes [38,43].

Indicative measures include:

- ICT proficiency levels
- Staff training participation rates
- Extent of digital tool integration in academic and governance functions

Institutional Readiness:

Institutional readiness captures the organizational conditions that enable or constrain digital transformation. This includes digital infrastructure, leadership commitment, financial capacity, governance structures, and organizational culture [42,44].

Indicative measures include:

- ICT infrastructure investment
- Existence of institutional digital strategies
- Leadership support for digital initiatives
- Organizational adaptability and innovation capacity

Within the framework, institutional readiness functions as a mediating variable, translating digital competencies into effective transformation processes and outcomes.

Governance Alignment:

Governance alignment refers to the extent to which digital transformation initiatives are embedded within coherent policy frameworks, accountability structures, and stakeholder engagement processes [2].

A critical distinction is made between:

- Governance digitalization (use of digital tools such as dashboards and platforms), and
- Governance alignment (strategic coherence with institutional missions and public policy objectives).

Indicative measures include:

- Existence of digital governance policies
- Transparency mechanisms (e.g., open data platforms)
- Stakeholder participation frameworks
- Alignment with national and institutional development goals

Governance alignment operates as a moderating factor, shaping the extent to which institutional readiness leads to desirable public value outcomes.

Public Value Outcomes:

Public value outcomes represent the societal benefits generated through digital transformation in HEIs. These are conceptualized across three primary dimensions:

- Access and Inclusion (e.g., equitable enrollment and digital access)
- Transparency and Accountability (e.g., availability and quality of institutional data and reporting systems)
- Trust and Legitimacy (e.g., stakeholder confidence and institutional credibility)

Importantly, the framework also incorporates negative public value risks, including:

- Digital inequality
- Data privacy and security concerns
- Algorithmic bias

This acknowledges that digital transformation can generate unintended adverse consequences where governance systems are weak or misaligned.

4.3. Causal Structure and Analytical Pathways

The G-DTPVC framework conceptualizes digital transformation as a multi-stage and conditional process, rather than a linear technological progression.

Specifically:

- Digital competencies influence public value outcomes indirectly through institutional readiness (mediation effect)
- Governance alignment conditions the strength and direction of this relationship (moderation effect)
- These relationships are shaped by contextual factors such as national policy environments and resource constraints, particularly in Global South contexts

This yields the core analytical pathway:

- Digital Competencies → Institutional Readiness → Public Value Outcomes (Conditioned by Governance Alignment).

4.4. Propositions for Future Empirical Research

To enhance empirical applicability, the framework advances the following propositions:

- P1: Digital competencies positively influence institutional readiness in HEIs.
- P2: Institutional readiness mediates the relationship between digital competencies and public value outcomes.
- P3: Governance alignment moderates the relationship between institutional readiness and public value outcomes.
- P4: Weak governance alignment increases the likelihood of negative public value outcomes, including digital inequality and data governance risks.

4.5. Conceptual Model Description (Figure 1)

Figure 1 presents the G-DTPVC conceptual framework. The model illustrates how digital competencies shape institutional readiness, which drives digital transformation processes across academic, administrative, and governance domains. Governance alignment conditions these processes, determining whether they generate positive public value outcomes or reinforce inequalities and systemic risks. The framework further incorporates a feedback loop, emphasizing institutional learning, policy adaptation, and continuous digital innovation required for sustaining long-term transformation and public value creation.

5. Methodology

5.1. Research Design and Rationale

This study employed a systematic scoping review to examine how digital transformation in higher education institutions (HEIs) contributes to public value creation. The review followed the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Scoping Reviews) framework to ensure a transparent, replicable, and methodologically rigorous protocol for identifying, screening, and synthesizing evidence.

Scoping reviews are well suited to emerging, interdisciplinary fields where conceptual boundaries are fluid and the evidence base is heterogeneous. Research on digital transformation in higher education spans multiple domains—including educational technology, public administration, information systems, and governance—which makes a scoping approach appropriate for capturing disciplinary diversity while enabling conceptual integration. Unlike prior reviews that address isolated dimensions (e.g., digital literacy or technology adoption), this study systematically maps evidence across digital competencies, institutional readiness, governance alignment, and public-value outcomes to inform the development of the G-DTPVC framework.

5.2. Research Questions

Consistent with scoping review best practices, the review began with exploratory questions that were iteratively refined during the review process. The final set comprised one central question and six sub-questions:

Central question: How do digital competencies and institutional readiness shape public-value outcomes in higher education across different global contexts?

Sub-questions:

1. How are digital transformation, digital competencies, and institutional readiness conceptualized in the higher education literature?
2. Which public-value dimensions (e.g., equity, transparency, accountability, trust, legitimacy) are associated with digital transformation in HEIs?
3. How does digital capital influence human capabilities and institutional readiness?
4. What processes underpin digital transformation in HEIs?
5. How do public-value outcomes vary across regional and income-level contexts?
6. What patterns emerge across governance contexts (for example, Global North versus Global South)?

5.3. Scope and Temporal Delimitation

The review covered peer-reviewed publications from 2013 to 2025 to reflect the contemporary phase of digital transformation in higher education. This period captures the expansion of digital learning platforms, cloud computing, artificial intelligence, and data-driven governance, as well as the accelerated digitalization precipitated by global disruptions such as the COVID-19 pandemic.

5.4. Search Strategy and Data Sources

A comprehensive literature search was performed across four major academic databases: Scopus, Web of Science, ERIC, and Google Scholar. Searches were conducted between November 2025 and February 2026. Database-specific search strings were developed using Boolean operators and truncation to balance breadth and precision. Representative search strings included:

(“digital transformation” OR “digitalization” OR “digitalisation”) AND (“higher education” OR universit OR HEI)

("digital competenc" OR "digital literacy" OR "digital skills") AND ("higher education" OR universit)

("institutional readiness" OR "digital maturity" OR "digital strategy") AND ("higher education")

("public value" OR "equity" OR "accountability" OR "transparency" OR "governance") AND ("digital" AND "higher education")

The initial searches returned approximately 322,400 records across all databases, reflecting the breadth and fragmentation of the field. Automated filtering and relevance-based sorting reduced this set to 1284 records, which were then subjected to duplicate removal and manual screening. Full search strings, filters, and database-specific queries are provided in Appendix B.

5.5. Screening and Eligibility Process

The screening followed the PRISMA-ScR multi-stage protocol:

Duplicate removal: records were reduced from 1284 to 932 unique studies.

7. Title and abstract screening: 808 studies (86.7%) were excluded for lack of relevance, leaving 124 studies for full-text review.
8. Full-text eligibility assessment: 77 studies (62.1% of those reviewed in full) were excluded based on predefined criteria.
9. Final inclusion: 47 studies were retained for analysis.

Figure 2 (PRISMA-ScR flow diagram) provides a visual summary of this process and lists explicit reasons for exclusion (e.g., non-HE focus, insufficient methodological clarity, or lack of conceptual relevance).

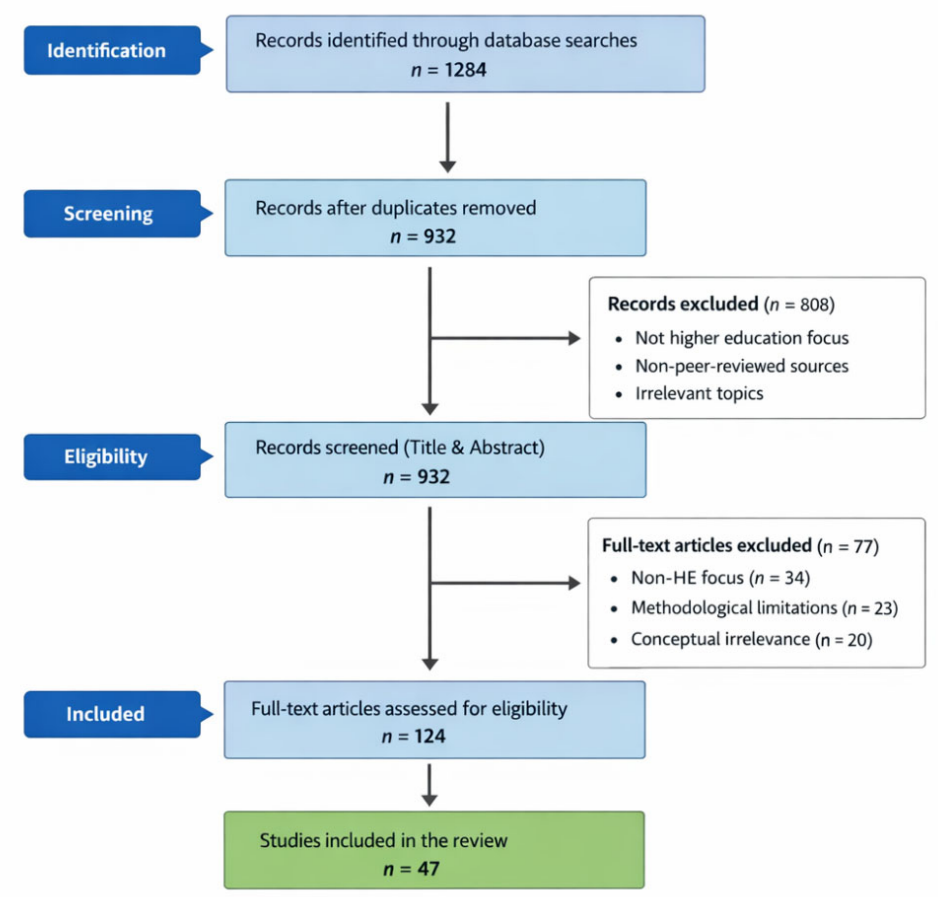


Figure 2. PRISMA-ScR flow diagram of study selection process.

5.6. Inclusion and Exclusion Criteria

Inclusion criteria

- Publication date between 2013 and 2025
- Peer-reviewed journal articles
- Focus on higher education institutions (HEIs)
- Address digital transformation, digital governance, or institutional digitalization
- Provide conceptual or empirical insights relevant to the study

Exclusion criteria

- Studies focused on primary or secondary education
- Purely technical or system-design studies without discussion of institutional implications
- Non-academic publications (e.g., reports, opinion pieces)
- Publications dated before 2013
- Articles lacking methodological transparency

In addition to studies explicitly focused on higher education institutions (HEIs), this review includes a limited number of studies from adjacent public sector, governance, and digital transformation contexts. These studies were retained where they provide transferable insights into digital governance mechanisms, institutional readiness, or public value creation processes that are directly applicable to higher education systems. This decision reflects the interdisciplinary nature of digital transformation research and addresses gaps in HE-specific literature, particularly in areas such as data governance, platform ecosystems, and public sector digitalization. To ensure analytical transparency, such studies are clearly identified in the data extraction and mapping framework (Appendix A).

5.7. Data Extraction and Coding Procedures

Data were extracted using a structured charting matrix that captured: study context (region, income level, HEI type), research design and methodology, theoretical frameworks, and key findings and thematic focus.

The analysis used a hybrid coding approach combining deductive and inductive methods. Deductive coding was guided by established theoretical frameworks, including the Technology Acceptance Model, Diffusion of Innovation theory, and the Technology–Organization–Environment (TOE) framework. Inductive coding identified emergent themes and patterns within the data.

Coding was carried out using qualitative analysis software by two independent coders. Discrepancies were resolved through discussion and consensus. Although formal inter-coder reliability statistics were not calculated—consistent with common scoping review practice—systematic cross-validation procedures were applied to enhance analytic consistency. An additional classification variable—"HE Relevance Type"—was introduced to distinguish between studies directly focused on higher education and those included for indirect or analogical relevance. In addition, a frequency-based thematic distribution analysis (Table 1) was conducted to quantify the prevalence of key dimensions across the reviewed studies, thereby enhancing analytical rigor and transparency.

Table 1. Thematic Distribution of Studies.

Theme	Number of Studies (n)	Percentage (%)
Institutional Readiness	38	80.9%
Digital Competencies	31	66.0%
Governance Alignment/Public Value	29	61.7%
Regional & Contextual Dynamics	16	34.0%

5.8. Analytical Approach

The study used descriptive and thematic synthesis techniques, focusing on frequency-based thematic distributions and pattern identification across the included studies (n = 47). Thematic frequencies were recalculated to align with the final dataset. Analysis followed reflexive thematic analysis procedures to identify key dimensions, relationships, and mechanisms linking digital transformation to public-value outcomes.

Four dominant themes emerged: (1) digital competencies, (2) institutional readiness, (3) governance and public-value outcomes, and (4) regional and contextual variations. These themes informed development of the G-DTPVC conceptual framework. In keeping with scoping review methodology, no formal risk-of-bias assessment was performed; however, limiting the review to peer-reviewed and methodologically robust studies helped ensure baseline quality.

5.9. Reporting Standards and Appendix A

To promote transparency and reproducibility, the PRISMA-ScR flow diagram (Figure 2) details the study selection process, and a completed PRISMA-ScR checklist is provided as Appendix A. Appendix A presents the full mapping table of included studies, and Appendix B contains detailed search strategies and database queries. In addition, a completed PRISMA-ScR reporting guidelines [45] checklist is provided in Appendix C to ensure full transparency and compliance with reporting standards.

6. Findings/Results

The findings are presented using a structured, hierarchical analytical approach designed to enhance clarity, coherence, and interpretive depth. The section is organized into three progressive layers. First, a descriptive synthesis provides an overview of the distribution of studies across geographical regions, methodological designs, and thematic orientations, thereby establishing the empirical landscape of the review. Second, a thematic analysis identifies dominant and emerging patterns across the literature, supported by frequency distributions and comparative insights. Third, the analysis advances beyond descriptive reporting by examining the relationships among key constructs—digital competencies, institutional readiness, and governance alignment—thereby uncovering the mechanisms through which digital transformation contributes to public value creation. This tiered structure ensures a clear progression from evidence presentation to analytical interpretation, addressing limitations in prior reviews that often lack systematic organization and explanatory depth.

This section presents a systematic synthesis of findings from the 47 included studies, focusing on descriptive patterns, thematic distributions, and relational dynamics among digital competencies, institutional readiness, governance alignment, and public-value outcomes. All analyses are explicitly anchored to the final dataset (n = 47), with recalculated thematic frequencies, clear evidence linkage, and deeper analytical interpretation.

6.1. Descriptive Overview of Included Studies

The reviewed literature shows a marked increase in scholarly attention to digital transformation in higher education, particularly from 2020 onward. Although the COVID-19 pandemic accelerated digital adoption, evidence suggests many transformation processes were already underway, with the pandemic functioning primarily as a catalytic shock rather than the sole driver.

Geographical distribution:

The dataset exhibits a pronounced geographical imbalance, with a concentration of studies in Europe and other high-income regions and limited representation from

Sub-Saharan Africa, Latin America, and parts of Asia. This uneven distribution biases the literature toward digitally mature systems and often underrepresents infrastructural deficits, governance fragility, and capacity constraints characteristic of many Global South contexts [10,38].

Methodological characteristics:

The evidence base is dominated by qualitative case studies and mixed-method approaches, with relatively few quantitative or longitudinal studies. This pattern indicates a conceptually rich but empirically fragmented field with limited generalizable evidence across institutional and regional contexts.

Analytical orientation:

Three dominant analytical orientations emerge: technology-centric (tools, platforms, digital adoption), institution-centric (organizational capacity and transformation), and governance-centric (policy alignment and accountability). These orientations are rarely integrated, underscoring the need for a multi-dimensional analytical framework.

6.2. Thematic Distribution of Studies (n = 47)

Thematic coding reveals overlapping but distinct emphases; because studies frequently address multiple dimensions, coding frequencies are non-mutually exclusive.

Interpretation:

Findings indicate a hierarchy of emphasis: institutional readiness is most prominent, digital competencies are widely acknowledged but insufficient on their own, governance and public-value considerations remain analytically underdeveloped, and regional/contextual factors are comparatively underexplored. This imbalance exposes a critical gap—the lack of integrative approaches linking capabilities, institutional conditions, and governance to public-value creation (see Table 1).

6.3. Digital Competencies as Transformative Capabilities

Digital competencies appear as a core enabling condition, identified in 31 of 47 studies.

Conceptual expansion: Studies conceptualize digital competencies as multi-dimensional, extending beyond technical proficiency to include digital pedagogy, data literacy and learning analytics, AI literacy and governance awareness, digital ethics and responsible data use, and strategic foresight and innovation management. Earlier frameworks emphasize technological literacy and institutional innovation capacity [46,47], while recent work extends these toward AI governance, sustainability, and ethical digitalization.

Empirical patterns: The literature emphasizes classroom technologies but documents limited investment in comprehensive capacity building—especially in critical and media literacies [1,31,48].

Constraints and resistance: Reported barriers include limited training and institutional support, increased workloads and administrative burden, and tensions with professional identity and pedagogical autonomy. Resistance often reflects structural institutional deficiencies rather than individual reluctance [21,27,49,50].

Contextual differentiation: Global North contexts emphasize advanced competencies (AI, analytics, optimization), whereas Global South contexts prioritize foundational skills, inclusion, and access. Thus, digital competencies are contextually embedded capabilities shaped by institutional and developmental conditions.

6.4. Institutional Readiness as a Mediating Mechanism

Institutional readiness is the most consistently emphasized determinant, appearing in 38 of 47 studies.

Core dimensions: Institutional readiness comprises ICT infrastructure and digital ecosystems, leadership commitment and strategic vision, organizational culture and adapt-

ability, funding and resource allocation, governance structures and regulatory coherence, and quality assurance and institutional trust.

Mediating function: A central finding is that institutional readiness mediates the relationship between digital competencies and transformation outcomes: competencies provide capacity, while readiness determines activation and impact.

Empirical evidence: Studies show that institutions with coherent digital strategies achieve more sustainable outcomes; fragmented initiatives produce limited systemic impact; and infrastructure-only approaches fail in the absence of governance and cultural alignment [1,3,7].

Contextual constraints: In many Global South settings, regulatory instability, funding limitations, and constrained institutional autonomy undermine readiness [2,38,51]. The COVID-19 period further demonstrated that readiness—not technology—determines resilience and continuity.

6.5. Governance Alignment and Public-Value Outcomes

Governance alignment is a critical but insufficiently theorized dimension, identified in 29 of 47 studies.

Governance alignment defined: Governance alignment refers to the extent to which digital transformation is strategically aligned with institutional missions, embedded in policy and regulatory frameworks, and supported by accountability, participation, and transparency mechanisms.

Public-value outcomes: The literature associates digital transformation with expanded access and inclusion, enhanced transparency and accountability, improved institutional responsiveness, strengthened trust and legitimacy, and contributions to broader goals such as the SDGs.

Negative public value: Several studies also document risks: digital inequality and exclusion, data privacy and surveillance concerns, algorithmic bias, fragmented governance systems, and forms of data colonialism within global knowledge systems.

Analytical gap: Research remains skewed toward teaching technologies rather than governance systems, with limited integration of academic, administrative, and governance dimensions and weak application of multi-dimensional public-value frameworks [3,49,52]. Consequently, public-value outcomes are conditional on alignment among competencies, readiness, and governance.

6.6. Regional Comparative Trends: Global North Versus Global South

Comparative evidence reveals structurally differentiated trajectories.

Global North contexts: These are characterized by mature governance systems, stable regulatory frameworks, robust funding environments, and advanced digital infrastructure. Priorities include AI governance, learning analytics, strategic innovation, and institutional resilience.

Global South contexts: These are marked by infrastructure deficits, funding constraints, governance capacity limitations, and urban–rural disparities. Studies highlight persistent digital divides, weak regulatory enforcement, limited professional development systems, and risks of data dependency and digital colonialism.

Policy transfer challenges: Policy models imported from high-income contexts often fail in structurally different settings, producing implementation gaps [7,10,38].

Emerging convergence: Despite differences, the COVID-19 pandemic accelerated digital adoption globally and surfaced shared concerns—AI governance, digital ethics, and sustainability. Regional differences thus appear institutional and structural rather than solely technological.

6.7. Absence of Dynamic and Longitudinal Perspectives

A pervasive limitation across the literature is the scarcity of temporal and systems-oriented analyses.

Dominant approaches: Most studies rely on cross-sectional surveys, case studies, or short-term evaluations, frequently undertaken during early implementation phases or crisis contexts [1,10,48].

Missing dimensions: Few studies investigate long-term institutionalization of digital reforms, feedback loops and path dependencies, the evolution of stakeholder trust and perceptions, or the sustainability of initiatives over time.

Implications: This gap constrains understanding of whether early gains persist, how risks evolve, and how governance systems adapt dynamically.

6.8. Synthesis of Findings and Implications for Framework Development

Overall, the findings conceptualize digital transformation in higher education as a multi-level, socio-technical, and governance-embedded process rather than a purely technological shift.

Key synthesis insights:

- Digital competencies enable transformation but are insufficient on their own.
- Institutional readiness mediates the translation of capacity into outcomes.
- Governance alignment conditions whether transformation produces public value.
- Regional and contextual factors shape all dimensions.
- Temporal dynamics remain underexplored.

Persistent gaps: The literature remains fragmented across domains (teaching, administration, governance), divided between efficiency and equity perspectives, biased toward Global North contexts, and weak in addressing power, politics, and long-term dynamics.

Framework justification: These gaps motivate the development of the Global Digital Transformation–Public Value Creation (G-DTPVC) Framework, which integrates competencies, readiness, governance, and outcomes; incorporates contextual moderators (regional, institutional, policy); embeds transformation within a dynamic systems perspective; and explicitly links digital transformation to public-value creation.

7. Discussion

This section interprets the findings by situating them within broader theoretical and policy debates on digital transformation and public value creation in higher education. Moving beyond descriptive synthesis, it elucidates how the interaction between digital competencies, institutional readiness, and governance alignment shapes transformation outcomes across diverse contexts. The findings indicate that while digital competencies are a necessary foundation for transformation, their impact depends on supportive institutional conditions that enable adoption, coordination, capacity building, and scalability. Governance alignment further emerges as a critical moderating mechanism: by shaping how policy, regulation, accountability, and resource allocation coherently align with digital initiatives, it influences the extent to which transformation translates into equitable, efficient, and sustainable public value outcomes. These insights extend public value theory by adopting a dynamic, multi-level perspective that accounts for both organizational and systemic constraints and enabling conditions. They also highlight important contextual disparities—particularly between Global North and Global South settings—where differences in infrastructure, policy capacity, and institutional coordination significantly alter transformation trajectories. Overall, the discussion reinforces the view of digital transformation as a governance-embedded, multi-level, and socio-technical process, while

clarifying the relational pathways through which competencies, organizational readiness, and systemic alignment jointly produce public value in HEIs.

7.1. Theoretical Contributions and Advancement of the G-DTPVC Framework

A central contribution of this study lies in the development and empirical grounding of the Global Digital Transformation–Public Value Creation (G-DTPVC) framework, which integrates technological, organizational, and governance perspectives into a unified analytical model. While prior studies often treat digital transformation as a technical or managerial process, this study conceptualizes it as a multi-dimensional and context-dependent phenomenon, shaped by the interaction of capabilities, institutional conditions, and governance structures.

The framework builds on and extends established theoretical traditions. The Technology–Organization–Environment (TOE) framework highlights how organizational and environmental conditions shape technology adoption [53], while public value theory emphasizes the alignment of institutional activities with societal outcomes [54,55]. Institutional perspectives further explain how governance norms, regulatory environments, and cultural contexts influence transformation trajectories.

Importantly, the findings provide empirical validation of relational mechanisms within the framework:

- Institutional readiness mediates the relationship between digital competencies and transformation outcomes
- Governance alignment moderates how these outcomes translate into public value

This contributes to the literature by moving beyond linear models of technology adoption toward a configurational and interaction-based explanation of digital transformation. It also responds directly to the fragmentation identified in prior research, where competencies, institutions, and governance are often examined in isolation [3,7].

7.2. Digital Competencies and Organizational Transformation

The findings reinforce that digital competencies are foundational but insufficient drivers of transformation. Consistent with prior research, competencies extend beyond technical skills to include pedagogical innovation, data literacy, and managerial capabilities necessary for integrating digital technologies into teaching and administration [12,14,56,57].

This aligns with broader scholarship emphasizing human capital and organizational learning as key enablers of technological innovation [58,59]. Continuous professional development and capacity-building initiatives are therefore critical for fostering a culture of digital innovation. However, the findings also highlight persistent gaps in critical and advanced competencies, particularly in areas such as AI governance and digital ethics.

Moreover, resistance to digital transformation is not simply attitudinal but often reflects structural and institutional constraints, including inadequate training, increased workload, and tensions with professional identity. This supports emerging arguments that digital transformation should be understood as an organizational change process, rather than a purely technological upgrade [2].

7.3. Institutional Readiness as a Critical Mediating Condition

Institutional readiness emerges as the most influential determinant of digital transformation outcomes, reinforcing its central role within the G-DTPVC framework. Consistent with the TOE framework, organizational factors—such as infrastructure, leadership, governance structures, and financial resources—shape the extent to which digital competencies can be effectively mobilized [2,4,53].

The findings demonstrate that:

- Institutions with strong leadership commitment and strategic coherence achieve more sustainable and integrated transformation outcomes
- Conversely, institutions lacking readiness tend to implement fragmented and short-lived digital initiatives

This mediating role of institutional readiness highlights that technological capacity alone does not guarantee transformation success. Instead, outcomes depend on the alignment of competencies with enabling institutional environments.

The COVID-19 period further underscored this dynamic, revealing stark differences in institutional resilience. HEIs with established digital ecosystems and governance structures were able to adapt more effectively, while those with weak readiness faced significant disruptions. This reinforces the argument that readiness is a precondition for both transformation and crisis response.

7.4. Governance Alignment and Public Value Creation

Governance alignment represents a critical bridge between digital transformation and societal outcomes, positioning HEIs as key actors in public value creation. Drawing on public value theory, the study shows that digital transformation generates value when institutional activities align with broader societal needs, policy goals, and stakeholder expectations [54,55,60,61].

The findings indicate that digital transformation contributes to public value through:

- Expanded access to education and flexible learning pathways
- Enhanced transparency and accountability via data-driven governance
- Improved institutional responsiveness and service delivery

These outcomes reinforce the role of universities as knowledge institutions that support social innovation and sustainable development [21,60].

However, the study also identifies a significant gap in the literature: the underdevelopment of governance digitalization as an analytical domain. While teaching and learning technologies dominate the discourse, fewer studies examine how digital tools reshape governance processes such as decision-making, accountability, and stakeholder participation [3,52].

7.5. Reframing Public Value: Benefits and Risks

A major contribution of this study is the reframing of public value as both positive and negative, challenging overly optimistic narratives of digital transformation.

Positive Outcomes:

Digital transformation enhances:

- Educational inclusion and access
- Transparency and institutional accountability
- Efficiency and responsiveness in service delivery
- Alignment with sustainability and development goals

Negative Public Value and Risks:

At the same time, the findings reveal critical risks:

- Digital inequality and exclusion of marginalized groups
- Data privacy and surveillance concerns
- Algorithmic bias and governance opacity
- Data colonialism and power asymmetries in global education systems [29,61]

These risks highlight that digital transformation can undermine public value if governance mechanisms are weak or misaligned. This reinforces the need for ethical, inclusive, and accountable digital governance frameworks.

7.6. Global Inequalities and Contextual Variations

The study reveals significant regional disparities in digital transformation trajectories. High-income contexts are characterized by:

- Mature governance systems
- Advanced digital infrastructure
- Strategic focus on AI, analytics, and innovation optimization

In contrast, Global South contexts face:

- Infrastructure deficits
- Funding constraints
- Governance capacity limitations
- Persistent digital divides

These findings align with comparative research showing that national policy environments and governance arrangements condition institutional capacity and transformation outcomes [2,7,10,38,51]. Importantly, the study highlights the limitations of policy transfer models, where strategies from high-income contexts are applied without adapting to local institutional realities. This often leads to implementation gaps and unsustainable outcomes.

Nevertheless, emerging convergence is observed in:

- Global adoption of online learning during COVID-19
- Shared concerns around AI governance, digital ethics, and sustainability

These patterns suggest that while digital transformation is globally relevant, its outcomes remain highly context-dependent.

7.7. Policy and Governance Implications

The findings underscore that effective digital transformation requires integrated, multi-level governance approaches.

Institutional Level:

- Invest in digital skills development and professional training
- Strengthen leadership capacity and strategic planning
- Build adaptive and innovation-oriented organizational cultures

National Policy Level:

- Align higher education digital strategies with development priorities
- Establish regulatory frameworks for data governance and digital inclusion
- Support funding and infrastructure development

Global Level:

- Promote collaboration and knowledge transfer across regions
- Address structural inequalities in digital access
- Align digital transformation with global agendas such as SDGs 4, 9, and 16

These findings reinforce that technological investment must be complemented by institutional and governance reforms to achieve sustainable public value [2,4].

7.8. Toward a Dynamic and Future-Oriented Research Agenda

Finally, the study highlights a critical limitation in the literature: the absence of longitudinal and systems-oriented perspectives. Most studies rely on cross-sectional designs, limiting understanding of:

- Long-term institutional transformation
- Feedback loops and path dependencies
- Evolution of public value outcomes over time

Future research should therefore:

- Conduct longitudinal and comparative studies across diverse contexts
- Empirically test the G-DTPVC framework
- Examine the temporal dynamics of digital transformation and governance
- Explore emerging issues such as AI governance, digital ethics, and sustainability

Overall, this study advances a holistic and integrative understanding of digital transformation in higher education. It demonstrates that transformation is not merely a technological process but a complex interaction of competencies, institutional conditions, and governance structures, shaped by contextual and temporal dynamics.

The G-DTPVC framework provides a robust analytical tool for capturing these interactions and guiding future research and policy. By emphasizing integration, inclusivity, and governance alignment, the study contributes to a more nuanced understanding of how digital transformation can generate sustainable and equitable public value.

This study makes three interrelated contributions to the literature. First, it advances theory by developing an integrated framework that bridges fragmented perspectives on digital transformation, linking individual competencies, organizational readiness, and governance structures within a unified analytical model. Second, it offers an empirical contribution through a systematic and methodologically rigorous synthesis of 47 studies, identifying consistent patterns, relational dynamics, and critical gaps across diverse contexts. Third, it provides policy-relevant insights by outlining governance pathways that can enhance public value creation in higher education, particularly in resource-constrained environments characterized by institutional and policy fragmentation. Collectively, these contributions shift the discourse from isolated and descriptive analyses toward a more coherent, relational, and impact-oriented understanding of digital transformation, with direct implications for both scholarship and practice.

8. Conclusions

This study set out to systematically examine how digital transformation in higher education institutions (HEIs) contributes to public value creation, addressing a critical gap in the literature where technological adoption is often treated independently of broader societal outcomes. Using a PRISMA-ScR approach, the study synthesized evidence from 47 peer-reviewed studies published between 2013 and 2025, providing a comprehensive mapping of key drivers, processes, and contextual dynamics shaping digital transformation and its implications for public value.

The findings demonstrate that digital transformation in HEIs is not merely a technological or managerial shift, but a complex socio-institutional and governance-embedded process. Central to this process is the interaction of three interdependent dimensions: digital competencies, institutional readiness, and governance alignment. Digital competencies constitute the foundational capabilities required for engaging with digital technologies; however, their effectiveness depends on institutional readiness, which mediates the translation of capacity into implementation outcomes. Governance alignment, in turn, determines whether these outcomes generate meaningful, inclusive, and sustainable public value. This multi-dimensional and relational perspective advances existing scholarship by moving beyond fragmented approaches that treat these elements in isolation [1,3,14].

A major contribution of this study is the development and refinement of the Global Digital Transformation–Public Value Creation (G-DTPVC) framework, which offers an integrated and empirically grounded model for understanding digital transformation in

higher education. By specifying key constructs, relational pathways, and context-sensitive dynamics, the framework bridges technological, organizational, and governance perspectives within a unified analytical structure. It also provides a foundation for future empirical testing, comparative research, and policy-oriented analysis across diverse institutional and regional contexts.

From a theoretical standpoint, the study contributes to ongoing debates by demonstrating that digital transformation must be understood as a configurational and context-dependent phenomenon, shaped by institutional capacities, governance systems, and socio-political environments. It also extends public value theory by incorporating digital transformation dynamics, highlighting how value creation is contingent on alignment between technological innovation and societal objectives [7,61].

From a policy perspective, the findings underscore that effective digital transformation requires holistic and multi-level strategies that go beyond infrastructure investments. While digital transformation can enhance access to education, improve transparency, and strengthen institutional responsiveness, it also introduces significant risks, including digital inequality, data governance challenges, algorithmic bias, and emerging forms of data dependency. Addressing these challenges requires coordinated efforts across institutional, national, and global levels, with particular emphasis on:

- Capacity building and digital skills development
- Strengthening institutional readiness and leadership
- Establishing robust governance and regulatory frameworks
- Promoting inclusive and equitable access to digital education

Such integrated approaches are essential for ensuring that digital transformation contributes to sustainable and socially responsive higher education systems [2,4,13].

The study also situates digital transformation within broader global development agendas, particularly its alignment with Sustainable Development Goals (SDGs) 4 (quality education), 9 (industry, innovation, and infrastructure), and 16 (peace, justice, and strong institutions). By emphasizing governance, inclusivity, and institutional capacity, the study contributes to ongoing discussions on the role of higher education in advancing equitable and sustainable development pathways [12,60].

Importantly, the findings highlight persistent global inequalities and contextual disparities, with the literature heavily skewed toward high-income settings. This underscores the need for more context-sensitive research, particularly in the Global South, where infrastructural constraints, governance challenges, and resource limitations significantly shape digital transformation trajectories.

Finally, the study identifies key directions for future research. There is a need for:

- Empirical validation of the G-DTPVC framework using quantitative and comparative methods
- Longitudinal studies to capture the dynamic evolution of digital transformation and public value outcomes
- Greater focus on Global South contexts and underrepresented regions
- Deeper investigation into governance, ethics, and power dynamics, particularly in relation to AI and data-driven education systems.

A limitation of this review is the inclusion of a small number of studies outside the higher education sector. Although these were selected based on their conceptual relevance to digital governance and public value, their contextual differences may influence the transferability of findings. However, their inclusion strengthens the analytical depth of the review by capturing cross-sectoral insights that are increasingly relevant in digitally transforming higher education systems.

In conclusion, this study advances a holistic, integrative, and policy-relevant understanding of digital transformation in higher education. It demonstrates that achieving sustainable public value requires not only technological innovation but also institutional capacity, governance alignment, and inclusive policy design. The G-DTPVC framework provides a robust foundation for guiding both future research and practical interventions aimed at fostering equitable, accountable, and sustainable digital transformation in higher education systems globally.

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Appendix A. Mapping Global Patterns in Digital Competencies, Institutional Readiness, and Public Value Outcomes in Higher Education (n = 47 Studies)

Table A1 provides a structured mapping of the 47 studies included in this PRISMA-ScR review, summarizing their geographical contexts, institutional settings, competency domains, institutional readiness dimensions, transformation processes, and identified public value outcomes. Given the breadth and detail of the mapping, the table is presented in Appendix A to enhance readability. Rather than interpreting each study individually, the main text develops a narrative synthesis that identifies the key analytical patterns emerging from this mapping, particularly the relationships between digital competencies, institutional readiness, digital transformation pathways, and public value creation in higher education systems.

Note: While the review primarily focuses on higher education institutions (HEIs), a limited number of studies from broader public sector and digital governance contexts are included where they provide transferable insights relevant to HE digital transfor-mation. These studies are classified as "Indirect" in the "HE Relevance Type" column to ensure transparency and methodological consistency.

Table A1. Mapping Global Patterns in Digital Competencies, Institutional Readiness, and Public Value Outcomes in Higher Education (n = 47 Studies).

S/N	Author & Year	Country/ Region	Income Level	HEI Type	HE Relevance Type	Digital Competencies Focus	Institutional Readiness Dimensions	Digital Transformation Process	Public Value Outcomes Identified	Key Insight
1	[8]	Vietnam	Lower-middle	Public university	Direct HE study	Staff and organizational competencies	Strategy, technology, culture	Industry 4.0-oriented	Responsiveness, modernization	Readiness gaps constrain Industry 4.0 ambitions
2	[16]	Kosovo	Upper-middle	Public university	Direct HE study	Organizational digital skills	Infrastructure, leadership	Early digitalization	Administrative efficiency	Resource constraints shape readiness

Table A1. *Cont.*

S/N	Author & Year	Country/ Region	Income Level	HEI Type	HE Relevance Type	Digital Competencies Focus	Institutional Readiness Dimensions	Digital Transformation Process	Public Value Outcomes Identified	Key Insight
3	[11]	Europe	High	Higher education system	Direct HE study	Institutional-level competencies	Data governance, analytics capacity	Data-informed transformation	Accountability, decision quality	Enables evidence-based governance
4	[6]	Mexico	Upper-middle	Public university	Direct HE study	Organizational digital capability	Strategy, culture, infrastructure	Maturity-based	Efficiency, governance quality	Transformation maturity varies
5	[62]	Europe	High	Higher education system	Direct HE study	Faculty competencies	Professional learning ecosystems	Capability development	Teaching quality, innovation	Competencies drive transformation
6	[12]	Europe	High	Higher education system	Direct HE study	Organizational competencies	Innovation governance	Social transformation	Inclusion, social innovation	Public value beyond efficiency
7	[26]	Europe	High	Higher education system	Direct HE study	Digital pedagogy	Institutional frameworks	Risk-aware transformation	Quality assurance	Safeguards mitigate risks
8	[63]	Norway	High	Public university	Direct HE study	Organizational learning	Digital learning spaces	Evolutionary transformation	Learning quality	Transformation is layered
9	[64]	Saudi Arabia	High	Higher education system	Direct HE study	Quality 4.0 competencies	Governance, quality systems	Quality-driven	Accountability, service quality	Readiness determines outcomes
10	[65]	EU	High	Public sector (non-HE)	Indirect	Digital governance capabilities	Institutional capacity, leadership	Strategic governance transformation	Performance, citizen value	Governance reshapes outcomes
11	[66]	UK	High	Public university	Direct HE study	Governance competencies	Board structures, oversight	Governance-led reform	Public accountability	Governance drives transparency
12	[67]	Europe	High	Public sector (non-HE)	Indirect	Evaluation competencies	Performance systems	Evaluation-led transformation	Service quality, trust	Metrics enhance value assessment
13	[68]	Europe	High	Public sector (non-HE)	Indirect	Regulatory competencies	Public value safeguards	Platform governance	Protection of public values	Balance innovation and values
14	[69]	Sri Lanka	Lower-middle	Public sector (non-HE)	Indirect	E-government literacy	Institutional capacity	E-government adoption	Service efficiency	Digital maturity matters
15	[70]	Indonesia	Upper-middle	Public university	Direct HE study	Knowledge management capability	Digital maturity	Maturity progression	Organizational learning	KM drives capacity
16	[71]	Central Asia	Mixed	Higher education system	Direct HE study	Innovation skills	Legal, economic frameworks	Systemic reform	Human capital development	Cross-sector alignment matters
17	[72]	Portugal	High	Public university	Direct HE study	Digital literacies	Pedagogical culture	Pedagogical transformation	Learning quality	Literacies mediate outcomes
18	[47]	USA (global)	High	Higher education system	Direct HE study	Digital literacy, data skills	Leadership, IT governance	Strategic innovation	Competitiveness, quality	Leadership enables value
19	[73]	Russia	Upper-middle	Higher education system	Direct HE study	Digital human capital	Regional ecosystems	Regional digitalization	Workforce capacity	Ecosystems shape outcomes
20	[74]	Europe	High	Higher education system	Direct HE study	Digital capacity	Infrastructure, policy	Systemic transition	Educational quality	Capacity predicts outcomes
21	[75]	Middle East/ India	Upper-middle	Higher education system	Direct HE study	Digital learning orientation	Culture, readiness	Culture-driven transformation	Innovation	Culture moderates readiness
22	[76]	Vietnam	Lower-middle	Public university	Direct HE study	Digital readiness	Infrastructure, leadership	Early transition	Quality enhancement	Infrastructure gaps matter
23	[77]	Latin America	Upper-middle	Higher education system	Direct HE study	Teaching digital skills	Policy barriers	Barrier-constrained	Access, quality	Structural barriers persist
24	[4]	Middle East	High	Higher education system	Direct HE study	Integrated competencies	Policy, governance	Integrated transformation	Resilience	Integration reduces fragmentation
25	[78]	Balkans	Upper-middle	Public university	Direct HE study	Change readiness	LMS governance	LMS transformation	Sustainability	Readiness predicts success
26	[79]	Brazil	Upper-middle	Public university	Direct HE study	Strategic capability	Decision frameworks	Strategy-led transformation	Governance quality	Frameworks guide decisions
27	[80]	Portugal	High	Public university	Direct HE study	Organizational skills	Leadership, culture	Case-based transformation	Teaching improvement	Leadership alignment key
28	[81]	South Africa	Upper-middle	Public university	Direct HE study	Crisis digital skills	Emergency governance	COVID-driven	Continuity, equity	Crisis accelerated change
29	[82]	UK	High	Public university	Direct HE study	Blended-learning skills	Institutional frameworks	Guided transition	Teaching quality	Frameworks enable adoption
30	[83]	Saudi Arabia	High	Public university	Direct HE study	Industry 4.0 competencies	Change readiness	IR4.0 transformation	Innovation	Readiness factors clarified

Table A1. *Cont.*

S/N	Author & Year	Country/ Region	Income Level	HEI Type	HE Relevance Type	Digital Competencies Focus	Institutional Readiness Dimensions	Digital Transformation Process	Public Value Outcomes Identified	Key Insight
31	[84]	Ukraine	Lower-middle	Public university	Direct HE study	Integration competencies	Policy alignment	EU integration	Institutional alignment	Supports regional integration
32	[85]	China	Upper-middle	Public sector (non-HE)	Indirect	Digital economy capability	Institutional quality	Digital economy integration	Equity	Institutions mediate equity
33	[86]	Europe	Upper-middle	Public university	Direct HE study	Sustainability digital literacy	Governance quality	SD integration	Sustainability outcomes	Governance strengthens SD
34	[87]	Nether lands	High	Public university	Direct HE study	Future digital capability	Strategic foresight	Scenario-based transformation	Sustainability	Foresight enhances resilience
35	[88]	China	Upper-middle	Public sector (non-HE)	Indirect	Innovation capability	Governance interaction	Institutional reform	Innovation performance	Governance hybridity matters
36	[89]	China	Upper-middle	Public sector (non-HE)	Indirect	Knowledge transformation	Governance structures	Platform innovation	Innovation balance	Governance enables innovation
37	[90]	Norway & UK	High	Public university	Direct HE study	Governance competence	Trust, accountability	Governance reform	Legitimacy	Trust underpins transformation
38	[91]	South Africa	Upper-middle	Public sector (non-HE)	Indirect	Open governance skills	Transparency systems	E-governance	Service innovation	Openness enhances value
39	[92]	Turkey	Upper-middle	Public sector (non-HE)	Indirect	Public value literacy	Normative governance	Policy transformation	Value clarification	Public value is contested
40	[93]	Latin America	Upper-middle	Public university	Direct HE study	Strategic innovation skills	Governance modernization	Strategic transformation	Competitiveness	Governance drives innovation
41	[10]	Chile	Upper-middle	Mixed HEIs	Direct HE study	Digital maturity	Evaluation frameworks	Transformation assessment	Quality, sustainability	Frameworks guide maturity
42	[94]	Europe	High	Public university	Direct HE study	Online teaching skills	Support systems	Remote teaching	Teaching effectiveness	Teacher presence critical
43	[95]	Indonesia	Lower-middle	Public university	Direct HE study	Curriculum integration	Cultural governance	Curriculum innovation	Cultural sustainability	Local knowledge matters
44	[96]	Malaysia	Upper-middle	Public university	Direct HE study	Student readiness	Infrastructure, inclusion	E-learning adoption	Inclusion, success	Inequality shapes outcomes
45	[97]	Norway	High	Public university	Direct HE study	Digital entrepreneurship	Support structures	Online transformation	Capacity growth	Units act as change agents
46	[98]	Estonia	High	Public sector (non-HE)	Indirect	Digital state capability	National readiness	E-government transformation	Transparency, efficiency	National systems influence HE
47	[99]	Germany	High	Public university	Direct HE study	Governance competencies	Regulatory reform	Governance restructuring	Accountability	Governance shapes transformation

Source: Authors compilation, 2025.

Appendix B. Database Search Strategy and Retrieval Protocol

This Appendix B provides a detailed and reproducible account of the literature search strategy, prepared in accordance with PRISMA-ScR guidelines. It addresses concerns regarding transparency, completeness of search strings, database specificity, filtering procedures, and consistency in reporting timelines and dataset counts.

Appendix B.1. Databases and Search Scope

A comprehensive systematic search was conducted across four major academic databases to ensure broad disciplinary coverage:

- Scopus
- Web of Science Core Collection
- ERIC (Education Resources Information Center)
- Google Scholar

These databases were selected to capture interdisciplinary research spanning higher education, public administration, information systems, and digital governance.

The search covered peer-reviewed journal articles published between January 2013 and December 2025, reflecting the contemporary phase of digital transformation in higher education, including developments in digital learning, artificial intelligence, and data-driven governance.

Appendix B.2. Search Execution Dates

To ensure replicability and transparency, searches were executed on the following dates:

- Scopus: 12 November 2025
- Web of Science: 18 November 2025
- ERIC: 25 November 2025
- Google Scholar: 5 February 2026

These dates correspond to the final retrieval, validation, and updating phase of the dataset.

Appendix B.3. Database-Specific Search Strings

Search strings were constructed using Boolean operators (AND, OR), phrase searching, and truncation (*) to maximize sensitivity and specificity. All truncations and keywords were standardized and corrected.

Scopus search string

("digital transformation" OR "digitalization" OR "digitalisation" OR "digitization")

AND ("higher education" OR universit* OR "tertiary education" OR HEI*)

AND ("public value" OR governance OR "digital competenc*" OR "digital literacy" OR "institutional readiness" OR "digital maturity" OR "digital strategy")

Web of Science search string

TS = ("digital transformation" OR "digitalization" OR "digitalisation" OR "digitization")

AND TS = ("higher education" OR universit* OR "tertiary education" OR HEI*)

AND TS = ("public value" OR governance OR "digital competenc*" OR "digital literacy" OR "institutional readiness" OR "digital maturity" OR "digital strategy")

ERIC search string

("digital transformation" OR "digitalization" OR "digitalisation")

AND ("higher education" OR universit* OR "tertiary education")

AND ("digital competenc*" OR "digital literacy" OR "institutional readiness" OR "educational technology" OR governance)

Google Scholar search strategy

Due to platform constraints, keyword-based searches were used:

- "digital transformation higher education public value"
- "digital governance universities institutional readiness"
- "digital competencies higher education governance"

Screening of Google Scholar results was limited to the first 200 results per query, sorted by relevance, consistent with established scoping review practices.

Appendix B.4. Filters and Inclusion Parameters

The following filters and criteria were applied across databases:

- Document type: peer-reviewed journal articles only
- Language: English
- Timeframe: 2013–2025
- Subject areas:

- Education and Higher Education Studies
- Public Administration and Policy
- Information Systems and Digital Governance

Where database-specific filters differed, equivalent criteria were applied manually during screening.

Appendix B.5. Data Management, Screening, and Refinement Process

The screening process followed a multi-stage PRISMA-ScR protocol, supported by digital tools and manual validation.

Data management tools

- Zotero—reference management and duplicate removal
- Rayyan AI—title and abstract screening

Screening stages

Initial retrieval: Approximately 322,400 records were identified across databases.

10. Automated filtering and relevance sorting: Reduced to 1284 records based on keyword relevance.
11. Duplicate removal: Records reduced to 932 unique studies.
12. Title and abstract screening: 808 studies excluded due to lack of relevance.
13. Full-text eligibility assessment (n = 124): 77 studies excluded based on the following criteria:
    - Non-higher education focus
    - Insufficient methodological transparency
    - Lack of conceptual relevance to digital transformation or public value
    - Purely technical/system design focus without institutional implications
14. Final inclusion: 47 studies retained for analysis.

Appendix B.6. Data Extraction and Coding Transparency

Data from included studies were extracted using a structured charting matrix capturing:

- Bibliographic information (author, year, journal, DOI)
- Study context (region, income level, HEI type)
- Research design and methodology
- Theoretical frameworks
- Key findings and thematic classifications

A corresponding machine-readable dataset (CSV/XLSX) and a codebook defining variables and themes are provided as Appendix A, as recommended by PRISMA-ScR.

Appendix B.7. Consistency and Reporting Alignment

All search parameters, timelines, and dataset counts have been harmonized across the manuscript, including:

- Alignment of the search period (2013–2025)
- Consistency between Appendix B, the Methods section, and the PRISMA flow diagram
- Use of the final dataset size (n = 47) in all analyses

Appendix B.8. PRISMA-ScR Compliance

This appendix complements:

- Figure 2 (PRISMA-ScR flow diagram), which visually presents the study selection process, including reasons for exclusion
- The PRISMA-ScR checklist, provided as Appendix A

Together, these elements ensure full transparency, methodological rigor, and reproducibility of the review process.

Notes and recommendations (optional)

- Number tables and figures in the appendix using an appendix prefix (e.g., Table A1, Figure A1).
- If references appear only in the appendix, include them in the main reference list unless journal policy allows a separate appendix reference list.
- Deposit large datasets and code in a public repository and provide DOIs or URLs in the Appendix A section.

Appendix C. PRISMA-ScR Checklist

This appendix presents the PRISMA Extension for Scoping Reviews (PRISMA-ScR) checklist, following Tricco et al. (2018), to ensure transparency, methodological rigor, and reproducibility of the review process.

Table A2. PRISMA-ScR Checklist.

Section	Item	PRISMA-ScR Checklist Requirement	Reported in Manuscript
Title	1	Identify the report as a scoping review	Title page
Abstract	2	Provide a structured summary (background, objectives, methods, results, conclusions)	Abstract
Introduction	3	Describe the rationale in the context of existing knowledge	Section 1
Introduction	4	Provide explicit statement of objectives and research questions	Section 5.2
Methods	5	Indicate whether a protocol exists and where it can be accessed	Not registered (see Section 5)
Methods	6	Specify eligibility criteria (inclusion and exclusion)	Section 5.6
Methods	7	Describe all information sources (databases, coverage dates)	Section 5.4 and Appendix B
Methods	8	Present full electronic search strategy for at least one database	Appendix B
Methods	9	Describe the process for selecting sources of evidence	Section 5.5
Methods	10	Describe the data charting (extraction) process	Section 5.7
Methods	11	List and define all variables/data items extracted	Section 5.7 and Appendix B
Methods	12	Describe any critical appraisal of included sources	Not conducted (see Section 5.7)
Methods	13	Describe methods for synthesis of results	Section 5.8
Results	14	Provide numbers of sources screened, assessed, and included, with reasons for exclusions	Figure 2
Results	15	Describe characteristics of included sources	Section 6.1 and Appendix A
Results	16	Present results of individual sources (if applicable)	Appendix A
Results	17	Present synthesis of results	Section 6
Discussion	18	Summarize key results in relation to review questions	Section 7
Discussion	19	Discuss limitations of the scoping review process	Section 7
Discussion	20	Provide overall conclusions and implications	Section 8
Funding	21	Describe sources of funding and role of funders	Funding statement

Notes on PRISMA-ScR Compliance

This study adheres to the PRISMA-ScR reporting guidelines [36].

A formal review protocol was not registered. This is consistent with scoping review practice, and all methodological procedures are transparently documented within the manuscript.

No formal risk-of-bias or quality appraisal was conducted, in line with scoping review methodology, which prioritizes mapping the scope and nature of evidence rather than assessing study quality.

Detailed database search strategies, filters, and retrieval procedures are provided in Appendix B, while the study selection process, including reasons for exclusion, is presented in Figure 2 (PRISMA-ScR flow diagram).

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