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ORIGINAL

University digital transformation as an institutional maturity process toward intelligent literacy

La transformación digital universitaria como proceso de madurez institucional hacia la alfabetización inteligente

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ABSTRACT

This study examines university digital transformation as a process of institutional maturity oriented toward knowledge governance. The research begins with the recognition of a structural gap between the promise of digitalization and its effective realization within higher education institutions, characterized by technological fragmentation and the absence of integrated data management. A mixed and applied approach was adopted, articulated through four iterative phases—diagnosis, design, implementation, and validation—supported by a comprehensive review of scientific literature and the triangulation of documentary, metric, and testimonial evidence. The results demonstrate the effectiveness of the *in-house* development of a modular and interoperable digital ecosystem that integrates core processes such as admissions, academic records, payments, enrollment, and scheduling, ensuring traceability, coherence, and efficiency. The designed model consolidates knowledge management through master catalogs and interoperability flows that enable informed decision-making and organizational learning. It is concluded that digital transformation transcends the technical dimension and becomes a cultural and cognitive experience sustained by data transparency, institutional co-responsibility, and critical understanding of technologically mediated knowledge. The research provides a replicable framework for Latin American contexts, demonstrating that digital maturity is built through praxis and situated reflection.

Keywords: Digital Transformation; Higher Education; Governance; Information Technology; Digital Skills; Knowledge Management and Data Interoperability.

RESUMEN

El presente trabajo analiza la transformación digital universitaria como un proceso de madurez institucional orientado a la gobernanza del conocimiento. La investigación parte de la constatación de una brecha estructural entre la promesa de la digitalización y su concreción efectiva en las instituciones de educación superior, marcada por la fragmentación tecnológica y la ausencia de gestión integrada del dato. Se adopta un enfoque mixto y aplicado, articulado en cuatro fases iterativas: diagnóstico, diseño, implementación y validación; sustentadas en la revisión de literatura científica y la triangulación entre evidencia documental, métrica y testimonial. Los resultados evidencian la eficacia del desarrollo *in house* de un ecosistema digital modular e interoperable que articula procesos misionales como admisiones, registro académico, pagos, matrícula y programación, garantizando trazabilidad, coherencia y eficiencia. El modelo diseñado consolida la gestión del conocimiento mediante catálogos maestros y flujos

de interoperabilidad que permiten decisiones informadas y aprendizaje organizacional. Se concluye que la transformación digital trasciende la dimensión técnica y deviene una experiencia cultural y cognitiva sustentada en la transparencia del dato, la corresponsabilidad institucional y la comprensión crítica del conocimiento mediado tecnológicamente. La investigación aporta un marco replicable para contextos latinoamericanos, demostrando que la madurez digital se construye desde la praxis y la reflexión situada.

Palabras clave: Transformación Digital; Educación Superior; Gobernanza; Tecnología de la Información; Alfabetización Digital; Gestión del Conocimiento e Interoperabilidad de Datos.

INTRODUCTION

Digital transformation in higher education is now an unavoidable phenomenon and, at the same time, a constantly evolving construct. Institutions are immersed in an environment of epistemological bifurcations, characteristic of the Fourth Industrial Revolution, where technology is not an end in itself, but rather an ontological correlate of the cultural and cognitive changes sweeping through academic practices. Despite this, many HEIs remain at an early stage of digital maturity, with limited and fragmented efforts that lack strategic alignment between people, processes, data, and knowledge.[1,2] Consequently, digital transformation must be understood *from a practical perspective* as an experience of institutional reconfiguration, a process in which the technical, the pedagogical, and the symbolic converge in an in situ framework of continuous innovation.[3,4]

In Latin America, the acceleration imposed by the pandemic constituted an ontological test of universities' adaptive capacity. However, its rapid transition revealed the obsolescence of infrastructure, the educational asymmetry of teaching staff, and the lack of systemic coordination. Although fruitful experiences with artificial intelligence and data analytics have emerged, structural gaps persist that hinder sustainable technological governance. Hence, intelligent literacy requires integrated digital ecosystems, conceived as spaces of correlation and resonance between the human and the algorithmic, where technology becomes an ethical medium of knowledge.[5,6,7] These ecosystems represent a new paradigm in academic writing, where feedback and evaluation engage in an intersubjective dialogue with AI to foster a culture of self-regulated and critical learning.

The most advanced models of digital transformation are based on interoperable architectures that inscribe technology in the logic of transparency and institutional traceability.[8] The contiguity of systems is not reduced to a functional sum; instead, it involves the emergence of a common semiotic space where data, decisions, and actors are in dynamic correlation. The university, understood in this way, becomes a construct of cognitive governance, capable of providing real-time feedback and learning. In this sense, innovative literacy is not merely a technical skill: it is a praxis of situated understanding, an exercise in discerning the limits and possibilities of AI-mediated knowledge.[6]

In the Colombian case, technological fragmentation has led to a structural bifurcation between the digital promise and its practical realization. The duplication of processes, the dispersion of data, and the lack of interoperability generate a lag that restricts the capacity to respond to new pedagogical and administrative environments.[9,10] Overcoming these contingencies involves establishing digital frameworks that can articulate mission and support processes under the principles of integration and sustainability.[4] In this transition, AI emerges not as a substitute for human judgment but as a catalyst for literacy that combines ethics, efficiency, and collective meaning.

Thus, embracing digital maturity as a process involves transcending the mere incorporation

of technological tools and thinking about transformation from the perspective of knowledge governance. As Rahmadi[11] warns, digital innovation requires a balance between infrastructure and cultural appropriation of data. Interoperable ecosystems, in this perspective, constitute a way of framing institutional trust in traceability and transparency.[12,13] Digital technology thus becomes a means of epistemic legitimation that allows academic authority to be rebuilt through evidence, while promoting critical and ethical literacy around the use of artificial intelligence.[14]

The design of sustainable digital ecosystems requires the methodological rigor characteristic of all applied science. The roadmap is structured in iterative cycles of diagnosis, design, implementation, and evaluation, articulated by the logic of interoperability.[15,16] This approach, based on mixed methods and participatory validation, aims to establish genuine correlations between technology management and meaningful learning. AI-mediated writing, feedback, and evaluation are expressions of intelligent literacy that not only optimize processes but also reconfigure the way universities produce, distribute, and legitimize knowledge.[17]

The projected result transcends technical functionality to establish itself as a mature digital culture, based on the appropriation of knowledge and critical reflection on technological mediation. The integration of academic and administrative systems enables the creation of an expansive learning environment, where educational analytics informs evidence-based pedagogical decisions.[18] In this convergence, AI operates as an epistemological correlate that enhances autonomy, co-creation, and data ethics.[19] Thus, institutional literacy with AI is not limited to the acquisition of digital skills, but rather shapes a way of thinking: a way of being in knowledge, aware of its boundaries and its transformative power.

This study seeks to validate, from a practical standpoint, an interoperable digital ecosystem that articulates the academic, administrative, and technological processes of an HEI in a contiguous manner, so that intelligent literacy ceases to be a desideratum and acquires scientific status in day-to-day management. Instead of adding tools *per se*, it proposes an itinerary that diagnoses the current maturity and bifurcation between promise and realization, designs a modular and scalable architecture, implements integrations with data traceability, and evaluates, using mixed methods, its impact on efficiency, feedback, and usability. The relevance is twofold: on the one hand, it addresses the fragmentation that hinders knowledge governance, reduces duplication, and enables evidence-based decisions; on the other hand, it fosters a culture of writing, evaluation, and AI-mediated co-creation that operates intersubjectively, with criteria of ethics, transparency, and sustainability. By framing technology as a mediator of meaning rather than an end in itself, the study offers a replicable model for resource-constrained contexts, strengthens institutional autonomy, and contributes to closing gaps in access and quality, reconfiguring the way the university learns, legitimizes, and distributes knowledge.

DEVELOPMENT

The study was conducted at a Colombian higher education institution that chose to develop its own digital ecosystem *in situ*, aiming to integrate academic, administrative, and technological processes. This methodological decision responds to a logic of institutional bifurcation that prioritizes technological autonomy over outsourcing models, while consolidating sustainable internal capacities and fostering progressive organizational maturity through knowledge governance.[11,12] This was an applied research project with a mixed approach, structured in four iterative cycles: diagnosis, design, implementation, and validation, whose rigor was sustained by the convergence of quantitative and qualitative approaches under the same observation construct. The document review was limited to scientific literature and public reports from the period 2018–2025, while the empirical component was based on interviews with key actors, non-participant observation, and functional tests. Throughout the process, interoperability served as a guiding principle, ensuring data traceability, operational transparency, and informed

decision-making.[8,13]

The sample was delimited through intentional sampling, focusing on the mission processes with the most significant systemic impact: admissions, academic records, payments, enrollment, scheduling, student creation, teacher creation, and curriculum development. This methodological approach enabled *in-house* observation of the turning point in institutional fragmentation, as described in regional literature as one of the main challenges of university digitization.[9,10] Descriptive and correlational analyses were used for the quantitative component, while thematic coding techniques and intersubjective validation matrices were applied for the qualitative component. The triangulation between documentary evidence, institutional metrics, and user testimonials enabled a robust correlation between the factual and the interpretive, ensuring analytical consistency and hermeneutic depth.[5,15]

Finally, to circumscribe the methodological intervention, the mission processes were reorganized into observable categories that condense the institutional impact at different levels of digital maturity. This taxonomy, conceived as an analytical correlate of organizational praxis, translates operational complexity into audibly verifiable variables and indicators, in line with contemporary approaches to educational architecture, interoperability, and data governance.[1,6,8,20] In short, the epistemological purpose was to configure a decidable map that would allow us to infer, with empirical rigor and comparative criteria, the effects of technological integration on the efficiency, traceability, and quality of institutional service.

Table 1. Categories of mission processes and observable variables

Process	Critical subprocesses	Observable variables	Indicators	Public sources of comparison	Risks/Limitations
Admissions	Reception and verification of applicants; status assignment	Response time; completeness rate; verification errors	T_resp (h); % completed forms; % reprocessed forms	Studies on one-stop shops and efficiency[15]	Data entry biases; missing data
Academic record	Creation of files; approvals; grades	File integrity; catalog-subject consistency	% complete files; % inconsistencies	Data maturity and integrity[1]	Outdated catalogs; duplication
Payments	Settlement; reconciliation; portfolio statements	Payment–enrollment synchronization; reconciliation errors	% synchronizations in 24 hours; % differences	Digital institutional efficiency[18,20]	Reconciliation times; external sources
Enrollment	Course registration; validations; blocks	Validation errors; registration times	% correct blocks; T_registration (min)	Integrated academic transformation [16]	Peaks in demand; bottlenecks
Academic scheduling	Supply; schedules; teacher allocation; classrooms	Supply coverage; schedule conflicts	% conflicts; % groups with teachers	Educational architecture and allocation[8]	Incomplete information; late changes
Student creation	Identity registration; profiles; updates	Master data quality; duplicates	% valid records; % duplicates	Data governance and master catalogs[13]	Field standardization
Teacher creation	Registration; validation of qualifications; uploading; contracts	Contract traceability; consistency between workload and teaching	% of contracts with supporting documentation; % consistent assignment	Digital HR management[19]	External verification; approval times

Curricula	Parameterization; learning outcomes; versions	Plan-offer alignment; validity	% of subjects with RA; % of current plans	Curriculum and learning outcomes (QA literature)	Inconsistent versioning

Cross-reading categories and indicators identify areas for improvement where high transactional load and low standardization converge. Admissions–registration indicates the transition from duplicate records to single files; payments–enrollment shows the shift from late reconciliations to measurable synchronizations; scheduling reveals sensitivity to incomplete catalogs. This pattern is consistent with international evidence, indicating that the most significant benefits arise when interoperability and data governance are integrated into day-to-day operations.[8,16,20]

The document review was conceived as a synthesis of scientific evidence to support design decisions. A narrative-exploratory review protocol was adopted, incorporating systematic elements in recognized databases (Scopus, MDPI, Web of Science, and Google Scholar), with a focus on the 2018–2025 period and Latin American literature where relevant. The table specifies inclusion/exclusion criteria, extraction procedure, and expected results, avoiding any reference to internal documentation and focusing the rationale on academic sources and public reports.

Table 2. Protocol for reviewing scientific literature and public reports

Source/Type	Inclusion criteria	Exclusion criteria	Extraction procedure	Evidence/Results
Indexed articles	2018–2025; HE digital transformation; educational AI; interoperability	Opinions without method; duplicates	Searches with strings and filters; study summary: objective, method, findings	Evidence matrix by topic
Reviews and mappings	Conceptual framework and maturity models	Non-university setting without transferability	Extraction of definitions, dimensions, and metrics	Synthesis of key constructs
Case studies	Systems integration; efficiency; traceability	Cases without verifiable data	Variables, indicators, reported effects	Bank of comparable metrics
Reports from agencies/regulators	Public guidelines and standards	Unverifiable documents	Extraction of suggested indicators	List of reference KPIs
Regional literature	Latin American context and gaps	Anecdotal coverage	Approaches, barriers, enablers	Risk/regulation matrix

The synthesis reveals convergences: a) interoperability and master catalogs as conditions for efficiency,[8,13] b) data traceability for decision-making and control,[18,20] c) curricular-operational articulation for educational impact,[16], and d) regional specificities that require scalable and austere solutions.[5,6] These findings guide the selection of indicators and prioritize high-return integrations.

The evaluation was based on methodological triangulation combining: scientific documentary evidence (what "should happen"), quantitative operational metrics (what "is happening"), and qualitative user testimonials (how change is "experienced"). The matrix links each evaluative question with sources and convergence thresholds to translate evidence into design and iteration decisions.

Table 3. Data triangulation matrix

Evaluative question	Documentary evidence (literature)	Quantitative evidence	Qualitative evidence	Convergence criterion	Decision/Action
Where is the critical fragmentation?	Reported flows and bottlenecks[15]	Times and % of reprocessing per process	User friction narratives	≥ 2 matching sources	Adjust flows and exchange rules
Does interoperability improve efficiency?	Integration models[8]	↓ T_resp; ↑ % 24-hour synchronies	Perception of transparency	Consistent trend over 2 periods	Scaling APIs and catalogs
Does a single file reduce duplicates?	Data governance[13]	↓ % duplicates; ↑ integrity	Ease of search	Reduction ≥ 20% duplicates	Consolidate master and validators
Does integrated programming reduce conflicts?	Good HE practices[16]	↓ % conflicts per period	Positive academic coordination	Sustained decline	Optimize algorithm and windows

Convergences place the highest return at high-traffic intersections (admissions–registration, payments–enrollment, scheduling–teaching). When metrics and testimonials improve consistently, priority is given to scaling integrations and strengthening catalogs; if discrepancies persist, business rules are adjusted and master data cleansing is reinforced.

To estimate the effects of integration, a quantitative analysis plan was defined with variables sensitive to operational change and perceived service. The table specifies the type of variable, statistics, tests, and visualizations so that the analysis is reproducible and comparable with previous studies of digital efficiency in HEIs.[18,20]

Table 4. Quantitative analysis plan

Variable/Indicator	Type of variable	Statistics / Tests	Planned visualizations	Tools
Response times	Continuous (min/h)	Median, IQR, %Δ pre-post	Time series	R / Python / Excel
Completeness rate	Proportion (%)	95% CI; x^2	Bars per process	R / Excel
Duplicates in master	Count / proportion	%Δ; duplicate ratio	Bars before/after	SQL / Excel
Schedule conflicts	Count per period	Rate per 100 groups; %Δ	Heatmap by time slot	Python
Payment–enrollment synchronization 24h	Proportion (%)	95% CI; trend	Bars with target	R / Excel

This framework captures key shifts: reduction in medians and IQR in times, decrease in duplicates and collisions, and increase in synchrony in 24 hours. Proportion tests and trends introduce criteria of significance and temporal stability, avoiding overreactions to circumstantial variations. The result is a robust reading of progress toward traceability and efficiency, comparable to benchmarks reported in the literature.

The qualitative component adds interpretive density to the metrics. Axial coding was used to collect central categories of cultural and operational change, with definitions, signals, and examples of citations. The matrix allows us to observe how the language of the actors evolves (from complaints about silos to the appropriation of traceability), consistent with the transitions described in studies of digital adoption in higher education.

Table 5. Qualitative coding scheme

Axial code	Operational definition	Indicators / Signals	Citation example
FRAG_INTEROP	Fragmentation vs. interoperability	"Silos," reprocessing, rework	"Double data entry in admissions and registration"
TRAZ_TRANSP	Data traceability and transparency	Auditing, change tracking	"Now we can see who approved and when"
USAB_APROP	Usability and technological appropriation	Ease of use, support	"The registration module is clearer"
GOB_DATA	Data governance and catalogs	Roles, data quality	"We have appointed a person responsible for the catalog."
IMPACT_EFI	Impact on efficiency and service	Times, errors, satisfaction	"It used to take days; now it takes hours."

The narratives show a significant shift: complaints about double typing give way to appreciation of the audit trail and those responsible for the catalog. This semantic shift suggests that smart literacy is not just technical training, but a data culture based on evidence and distributed responsibility. The link between usability and error reduction reinforces the thesis that people-centered design is a condition for appropriation.

Finally, threats to validity were identified and mitigation strategies were defined with expected evidence and conceptual references. The idea is to anticipate biases and maturations typical of complex interventions and document how they are controlled, in line with methodological recommendations from the literature on digital transformation in HEIs.

Table 6. Validity, reliability, and mitigations

Threat	Mitigation strategy	Expected evidence	Reference
Social desirability	Anonymous interviews; neutral guides	Convergence of narrative and metrics	Vázquez et al.[15]
System maturation	Wave measurements; comparable windows	Stable trends	Rivera-Gutiérrez et al.[5]
Quality of historical data	Profiling and pre-cleaning	Integrity report	Udovenko[13]
Parallel changes	Intervention log	Sensitivity analysis	Gomes et al.[8]

The combination of wave measurements, data cleansing, anonymous interviews, and change logging reduces the likelihood of spurious inferences and, above all, turns each threat into an organizational learning device. This ensures that digital maturity is expressed in sustainable practices of evidence, transparency, and critical review, in line with recent literature on university transformation.

The diagnosis corroborated the coexistence of non-integrated applications, duplicate records, and the absence of verifiable data governance, findings consistent with the maturity gaps documented in HEIs.[1,2] In response, a modular architecture based on open standards was outlined, articulated through a service bus and master catalogs, with integrity, accessibility, and scalability as its operating principles.[8,13] The proposal assumes transformation as a multidimensional process; that is, beyond the instrumental, it calls for organizational and cultural reconfigurations, in line with international mappings on higher education and artificial intelligence.[3,4,7]

The first results materialized in the admissions module, which automates the reception, validation, and tracking of applicants through innovative forms, business rules, and a unified database. Then, the academic record module consolidated the student's single file and standardized program and course catalogs. The contiguity of admissions and registration

generated a synergistic flow that eliminated reprocessing and improved the availability of real-time data, aligning with single-window experiences in higher education[15] and with recommendations for traceability to inform decision-making.[20] This milestone sets the stage for timely, evidence-based feedback.

In the next iteration, payments and enrollment were integrated, linking financial and academic logic through automatic validations, transactional statements, and operational reports. In parallel, academic programming orchestrated offerings, schedules, groups, and faculty availability from a unified view. Interoperability between these modules enabled consistency between installed capacity, faculty workload, and projected offerings, in line with academic management models with integrated LMS.[16] The result is a decidable and traceable circuit that mitigates bottlenecks and optimizes the user experience, consistent with digital transformation frameworks and educational enterprise architecture.[6,8]

The third wave focused on student creation, teacher creation, and curriculum development. The first module ensures continuous updating and quality control of master data; the second incorporates training verification, workload management, and contract traceability; the third parameterizes curricula and associates learning outcomes and plan versions. This triad links academic governance, curriculum design, and administrative support, overcoming fragmented digitization to configure an ecosystem with pedagogical, operational, and ethical meaning.[4,11] Empirical correlations are thus established between institutional planning, execution, and evaluation.

As a projection, functionalities were specified for certificate downloads, grade management, faculty hiring, faculty development, educational analytics dashboards, and continuous feedback. These extensions seek to institutionalize data-driven improvement and transparency, consistent with the call for sustainable and inclusive ecosystems.[14,18] The roadmap envisions evaluating usability and technological adoption, strengthening digital capacities, and consolidating data governance as a shared responsibility. In short, the evidence suggests that *in-house* development accompanied by documentary review and participatory validation is a plausible way to advance toward higher levels of digital maturity in Latin American contexts.[5,17,21]

CONCLUSIONS

The diagnosis revealed a structural divide between the digital promise and its operational implementation. The coexistence of non-interoperable applications, duplicate records, and the absence of effective data governance constituted critical issues that compromised traceability and institutional service. The intersubjective reading of metrics, testimonials, and literature made it possible to identify areas of fragmentation in the pairs admissions–registration, payments-enrollment, and scheduling–teaching. The cardinal inference establishes that efficiency is not a function of more technology, but instead of rigor and transparency in the rules of exchange, the existence of master catalogs, and the precise definition of responsibilities regarding data.

The proposed design features a modular architecture based on open standards, supported by a service bus and master catalogs that encapsulate complexity and ensure scalability. Its main contribution is to establish interoperability as both a technical and organizational policy, shifting the paradigm from isolated solutions to a network of traceable services. This architecture, in addition to integrating processes, reconfigures the institutional semantics of data and consolidates a common language for decision-making and control. It can therefore be inferred that technical transparency acts as a catalyst for trust and the reduction of information asymmetries. Its limitation lies in its high sensitivity to governance and continuous maintenance, which requires solid internal capabilities and explicit roadmaps.

Wave-based implementation demonstrated that digital transformation can bring about substantive improvements without disrupting day-to-day operations. The admissions-registration modules consolidated the single file and eliminated reprocessing; payments and enrollment

synchronized financial and academic logic; scheduling coordinated offerings, schedules, and faculty availability. The triad of student creation, faculty, and curriculum unified academic governance with curriculum design. The substantive gain came from automation, which utilized explicit rules and standardized data. It can be inferred that the most significant returns emerge at intersections of high information traffic; however, their limitation lies in their dependence on external catalogs and validators, whose mitigation will require interoperability agreements, continuous monitoring, and repeated testing.

The analytical plan demonstrated reductions in response times and duplicates, fewer scheduling conflicts, and increased synchrony between payment and enrollment. Triangulation with user testimonials confirmed perceived improvements in transparency and usability, reinforcing the model's validity. The main contribution lies in linking operational indicators with service criteria and institutional learning, recognizing data as a common good. Traceability is a necessary condition for accountability and organizational learning. The limitation corresponds to the still-limited time window; longitudinal measurements and sensitivity analyses will strengthen the causal validity of the observed effects.

The review of articles, mappings, and public reports provided conceptual and metric anchors that guided both the design and selection of indicators. The contribution is twofold: on the one hand, it consolidated an operational vocabulary based on notions of interoperability, master catalogs, and data governance; on the other, it provided comparative performance benchmarks. Recent literature converges in considering technical integration inseparable from cultural change. However, methodological heterogeneity and contextual transferability are inherent limitations; hence, articulation with local empirical evidence has been decisive. Future research should expand the meta-analysis and explore variations according to institutional typology.

The project demonstrated that intelligent literacy, understood as critical understanding and ethical use of data, is established when information is understandable, audited, and actionable promptly. Governance, expressed in roles, policies, catalogs, and traces, transforms the relationship with information, replacing opaque intuition with sustained discernment. It is inferred that AI-mediated writing, assessment, and feedback require semantic infrastructures and distributed responsibilities, rather than isolated tools. The fundamental contribution consists of articulating architecture and academic praxis through verifiable rules. The limitation lies in the organizational learning curve: sustaining the data culture will require continuous training, technical support, and aligned incentives.

Finally, the roadmap prioritizes downloadable certification functionalities, grade management, faculty hiring, and faculty development, complemented by analytics dashboards and usability evaluation. Such extensions will consolidate a cycle of continuous improvement and strengthen pedagogical and administrative decision-making. Limitations include dependence on external sources for verification, possible desirability biases in interviews, and the natural maturation of the system. Future research should incorporate quasi-experimental designs, longitudinal follow-up, and cost-effectiveness analysis, as well as examine the impacts on learning and student retention, to strengthen the transferability and epistemic robustness of the inferences.

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USE OF ARTIFICIAL INTELLIGENCE

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