



Institutional entrepreneurship and digital transformation in higher education: a configurational and structural analysis of digital maturity

Carlos Llopis-Albert¹ · David Juárez-Varón¹ · Jasna Pocek² · Ricardo Costa-Climent³

Accepted: 16 April 2026
© The Author(s) 2026

Abstract

Digital transformation in higher education can be understood as a process of institutional entrepreneurship in which universities mobilize leadership, governance structures and organizational capabilities to reconfigure routines and embed data-intensive technologies into their core missions. Building on this perspective, the study examines how Spanish universities advance digital maturity through a mixed-methods design that integrates institutional-level fsQCA with individual-level SEM. The empirical setting comprises 52 universities and 200 respondents representing faculty, administrators, policymakers and students. At the institutional level, the fsQCA identifies several equifinal configurations that lead to high digital maturity, all of them anchored in the joint presence of faculty digital competence and robust technological infrastructure. At the individual level, the SEM quantifies the structural relationships among five capability domains—strategy, competence, stakeholder involvement, infrastructure and pedagogical innovation—showing that competence and infrastructure exert the strongest net effects, while the remaining domains operate as complementary enablers. Taken together, these findings frame digital maturity as a strategic capability that emerges from the assembly of technological, human and governance resources rather than from linear policy implementation. The study offers a theoretically grounded account of how institutional entrepreneurship shapes digital transformation in universities and provides actionable guidance for strengthening faculty development, infrastructure resilience and participatory governance.

Keywords Digital transformation in higher education · Institutional entrepreneurship · Strategic institutional planning · Faculty digital competence development · ICT infrastructure and governance · Sustainable educational innovation

Extended author information available on the last page of the article

Introduction

Digital transformation has become one of the most significant vectors of strategic renewal in higher education. While universities have progressively incorporated digital technologies over the past two decades, recent European and national initiatives—such as the Digital Education Action Plan 2021–2027—have accelerated the adoption of data-intensive systems, hybrid learning infrastructures and digital governance frameworks (European Commission, 2020, 2023a, 2023b). In Spain, these developments have been reinforced by broader institutional modernization efforts and by the digitalization agenda of public administrations (MAETD, 2021; Greenwood & Suddaby, 2006; Redecker & Punie, 2017). Yet, despite this momentum, implementation patterns remain uneven across institutions, producing marked differences in digital maturity, investment capacity, pedagogical innovation and faculty readiness.

The pandemic played a catalytic role in revealing these disparities. Universities were compelled to deploy remote learning platforms, communication tools and data-driven decision systems at unprecedented speed. Although this shift expanded the diffusion of digital technologies, it also exposed persistent weaknesses: variability in infrastructure quality, uneven digital training among faculty, limited cross-unit coordination and the insufficient integration of technology into pedagogical and organizational routines (Ifenthaler et al., 2021; García-Peñalvo & Corell, 2020). Recent studies indicate that, while administrative digitalization has advanced in many institutions, integrating digital competencies, learning analytics and pedagogical innovation into teaching, assessment and governance remains a challenging endeavor (Bygstad et al., 2022; Esteve-Mon et al., 2023). Analyses of Spanish universities' digital plans similarly highlight disconnections between strategic aspirations and the operational articulation of resources, people and processes (Castañeda et al., 2023).

This growing body of evidence supports the notion that digital transformation is not merely a technological upgrade but a multidimensional institutional change process. From a strategic management perspective, it can be understood as a form of institutional entrepreneurship in which actors—rectors, deans, program directors and digital strategy units—mobilize resources, legitimate new practices and construct narratives of change that challenge established institutional arrangements (Hinings et al., 2018). This lens is particularly valuable in higher education, where historical legacies, professional norms and governance structures interact with emerging digital infrastructures to shape organizational trajectories. It also clarifies why institutions with comparable technological environments may diverge sharply in their ability to achieve sustainable digital maturity.

Within this institutional-entrepreneurship perspective, digital transformation gives rise to digital institutional infrastructures—platforms, analytics systems, cloud-based services—and to new digital organizational forms, such as hybrid learning models, digitalized academic services and algorithmically informed decision routines. Their legitimacy depends on stakeholder acceptance and alignment with academic missions and values (Hinings et al., 2018). Research on absorptive capacity in data-rich environments reinforces this point: the strategic value of data and algorithms hinges not only on their technical deployment but also on coordination mechanisms, formalization practices, socialization processes and the effective integration of tacit and

codified knowledge within organizations (Neirotti et al., 2021). While much of this work emerges from corporate contexts, its insights are directly relevant for universities seeking to build resilient, coherent and participatory digital ecosystems.

Parallel research in higher education has developed maturity models that emphasize technological infrastructure, faculty competencies, organizational culture, governance and pedagogical innovation as key domains shaping digital readiness (Llorens et al., 2021; Gkrimpizi et al., 2024). However, many of these frameworks rely on linear or unidimensional approaches that struggle to capture the configurational nature of institutional change. Empirical evidence increasingly suggests that pathways toward digital maturity exhibit equifinality: different combinations of capabilities can yield comparable outcomes, and no single factor—strategy, technology or training—is sufficient on its own (Hashim et al., 2022). Universities that successfully embed digital practices tend to do so through coherent configurations of capabilities rather than isolated initiatives.

Against this backdrop, methodological approaches capable of capturing complexity, asymmetry and equifinality become essential. Qualitative Comparative Analysis (QCA), particularly its fuzzy-set variant, enables researchers to identify causal configurations associated with high or low digital maturity, recognizing that institutions may succeed through multiple strategic pathways (Ragin, 2008; Llopis-Albert et al., 2018, 2019). Structural Equation Modeling (SEM), in turn, quantifies the relationships among latent constructs such as digital competence, stakeholder involvement, infrastructure quality and innovation orientation (Hair et al., 2019; Kline, 2015). Combining fsQCA and SEM offers a richer explanatory framework: fsQCA clarifies how conditions combine into sufficient configurations, while SEM clarifies to what extent these same capability domains exert direct or indirect effects at the individual-perceptual level.

Despite the relevance of these approaches, empirical studies that integrate fsQCA and SEM in the field of digital transformation in higher education remain scarce. This is particularly true in Spain, where universities operate under strong regulatory pressures, complex governance structures and heterogeneous resource allocations. Understanding how digital transformation unfolds in such a highly institutionalized system requires a design capable of capturing both institutional-level capability patterns and individual-level mechanisms.

This study addresses that need by combining documentary analysis of digital transformation plans from 52 Spanish universities with survey data from 200 faculty members, administrators, policymakers and students. At the institutional level, we use fsQCA to identify sufficient and necessary configurations across five capability domains: institutional digital strategy, faculty digital competence, stakeholder involvement, technological infrastructure and pedagogical innovation. At the individual level, we estimate a SEM model that examines the structural relationships among these same constructs, providing complementary insight into their interdependencies and explanatory power.

This dual approach yields several contributions. Conceptually, it positions digital maturity as a strategic capability emerging from the interaction of technological, human and organizational factors, rather than as a technical endpoint. This view aligns digital transformation research with institutional entrepreneurship, dynamic capabilities and absorptive capacity frameworks (Hinings et al., 2018; Warner &

Wäger, 2019; Neirotti et al., 2021). Empirically, the integration of fsQCA and SEM reveals multiple viable pathways toward high digital maturity and demonstrates the foundational role of faculty competencies and technological infrastructure in enabling strategy, governance and pedagogical innovation to generate meaningful institutional change. This finding resonates with recent analyses highlighting the shift from infrastructure-centered investment to integrative pedagogical and organizational innovation (Romero et al., 2023; Castañeda et al., 2023). Practically, the results provide evidence-based guidance for university leaders, policymakers and digital transformation units seeking to design coherent, participatory and sustainable digital strategies.

Taken together, these contributions support an understanding of digital transformation in higher education as an institutional and strategic process shaped by configurations of capabilities and by the agency of actors engaged in organizational renewal. By combining configurational and structural analytical techniques, this article offers a comprehensive and empirically grounded account of how universities navigate this process.

Literature review

Digital transformation in higher education has progressively shifted from being understood as the mere migration from analog to digital processes to being conceptualized as a multidimensional institutional change process. Initial policy narratives emphasized infrastructure deployment, platform expansion and administrative digitalization (European Commission, 2020, 2023a, 2023b), leading universities to invest heavily in learning management systems, cloud solutions and analytics dashboards. However, empirical studies soon revealed that the availability of technology alone does not explain institutional performance: the adoption and meaningful use of digital tools remain uneven, and pedagogical innovation often lags behind more operational forms of digitalization (García-Peñalvo & Corell, 2020; Bygstad et al., 2022). Analyses of Spanish public universities reinforce this pattern, highlighting gaps between strategic ambitions and their operational articulation, especially in areas such as faculty development, participatory governance and curricular redesign (Castañeda et al., 2023). These findings point to digital transformation (DT) as a systemic and organizationally embedded process in which strategy, resources, culture and structures intersect to condition digital outcomes.

Recent frameworks have therefore advanced more holistic visions of DT, incorporating dimensions such as infrastructure resilience, human capabilities, governance arrangements and ethical data practices. UNESCO's "six pillars" framework, for instance, places people, pedagogy and policy at the same level as infrastructure, data and leadership, arguing for configurations that balance innovation with equity and quality (UNESCO, 2024). In the Ibero-American context, maturity studies by MetaRed/Universia similarly show that institutions follow heterogeneous pathways toward digital maturity depending on how they combine strategic planning, investment models and stakeholder participation (Llorens et al., 2021). This recognition of diversity aligns closely with configurational theories of organizational change, which understand institutional outcomes as the product of multiple interacting conditions rather than as the result of single-factor causal relationships.

Institutional theory offers a powerful lens through which to interpret these dynamics. At its core, institutional theory posits that organizational change is shaped by field-level infrastructures, legitimacy pressures and professional norms that define what is considered acceptable and appropriate (Hinings et al., 2018). Applied to DT, this perspective underscores that technological adoption is inseparable from the institutional work of framing, legitimizing and embedding new practices. Digital transformation, in this sense, takes the form of institutional entrepreneurship: actors such as rectors, deans, program directors and digital units mobilize resources and build coalitions to advance digital infrastructures—platforms, standards, governance routines—whose acceptance depends on their alignment with academic missions and stakeholder expectations (Hinings et al., 2018). This institutional lens clarifies why similar technologies can produce divergent outcomes across universities: field-level structures, professional associations and regulatory bodies create enabling constraints that shape what is feasible, prudent and legitimate at a given point in time (European Commission, 2020).

Within this institutional context, digital maturity emerges not as a static endpoint but as a strategic capability. Drawing on dynamic-capability theory, digital maturity can be understood as an emergent and adaptive configuration of resources, skills and routines that enables the coherent integration of digital practices into teaching, research and service (Warner & Wäger, 2019). Empirical evidence in higher education has converged around several capability domains that consistently influence digital maturity: institutional strategy and leadership, faculty digital competence, stakeholder involvement, technological infrastructure and pedagogical innovation (Llorens et al., 2021; Gkrimpizi et al., 2024). Among these domains, faculty competence and infrastructure frequently function as foundational enablers: without them, digital pedagogies, analytics and innovation efforts struggle to scale or deliver consistent value (Bygstad et al., 2022; European Commission, 2023a). This capability-based understanding resonates with institutional theory, which highlights that new infrastructures require legitimation, training and governance mechanisms that align stakeholders around a shared purpose (Hinings et al., 2018).

The increasingly data-rich nature of universities further reinforces this interpretation. Institutions rely on algorithms and analytics to monitor activities, support decision-making and personalize learning, but the value extracted from these systems depends on organizational mechanisms that transcend technology. Research on absorptive capacity shows that effective use of data requires coordination mechanisms to bridge digital specialists and domain experts, formalization to ensure data quality and reliable workflows, and socialization tactics to integrate tacit and codified knowledge while reducing skepticism toward algorithmic outputs (Neirotti et al., 2021). These insights, although often derived from industrial settings, map closely onto academic environments, where data-informed decisions depend on shared interpretive frameworks across roles and units (García-Peñalvo & Corell, 2020; Romero et al., 2023). Universities that institutionalize liaison roles, codify data-related routines and invest in training are therefore better positioned to convert both “small data” (local, experiential, tacit) and “big data” (platform-level analytics) into coherent strategies and pedagogical innovation (Neirotti et al., 2021; Warner & Wäger, 2019).

Against this backdrop, methodological approaches capable of capturing the complexity, asymmetry and equifinality inherent in DT become essential. Fuzzy-set Qualitative Comparative Analysis (fsQCA) has gained prominence precisely because it models how different combinations of conditions—not necessarily symmetric or linear—produce high or low digital maturity (Ragin, 2008). Prior applications in organizational and educational contexts highlight that fsQCA is especially suitable when outcomes arise from interacting capabilities rather than from isolated drivers (Llopis-Albert et al., 2018, 2019). Complementarily, Structural Equation Modeling (SEM) quantifies the strength of associations among latent constructs, assesses global and local model fit, and estimates both direct and indirect effects (Hair et al., 2019; Kline, 2015). When used together, fsQCA and SEM offer convergent yet distinctive insights: fsQCA illuminates causal configurations and necessity/sufficiency patterns at the institutional level, whereas SEM examines average directional relationships at the individual level, enhancing internal validity and interpretability.

This mixed-method perspective is particularly relevant in higher education systems that exhibit strong institutionalization, such as the Spanish context. Maintaining separate levels of analysis—institutions as cases in fsQCA; individuals as statistical observations in SEM—helps avoid ecological fallacy and clarifies how centrally set strategies interact with locally enacted practices (Ragin, 2008; Hair et al., 2019). It also discourages uniform prescriptions, acknowledging heterogeneity in governance, culture and resources across universities (Castañeda et al., 2023; Llorens et al., 2021).

Synthesizing these streams, the present study focuses on five capability domains central to digital maturity. Institutional Digital Strategy (C1) encompasses strategy, leadership commitment, dedicated funding and policy adaptation; although frequently enabling, it is not uniformly necessary, and bottom-up faculty innovation can compensate in some cases (Hinings et al., 2018; Llorens et al., 2021). Faculty Digital Competence (C2) relates to training, confidence with digital tools and integration into pedagogical practice, and is consistently identified as a decisive driver of effective digitalization (García-Peñalvo & Corell, 2020; Romero et al., 2023). Stakeholder Involvement (C3) encompasses participatory governance and cross-unit collaboration, which support legitimacy and adoption (Hinings et al., 2018; Llorens et al., 2021). Technological Infrastructure (C4) refers to network reliability, platform availability, cybersecurity and service support (Bygstad et al., 2022; European Commission, 2020). Pedagogical Innovation (C5) encompasses AI-enhanced learning, analytics-informed assessment, blended/flipped designs and open educational resources, although its impact is contingent upon competence and infrastructure (Castañeda et al., 2023; Romero et al., 2023). These domains reflect digital maturity as capability assembly: a property emerging from configurations rather than from isolated strengths (Llorens et al., 2021; Hashim et al., 2022).

Building on this theoretical foundation, the study formulates hypotheses aligning with both the institutional-entrepreneurship lens and the capability view of digital maturity. Institutional strategy is expected to exert a moderate positive effect (Hinings et al., 2018; Llorens et al., 2021), faculty competence and infrastructure stronger effects (García-Peñalvo & Corell, 2020; Romero et al., 2023; Warner & Wäger, 2019), pedagogical innovation a smaller but positive effect when properly anchored

(Castañeda et al., 2023; Bygstad et al., 2022), and stakeholder involvement a positive effect linked to legitimacy and diffusion (Hinings et al., 2018; Llorens et al., 2021).

The conceptual model, depicted in Fig. 1, visually represents these relationships and synthesizes the causal logic developed throughout the literature. Recognizing that universities vary in governance structures, historical legacies and resource endowments, the model also considers how capability domains may combine into multiple alternative pathways toward high digital maturity. These complementarities are not modeled as interaction terms in SEM but evaluated configurationally through fsQCA, which identifies sufficient sets of conditions—such as the joint presence of strong faculty competence and robust infrastructure with either participatory governance or institutional strategy—that align with equifinal patterns observed in previous research. fsQCA additionally assesses necessity, examining whether conditions such as faculty competence or ICT infrastructure reach consistency thresholds associated with necessary or quasi-necessary roles.

By grounding digital transformation in institutional entrepreneurship and capability assembly, and by situating the five capability domains within both structural (SEM) and configurational (fsQCA) analytical perspectives, the model provides a coherent and theoretically informed basis for the empirical analyses that follow.

Methodology

This study adopts a mixed-methods design to capture both the configurational and structural logics of digital transformation in Spanish universities. The approach integrates institutional-level fuzzy-set Qualitative Comparative Analysis (fsQCA) with individual-level Structural Equation Modeling (SEM), supported by documentary evidence and a multi-stakeholder survey. This dual strategy responds to the theoretical premise that digital maturity emerges from the interplay of multiple capabilities rather

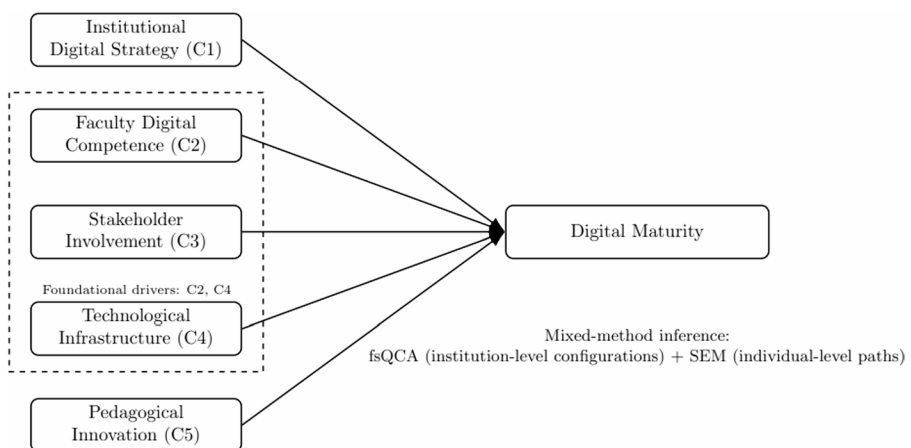


Fig. 1 Conceptual model linking five capability constructs (C1–C5) to digital maturity. Direct effects are assessed via SEM; configurational sufficiency/necessity are assessed via fsQCA

than from single or linear drivers, and to the empirical need to quantify the strength and direction of these relationships (Ragin, 2008; Hair et al., 2019; Kline, 2015). It also aligns with contemporary institutional and capability-based interpretations of digital transformation (Hinings et al., 2018; Warner & Wäger, 2019), as well as with maturity-assessment initiatives in the Ibero-American context (Llorens et al., 2021).

Research setting, data sources, and sample

The empirical setting comprises the Spanish university system, which includes public and private institutions operating under strong regulatory oversight, diverse governance arrangements and heterogeneous resource endowments. To capture both strategic and operational dimensions of digital transformation, the analysis draws on two complementary data sources. First, we conducted a documentary review of institutional digital strategies, public plans and official communications available on university websites and governmental repositories. These documents provide contextual evidence regarding strategic orientations, governance arrangements and infrastructural commitments, consistent with documentary traditions in institutional research (Hinings et al., 2018) and with European digital-education policy frameworks (European Commission, 2023a, 2023b).

Second, we administered a structured survey to stakeholders across Spanish universities, including faculty, administrators, policymakers and students, in order to capture perceptions and practices related to the five capability domains examined in this study: Institutional Digital Strategy (C1), Faculty Digital Competence (C2), Stakeholder Involvement (C3), Technological Infrastructure (C4) and Pedagogical Innovation (C5). A stratified sampling strategy ensured variation by institutional type (public/private), size and geographic region. The fsQCA analysis treats each of the 52 universities as a case, while the SEM analysis draws on 200 valid survey responses, satisfying recommended sample-size thresholds for models of moderate complexity involving five latent constructs (Hair et al., 2019; Kline, 2015) (Table 1).

Participation in the survey was voluntary and anonymous. Respondents provided informed consent electronically, no personal identifiers were collected and all data management procedures complied with the general data protection regulation (GDPR). Institutional characteristics and respondent demographics are summarized in Table 2 of the results section, where variation and representativeness across strata are also discussed.

Survey instrument and construct operationalization

The survey instrument operationalizes the five capability constructs as latent variables measured through multi-item, seven-point Likert scales (1 = strongly disagree; 7 = strongly agree). Items combine elements from validated frameworks with indicators specifically adapted to the higher-education context. The Faculty Digital Competence model (C2), for example, incorporates dimensions from the Digital Competence Framework for Educators (DigCompEdu)—including professional engagement, digital resources, teaching and learning practices, assessment strategies, and learner empowerment—adjusted to reflect course-level activities (European Commission

Table 1 Description of conditions and subfactors (C1–C5)

Condition	Subfactors	Operational definition (indicators)	Primary data source
C1 Institutional Digital Strategy	Leadership commitment; Dedicated funding; Formal strategy document; Policy adaptation mechanism	Presence/quality ratings of official plans; budget lines earmarked for digital transformation; evidence of governance routines (steering committees, roadmaps)	Documentary coding (institutional websites, official plans)
C2 Faculty Digital Competency	Training participation; Integration in courses; Assessment practices	Seven-point items on confidence in tools, course redesign, and assessment use; proportion of modules using digital assessment rubrics	Survey (faculty)
C3 Stakeholder Involvement	Participatory decision-making; Feedback loops; Cross-unit collaboration	Engagement scales; existence of mixed committees; documented cycles of feedback from students and staff	Survey+public minutes
C4 Technological Infrastructure	Network reliability; Platform availability; User support; Cybersecurity posture	Service levels (uptime \geq 99.5%); incident rate per 1,000 users; support response time; coverage of MFA and endpoint security	Documentary coding+IT service reports
C5 Pedagogical Innovation	Analytics-informed assessment; Blended/flipped designs; Open educational resources	Counts/ratings of course level innovations; breadth of adoption across schools/departments	Survey (faculty/administrators)

Note: Calibration of continuous indicators into fuzzy memberships uses percentile anchors: full non-membership (5th), crossover (median), full membership (95th) (Ragin, 2008)

Table 2 Sample characteristics and respondent roles

Institutional sample (fsQCA level)	Count	Percent
Universities (total cases)	52	100.0
Public / Private	42 / 10	80.8 / 19.2
Regions (NUTS1/2)	5	-
Size bands (enrolment)	12 / 23 / 17	23.1 / 44.2 / 32.7
Respondent roles (SEM level; $n=200$)	Count	Percent
Faculty	120	60.0
Administrators	50	25.0
Students / Policymakers	30	15.0

Note: the stratified design ensures variance by type, size and region

2023b). Technological Infrastructure (C4) captures platform availability, network reliability, device provision, cybersecurity posture and support services, consistent with maturity studies in the Ibero-American region (Llorens et al., 2021) and with analyses of digital learning spaces (Bygstad et al., 2022). Institutional Strategy (C1) assesses the existence of formal digital plans, leadership commitment, dedicated funding and mechanisms for policy adaptation, reflecting the institutional-entrepreneurship perspective (Hinings et al., 2018). Stakeholder Involvement (C3) refers to participatory decision-making, feedback loops and cross-unit collaboration. Pedagogical Innovation (C5) encompasses AI-enhanced learning, analytics-informed assessment, blended and flipped designs, and the use of open educational resources,

aligning with critiques of plan-practice gaps in Spanish universities (Castañeda et al., 2023) and with case evidence from the UOC (Romero et al., 2023).

To ensure clarity and contextual relevance, items were pretested with a panel of domain experts, and wording was refined to reduce social-desirability bias and avoid double-barrelled formulations. To maintain the integrity and standardization of the measurement instrument, detailed item-level materials are not reproduced in the manuscript; instead, Table 3 reports all relevant measurement properties (loadings, reliability and validity indices). Measurement-model properties—including factor loadings, reliability and validity indicators—are reported in Table 3 of the results section.

Analytical strategy: institutional fsQCA

At the institutional level, we apply fuzzy-set Qualitative Comparative Analysis to identify configurations of capability conditions (C1–C5) associated with high digital maturity. Using the direct method of calibration, continuous indicators derived from documentary coding and aggregated survey responses are transformed into fuzzy-set membership scores using three anchors: full membership at the 95th percentile, the crossover at the median and full non-membership at the 5th percentile. This percentile-anchored approach is widely adopted in organizational fsQCA applications because it preserves distributional meaning and avoids arbitrary cut-offs (Ragin, 2008; Llopis-Albert et al., 2018, 2019).

A truth table is constructed using the five conditions and the outcome (digital maturity), applying a frequency threshold appropriate to the number of cases and a sufficiency-consistency threshold in the 0.80–0.85 range. Necessity is evaluated against the conventional 0.90 benchmark (Ragin, 2008). Solution terms are derived from the intermediate solution, using theoretically informed directional expectations—such

Table 3 Measurement model diagnostics (confirmatory factor analysis)

Construct	Item	Std. loading	Cronbach's α	Composite reliability	AVE	HTMT range
C1: Institutional Digital Strategy	C1_i1 /	0.79 / 0.82 /	0.83	0.86	0.67	0.42–0.68
	C1_i2 /	0.76				
	C1_i3					
C2: Faculty Digital Competency	C2_i1 /	0.80 / 0.84 /	0.85	0.88	0.70	0.45–0.63
	C2_i2 /	0.78				
	C2_i3					
C3: Stakeholder Involvement	C3_i1 /	0.74 / 0.77 /	0.79	0.82	0.60	0.39–0.58
	C3_i2 /	0.72				
	C3_i3					
C4: Technological Infrastructure	C4_i1 /	0.81 / 0.85 /	0.86	0.89	0.72	0.41–0.61
	C4_i2 /	0.80				
	C4_i3					
C5: Pedagogical Innovation	C5_i1 /	0.71 / 0.76 /	0.78	0.81	0.58	0.37–0.55
	C5_i2 /	0.73				
	C5_i3					
Digital Maturity	DM_i1 /	0.78 / 0.83 /	0.84	0.87	0.69	-
	DM_i2 /	0.80				
	DM_i3					

Note: Global CFA fit: RMSEA=0.049, CFI=0.952, TLI=0.941, $\chi^2/df=1.98$

as the anticipated positive roles of faculty competence (C2) and infrastructure (C4). For each configuration, we report raw coverage, unique coverage and consistency. Robustness checks include varying calibration anchors, adjusting consistency thresholds and comparing intermediate and parsimonious solutions. All analyses are performed with fsQCA 3.0. Table 4 summarises the necessity tests and the sufficient configurations identified. Additional distributional details and intermediate computational outputs are omitted for brevity, as they do not affect the interpretation of the results. This configurational approach captures equifinality and causal asymmetry, complementing linear models in institutional settings (Ragin, 2008; Llopis-Albert et al., 2018, 2019).

Analytical strategy: individual-level SEM

At the individual level, we estimate a covariance-based Structural Equation Model to quantify the structural relationships among the five capability constructs and digital maturity. The SEM specification distinguishes measurement and structural components, with digital maturity modeled as a latent construct shaped by the five exogenous capabilities. Figure 2 presents the model architecture, which guides estimation and the evaluation of measurement quality (Hair et al., 2019; Kline, 2015).

Table 4 Fuzzy-set QCA: necessary conditions and sufficient configurations

Panel A: Necessary conditions for high Digital Maturity					
Condition		Consistency		Coverage	
C1		0.85		0.78	
C2		0.88		0.79	
C3		0.83		0.76	
C4		0.87		0.76	
C5		0.82		0.73	
Panel B: Sufficient configurations (intermediate solution)					
Configuration	Raw coverage	Unique coverage	Consistency	Case IDs	Interpretation
C1*C2*C4	0.45	0.18	0.90	(with-held)	Strategy-driven pathway anchored by competence and infrastructure
C2*C4*C3	0.38	0.14	0.88	(with-held)	Stakeholder-engaged pathway with foundational drivers
C2*C5*C4	0.33	0.11	0.86	(with-held)	Faculty-led innovation anchored in infrastructure

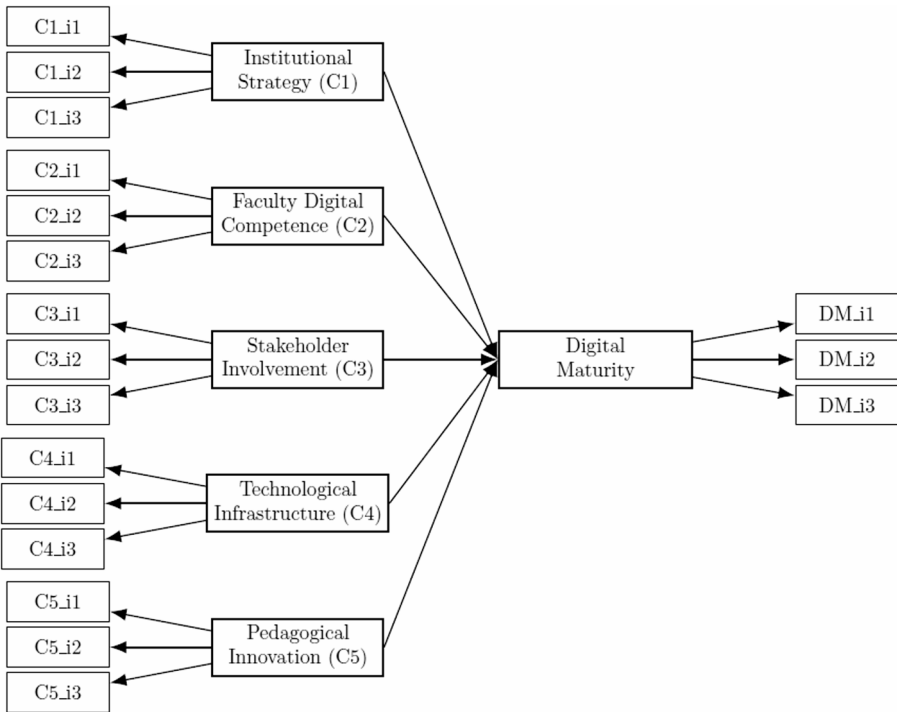


Fig. 2 SEM specification diagram: the measurement model (latent constructs C1–C5 and digital maturity with illustrative indicators) and the structural model (paths from C1–C5 to digital maturity). Coefficients are estimated and reported in the results section

We estimate the model using maximum likelihood with robust corrections (MLR) to address mild non-normality. Missing data are handled through Full Information Maximum Likelihood (FIML) under the Missing At Random (MAR) assumption. Prior to testing structural paths, we assess the measurement model through confirmatory factor analysis, reporting standardized loadings, Cronbach’s alpha, Composite Reliability (CR) and Average Variance Extracted (AVE). Discriminant validity is examined using both the Heterotrait–Monotrait Ratio of Correlations (HTMT) criterion and the Fornell–Larcker framework. Additional diagnostics include variance-inflation factors to assess multicollinearity, Mahalanobis distance for outlier detection, and multi-group invariance tests across stakeholder roles (faculty, administrators, students/policymakers) to evaluate the stability of the model. The SEM results—including path estimates, standard errors, confidence intervals and significance levels—are presented in Table 5. Although coefficients are depicted visually in Fig. 2, they are fully interpreted in the results narrative to ensure clarity and transparency (Hair et al., 2019; Kline, 2015).

Integrating configurational and structural evidence

The mixed-methods logic follows a sequential-complementary design. fsQCA is used first to identify sufficient pathways and to assess necessity at the institutional

Table 5 SEM: path estimates and global fit

Path	β	Std. error	95% CI	<i>p</i> -value
C1 Institutional Strategy → DM	0.19	0.07	[0.05, 0.33]	0.012
C2 Faculty Digital Competence → DM	0.41	0.06	[0.29, 0.53]	<0.001
C3 Stakeholder Involvement →DM	0.16	0.07	[0.02, 0.30]	0.028
C4 Technological Infrastructure →DM	0.37	0.06	[0.25, 0.49]	<0.001
C5 Pedagogical Innovation →DM	0.09	0.05	[-0.01, 0.19]	0.085

Global SEM fit: RMSEA=0.047, CFI=0.955, TLI=0.943, /df=1.93.
DM Digital Maturity, CI confidence interval, RMSEA Root Mean Square Error of Approximation, CFI Comparative Fit Index, TLI Tucker–Lewis Index, standardized path coefficient; *p*-value: evidence against the null

level, capturing equifinality and asymmetry. SEM is then used to quantify the average directional effects among constructs at the individual level, enabling statistical inference on direct and indirect relationships. Convergence between methods is examined by assessing whether capability domains that appear systematically in fsQCA configurations—particularly Faculty Digital Competence and Technological Infrastructure—also exhibit substantive and significant effects in SEM. These convergent patterns align with both maturity frameworks and institutional-entrepreneurship expectations (Hinings et al., 2018; Llorens et al., 2021; Bygstad et al., 2022; Romero et al., 2023). When divergences arise, they are interpreted in light of level-of-analysis differences and aggregation procedures, avoiding ecological fallacy.

Ethics, data protection, and transparency

All procedures complied with established research-ethics standards. Survey participation was voluntary, informed consent was collected electronically, and all data were anonymized at source. Data storage and handling met GDPR-compatible standards applied in Spanish higher-education research. To maintain the integrity of the measurement instrument and protect institution-specific documentation collected under confidentiality, item-level materials, coding manuals and case-level fsQCA outputs are not reproduced in the manuscript. The analysis reports all information required for interpretation and replication at the level of constructs, calibration anchors and solution terms. Institutional documents used for coding are publicly accessible and their URLs are provided when relevant (European Commission, 2023a, 2023b; Llorens et al., 2021).

Data analysis and software

Data preparation followed a structured workflow to ensure comparability across institutions and respondent roles. Documentary evidence was coded using a predefined rubric, while survey responses were screened for missingness, extreme patterns and implausible completion times. At the institutional level, indicators for the five capa-

bility domains (C1–C5) were computed by combining coded documentary data with aggregated survey metrics, using role-weighted means, with robustness checks based on medians and trimmed means. These continuous indicators were calibrated into fuzzy-set memberships via the direct method using percentile anchors at the 95th, 50th and 5th percentiles (Ragin, 2008; Llopis-Albert et al., 2018). fsQCA analyses—including necessity and sufficiency tests, intermediate versus parsimonious solutions and sensitivity analyses—were conducted in fsQCA 3.0.

At the individual level, SEM estimation was performed in R (lavaan) using maximum likelihood with robust corrections (MLR) and Full Information Maximum Likelihood (FIML) for handling missing data under a Missing At Random (MAR) assumption. These procedures were complemented with the diagnostic checks outlined earlier, including assessments of multicollinearity, outlier detection using Mahalanobis distance, and tests of measurement and structural invariance across respondent roles. All analyses were conducted using standard practices for covariance-based SEM, ensuring that the results reported in Table 5 can be interpreted and replicated at the construct level without requiring item-level or case-level supplementary files.

Reporting conventions

Set-theoretic analyses report consistency and coverage values, where consistency reflects the degree to which cases that satisfy a condition or configuration also belong to the outcome set, and coverage reflects the empirical relevance of a condition or configuration in explaining that outcome. Necessity and sufficiency assessments rely on percentile-based direct calibration (5th, 50th, 95th percentiles) following established practice (Ragin, 2008).

SEM results follow conventional reporting standards (Hair et al., 2019; Kline, 2015), including standardized coefficients, robust standard errors, 95% confidence intervals and p-values. Global model fit is evaluated using the Root Mean Square Error of Approximation (RMSEA), the Comparative Fit Index (CFI), the Tucker–Lewis Index (TLI) and the ratio of chi-square to degrees of freedom (χ^2/df), with reference values such as $RMSEA \leq 0.06$, $CFI/TLI \geq 0.90–0.95$ and $\chi^2/df \approx 2$ commonly interpreted as acceptable for multi-construct covariance-based SEM.

Results

The results section presents the empirical findings following the logic of the mixed-methods design. We begin by reporting sample characteristics and the validation of the measurement model, which establish the foundations for the structural analysis. We then present the set-theoretic results at the institutional level, including necessity and sufficiency analyses, and subsequently examine the structural relationships among capability domains at the individual level using SEM. The section concludes with an integrated reading of the configurational and structural evidence.

The institutional dataset comprises 52 Spanish universities, of which 80.8% are public institutions. Representation across enrollment size is balanced, with small,

medium and large universities accounting for 23.1%, 44.2% and 32.7% respectively. The SEM subsample includes 200 individual respondents: 120 faculty members, 50 administrators and 30 students or policymakers. These distributions ensure meaningful variance in governance forms, regional contexts and organizational scales. Table 2 reports these characteristics.

Before examining structural and configurational patterns, we assessed the measurement model. Confirmatory factor analyses indicate that the latent constructs exhibit satisfactory psychometric properties. Global fit indices meet established thresholds (RMSEA=0.049; CFI=0.952; TLI=0.941; $\chi^2/df = 1.98$), suggesting that the multi-factor model provides an adequate representation of the observed data (Hair et al., 2019; Kline, 2015). Standardized loadings exceed 0.70 for all items, and internal consistency indicators are robust (Cronbach's $\alpha \geq 0.78$; $CR \geq 0.81$; $AVE \geq 0.58$). HTMT ratios remain within conservative bounds, supporting discriminant validity. Table 3 summarizes these diagnostics.

Necessity analysis

We first tested whether any single capability domain is necessary for high digital maturity. Table 4 (Panel A) reports necessity-consistency and coverage values. No condition reaches the 0.90 consistency benchmark required for necessity (Ragin, 2008). Institutional Strategy (C1) yields a consistency of 0.85, Faculty Digital Competence (C2) 0.88, Stakeholder Involvement (C3) 0.83, Technological Infrastructure (C4) 0.87 and Pedagogical Innovation (C5) 0.82. These findings indicate that while several domains are frequent components of successful cases, none is indispensable on its own—a pattern consistent with equifinality and with the capability-assembly logic highlighted in the literature.

To ensure transparency, we also inspected the absence-side necessity tests, none of which approached the threshold either. Membership distributions underpinning these calculations follow the usual percentile-based calibration and do not alter the interpretation reported in Table 4. Presenting the distributions is important because, in fsQCA, necessity is sensitive to the density of cases near the fuzzy-set boundaries. In our data, no single domain dominates the upper tail in a way that would warrant necessity.

Sufficiency analysis

We then conducted a sufficiency analysis to identify configurations of capability conditions associated with high digital maturity. Using the direct-method calibration described earlier, we constructed the truth table with all logically possible combinations of C1–C5. Given the size of the case base (52 universities), we applied a frequency threshold of 1 and a sufficiency-consistency threshold in the 0.80–0.85 range, values consistent with prior organizational studies (Ragin, 2008; Llopis-Albert et al., 2018, 2019).

Because the revisor requested greater transparency, the main text includes interpretive summaries of the truth-table structure. In total, the calibration produced 19 empirically populated rows out of 32 logical possibilities. Four rows displayed

contradictory configurations—a common occurrence in social-science applications. Contradictions were resolved by selecting the intermediate solution with theory-consistent directional expectations: specifically, the assumed positive contribution of Faculty Digital Competence (C2) and Technological Infrastructure (C4), both widely identified as enabling conditions in maturity frameworks.

The sufficiency analysis identifies three configurations that meet established consistency standards, summarized in Table 4 (Panel B). The strategy-driven configuration (C1*C2*C4) combines a formal institutional strategy with strong faculty competence and robust infrastructure. It has a raw coverage of 0.45, unique coverage of 0.18 and consistency of 0.90, indicating that this pathway is both empirically relevant and highly reliable.

The stakeholder-engaged configuration (C2*C4*C3) highlights the joint presence of competence, infrastructure and participatory governance. With coverage of 0.38 and consistency of 0.88, this configuration reflects universities where legitimacy processes—engagement, consultation and shared governance—reinforce digital transformation.

The faculty-led innovation configuration (C2*C5*C4) combines competence, pedagogical innovation and infrastructure. Although its coverage (0.33) and consistency (0.86) are slightly lower, it represents an important pathway in universities where innovation emerges from the academic core rather than from top-down strategy.

Across the three solutions, Faculty Digital Competence (C2) and Technological Infrastructure (C4) appear systematically, supporting the interpretation that these domains constitute foundational enablers of digital maturity. This finding mirrors prior analyses showing that innovation and strategy often depend on the operational base provided by competence and infrastructure.

SEM structural results

The structural model complements these configurational insights. Global fit indices again meet accepted standards (RMSEA=0.047; CFI=0.955; TLI=0.943; $\chi^2/df = 1.93$), confirming the adequacy of the SEM specification. Table 5 reports standardized path coefficients. Faculty Digital Competence (C2) exerts the strongest effect on digital maturity ($\beta = 0.41$, 95% CI [0.29, 0.53], $p < 0.001$), followed by Technological Infrastructure (C4) ($\beta = 0.37$, [0.25, 0.49], $p < 0.001$). Institutional Strategy (C1) ($\beta = 0.19$, [0.05, 0.33], $p = 0.012$) and Stakeholder Involvement (C3) ($\beta = 0.16$, [0.02, 0.30], $p = 0.028$) have moderate positive effects. Pedagogical Innovation (C5) has a small but directionally positive effect that does not reach conventional significance levels ($\beta = 0.09$, [-0.01, 0.19], $p = 0.085$).

These results reinforce the idea that competence and infrastructure underpin the system of relationships driving digital maturity, while strategy, participation and innovation operate as contextual enhancers.

Integrated interpretation of fsQCA and SEM

A central aim of the mixed-methods design is to place configurational and structural evidence in dialogue. Both analyses converge on the importance of Faculty Digital

Competence (C2) and Technological Infrastructure (C4). In fsQCA, they appear in all high-maturity configurations; in SEM, they exhibit the strongest net effects. This convergence strengthens the argument that these domains form the operational foundation upon which strategy, governance and innovation rely.

The analyses also highlight meaningful distinctions. SEM suggests that Pedagogical Innovation (C5) has a limited direct effect, whereas fsQCA shows that innovation contributes meaningfully when embedded within competence- and infrastructure-rich environments. This asymmetry aligns with institutional-entrepreneurship insights, which emphasize the role of capability interactions and contextual contingencies.

Finally, the presence of multiple sufficient pathways in fsQCA confirms that digital maturity is not achieved through a single mechanism but through distinct configurations of capabilities. Universities may progress via strategy-driven, stakeholder-engaged or faculty-led routes, depending on their institutional histories, governance structures and resource endowments.

Discussion

The findings of this study show that digital transformation in higher education is best understood as a capability-driven and institutionally embedded process rather than as a linear technological upgrade. By examining Spanish universities through a dual configurational-structural design, the analyses reveal that digital maturity emerges from combinations of strategic, human and infrastructural capabilities, with different institutions following distinct but equally viable pathways.

A first point of convergence between the fsQCA and SEM results concerns the foundational role of Faculty Digital Competence (C2) and Technological Infrastructure (C4). These two domains appear in every sufficient configuration for high maturity (C1*C2*C4, C2*C4*C3, C2*C5*C4) and also display the strongest structural effects in the SEM model. This dual evidence reinforces the idea that competence and infrastructure form the operational backbone of digital transformation: without skilled actors and resilient technological systems, neither institutional strategy, nor stakeholder participation, nor pedagogical innovation translate consistently into meaningful change. This pattern echoes prior literature that identifies the interaction between human capability and technical provisioning as the most stable predictor of institutional digitalisation outcomes (García-Peñalvo & Corell, 2020; Bygstad et al., 2022; Romero et al., 2023).

Yet competence and infrastructure alone do not determine institutional trajectories. The fsQCA identifies three equifinal pathways that illustrate how universities combine these foundational conditions with different complementary enablers. The strategy-driven pathway (C1*C2*C4) reflects institutions where formal leadership commitment and dedicated funding guide digital initiatives and where governance mechanisms align resources across units. This pathway is coherent with institutional entrepreneurship perspectives, which highlight the value of narrative framing, agenda setting and coalition building in enabling digital infrastructures to gain legitimacy in historically layered academic fields.

The stakeholder-engaged pathway (C2*C4*C3) underscores the role of participatory governance. Here, the presence of competence and infrastructure is paired with strong engagement of faculty, students and administrative staff, which appears to create the conditions for collective ownership and diffusion of digital routines. This result aligns with research showing that legitimacy work—through inclusive consultation, user-centred decision-making and feedback loops—helps bridge the gap between strategic intent and everyday academic practices.

The faculty-led innovation pathway (C2*C5*C4) suggests that some universities advance primarily through bottom-up pedagogical innovation when sufficiently supported by competent faculty and adequate infrastructure. This reinforces the idea that digital transformation does not always begin at the institutional-strategy level; it can also emerge organically through the academic core, where innovative teaching practices become the seed of broader organisational change. Such dynamics resonate with scholarship on professional agency in higher education, which emphasises the role of academics as institutional entrepreneurs capable of shaping digital agendas when organisational conditions are favourable.

The SEM results refine these configurational insights by showing that Institutional Strategy (C1) and Stakeholder Involvement (C3) exert moderate but significant net effects, while Pedagogical Innovation (C5) shows a small direct effect that becomes meaningful only when combined with C2 and C4. This asymmetry illustrates the limits of interpreting digital transformation through isolated variables. Innovations introduced without a strong competency base or without infrastructural stability tend to remain fragmented or short-lived, whereas innovations embedded within robust competence-infrastructure ecosystems generate more durable institutional momentum. In this sense, the SEM results complement the fsQCA by highlighting conditional rather than uniform relationships among capabilities.

Taken together, these findings advance the conceptualisation of digital maturity as a strategic capability assembled through interacting conditions, not as a fixed technical endpoint. The presence of multiple sufficient pathways confirms that universities can mobilise different combinations of strategy, participation and pedagogy depending on their governance structures, historical legacies and resource endowments—a point consistently emphasised in institutional theory. The results also show that the institutional environment shapes the types of capability assemblies that become viable. For example, strategy-driven configurations tend to emerge in universities with strong central governance, whereas stakeholder-engaged or faculty-led configurations may be more accessible to institutions with distributed decision-making cultures.

A final contribution of this study is methodological. By integrating fsQCA and SEM, we demonstrate how configurational and structural lenses can be brought into productive dialogue. fsQCA uncovers the combinatorial logic of digital transformation at the institutional level, while SEM clarifies the magnitude and direction of capability effects at the individual level. Their convergence on the dual centrality of competence and infrastructure strengthens the internal credibility of the findings, while their divergences illuminate contextual contingencies and non-linearities that linear models alone cannot capture.

Overall, these results reinforce international policy frameworks that call for balancing human, technological and governance dimensions in digital transformation strategies (European Commission, 2020; UNESCO, 2024). They also provide actionable insights for university leaders: investment in technology and training is essential but insufficient without governance structures or participatory mechanisms that anchor digital practices in everyday academic work. Conversely, institutions that wish to foster bottom-up innovation must ensure the presence of adequate infrastructure and skill depth to avoid isolated pockets of experimentation.

Therefore, the evidence portrays digital transformation as a multi-trajectory process shaped by institutional entrepreneurship, capability assembly and context-specific combinations of strategic, human and technological resources. Rather than converging on a single model of change, Spanish universities follow diverse but viable pathways toward digital maturity, reflecting the institutional diversity of the higher education sector.

Conclusions

This study shows that digital transformation in universities does not advance through isolated technological initiatives, but through the assembly of coherent and mutually reinforcing capabilities. The configurational analysis identified three distinct pathways to high digital maturity—strategy-driven ($C1 * C2 * C4$), stakeholder-engaged ($C2 * C4 * C3$) and faculty-led innovation ($C2 * C5 * C4$)—while the structural estimates clarified the average contribution of each capability domain. When read together, these strands of evidence converge on a clear message: Faculty Digital Competence (C2) and Technological Infrastructure (C4) constitute the operational foundation upon which institutional strategy, participatory governance and pedagogical innovation can be built, adapted and scaled. The absence of any single necessary condition and the presence of multiple sufficient configurations highlight the equifinality of institutional digital transformation, reinforcing the idea that universities can legitimately progress through different combinations of capabilities as long as the foundational drivers are in place.

Conceptually, the findings position digital maturity as a strategic capability that emerges from the interaction of people, platforms and governance arrangements. Rather than a simple indicator of technological readiness, maturity reflects how universities routinize, coordinate and legitimate new digital practices within the constraints and opportunities of their institutional environments. The fsQCA results illustrate the causal asymmetries that characterize capability assembly, while the SEM model quantifies how each domain contributes, on average, to digital maturity. Together, they reconcile institutional-entrepreneurship perspectives—which emphasize narrative framing, coalition building and legitimacy work—with capability-based accounts of strategic renewal that highlight sensing, seizing and transforming organisational routines.

Practically, the evidence offers actionable guidance for university leaders. Institutions aiming to make credible progress must first consolidate the operational base through sustained investment in faculty development and reliable infrastructure. Once this foundation is secure, institutional strategy and stakeholder involvement can be layered in ways that match governance styles and organisational cultures, enabling coordination, diffusion and scale. Pedagogical innovation, in turn, gains traction when embedded in skilled practice and supported by dependable systems, ensuring that experimentation translates into durable and institution-wide change. These implications align with European and UNESCO policy frameworks, which stress the importance of balancing people, platforms and governance in digital transformation agendas.

The study's limitations—its cross-sectional nature, the partial reliance on self-reported data, and the specificity of the Spanish institutional context—suggest caution in generalizing the results. They also open avenues for future research, including longitudinal evaluations of capability investments, multi-country comparisons of institutional infrastructures, mixed-level designs that trace how institutional configurations shape course-level practices, and extensions of the measurement model to address areas such as data governance, cybersecurity and student inclusion. Within these boundaries, the present findings offer a coherent and empirically grounded account of how universities can move from pilots to routinized digital adoption: by building a strong base of competence and infrastructure, by layering strategy and participation in context-sensitive ways, and by designing pedagogical innovation that can travel across the institution and persist over time.

Funding Open Access funding provided thanks to the CRUE-CSIC agreement with Springer Nature.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References





- Bygstad, B., Øvrelid, E., Ludvigsen, S., & Dæhlen, M. (2022). From dual digitalization to digital learning space: Exploring the digital transformation of higher education. *Computers & Education*, 182, 104463. <https://doi.org/10.1016/j.compedu.2022.104463>
- Castañeda, L., Esteve-Mon, F. M., & Adell, J. (2023). La universidad digital: Análisis crítico de los planes de transformación digital de las universidades públicas españolas. *Profesorado*, 27(1), 175–198. <https://doi.org/10.30827/profesorado.v27i1.23870>
- Esteve-Mon, F. M., Postigo-Fuentes, A. Y., & Castañeda, L. (2023). A strategic approach of the crucial elements for the implementation of digital tools and processes in Higher Education. *Higher Education Quarterly*, 77(3), 558–573. <https://doi.org/10.1111/hequ.12411>
- European Commission (2023a). Key enablers for the success of digital education and training (Council Recommendation). Publications Office of the European Union. <https://doi.org/10.2766/113>

- European Commission (2020). Digital education action plan 2021–2027: Resetting education and training for the digital age (COM(2020) 624 final). <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX%3A52020DC0624>
- European Commission. (2023b). *Improving the provision of digital skills in education and training (Council Recommendation)*. Publications Office of the European Union. <https://doi.org/10.2766/750>
- García-Peñalvo, F. J., & Corell, A. (2020). Online assessment in higher education in the time of COVID-19. *Education in the Knowledge Society*, 21(12), 1–26. <https://doi.org/10.14201/eks.23013>
- Gkrimpizi, T., Peristeras, V., & Magnisalis, I. (2024). Defining the meaning and scope of digital transformation in higher education institutions. *Administrative Sciences*, 14(3), 48. <https://doi.org/10.3390/admsci14030048>
- Greenwood, R., & Suddaby, R. (2006). Institutional entrepreneurship in mature fields: The big five accounting firms. *Academy of Management Journal*, 49(1), 27–48. <https://doi.org/10.5465/amj.2006.20785498>
- Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate data analysis* (8th ed.). Cengage Learning. <https://prod.cengageasia.com/title/default/detail?isbn=9781473756540>
- Hashim, M. A. M., Tlemsani, I., & Matthews, R. (2022). Higher education strategy in digital transformation. *Education and Information Technologies*, 27(3), 3171–3195. <https://doi.org/10.1007/s10639-021-10739-1>
- Hinings, B., Gegenhuber, T., & Greenwood, R. (2018). Digital innovation and transformation: An institutional perspective. *Information and Organization*, 28(1), 52–61. <https://doi.org/10.1016/j.infoandorg.2018.02.004>
- Ifenthaler, D., Hofhues, S., Egloffstein, M., & Helbig, C. (Eds.). (2021). *Digital transformation of learning organizations*. Springer. <https://doi.org/10.1007/978-3-030-55878-9>
- Kline, R. B. (2015). *Principles and practice of structural equation modeling* (4th ed.). Guilford Press.
- Llopis-Albert, C., Merigó, J. M., Xu, Y., & Liao, H. (2018). Application of fuzzy set/qualitative comparative analysis to public participation projects in support of the EU Water Framework Directive. *Water Environment Research*, 90(1), 74–83. <https://doi.org/10.2175/106143017X15054988926550>
- Llopis-Albert, C., Rubio, F., & Valero, F. (2019). Fuzzy-set qualitative comparative analysis applied to the design of a network flow of automated guided vehicles for improving business productivity. *Journal of Business Research*, 101, 737–742. <https://doi.org/10.1016/j.jbusres.2018.12.076>
- Llorens, F., Fernández, A., Rodríguez, T., Cadena, S., & Franco, C. (2021). UDigital 2020: Estudio de la madurez digital en sistemas universitarios iberoamericanos. [Report]. *MetaRed Universia*. <https://www.metared.org>
- MAETD (2021). Ministerio de Asuntos Económicos y Transformación Digital (España). Plan de Digitalización de las Administraciones Públicas 2021–2025. https://administracionelectronica.gob.es/pae_Home/dam/jcr:ae43f87a-9cdb-4ed9-9d78-d665a5d8491a/Plan_Digitalizacion_sp_ACC.pdf
- Neirotti, P., Pesce, D., & Battaglia, D. (2021). Algorithms for operational decision-making: An absorptive capacity perspective on the process of converting data into relevant knowledge. *Technological Forecasting & Social Change*, 173, 121088. <https://doi.org/10.1016/j.techfore.2021.121088>
- Ragin, C. C. (2008). *Redesigning social inquiry: Fuzzy sets and beyond*. University of Chicago Press. <https://doi.org/10.7208/chicago/9780226702797.001.0001>
- Redecker, C., & Punie, Y. (Eds.). (2017). *European framework for the digital competence of educators (DigCompEdu)* (EUR 28775 EN). Publications Office of the European Union. <https://doi.org/10.2760/159770>
- Romero, M., Romeu, T., Guitert, M., & Baztán, P. (2023). La transformación digital en la educación superior: el caso de la UOC. *RIED-Revista Iberoamericana de Educación a Distancia*, 26(1), 163–179. <https://doi.org/10.5944/ried.26.1.33998>
- UNESCO (2024). Six pillars for the digital transformation of education: A common framework (ED-2024/WS/23 Rev.). [Report]. <https://unesdoc.unesco.org/ark:/48223/pf0000391299>
- Warner, K. S. R., & Wäger, M. (2019). Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal. *Long Range Planning*, 52(3), 326–349. <https://doi.org/10.1016/j.lrp.2018.12.001>

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.

Authors and Affiliations

Carlos Llopis-Albert¹  · **David Juárez-Varón**¹  · **Jasna Pocek**²  ·
Ricardo Costa-Climent³ 

✉ Carlos Llopis-Albert
cllopisa@upvnet.upv.es

David Juárez-Varón
djuarez@upv.es

Jasna Pocek
jasna.pocek@santannapisa.it

Ricardo Costa-Climent
ricardo.costa@uv.es

¹ Department of Mechanical and Materials Engineering, Universitat Politècnica de València (UPV), Camino de Vera s/n, Valencia 46022, Spain

² MES Laboratory, Institute of Management Sant Anna School of Advanced Studies, Pisa, Italy

³ Department of Accounting, University of Valencia, Valencia, Spain