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Research on the Practical Path and Systematic Collaborative Development of Digital Intelligence Empowering Educational Governance Reform in Local Undergraduate Universities

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Keywords: Digital-intelligence empowerment; Educational governance reform; Local undergraduate universities; Coupling coordination degree; Organizational change intensity; Teacher digital literacy

Abstract: Drawing on the resource-based view, dynamic capabilities theory, and complex adaptive systems theory, this study builds and tests a moderated mediation model of how digital-intelligence empowerment (DIE) shapes educational governance reform (GOV) in local undergraduate universities, combining a survey of 486 respondents from 156 universities with a 2019–2025 provincial panel. Structural equation modelling shows that DIE affects GOV directly ($\beta = 0.411$, $p < 0.001$) and indirectly through organizational change intensity (0.151, 95% CI [0.079, 0.167]; 26.9% of the total effect), while teacher digital literacy (TDL) positively moderates the DIE–GOV link ($b = 0.117$, $p = 0.003$), its marginal effect staying positive across 98.97% of the observed range. Coupling coordination analysis shows monotonic gains in composite development and coordination (D: 0.599 → 0.886; Mann-Kendall $Z = 3.004$, $p = 0.003$). Four pathways—infrastructure-first, process reengineering, multi-agent collaboration, and data-driven decision-making—are distilled for governance transformation.

1. Introduction

The accelerating diffusion of artificial intelligence, big data, and cloud platforms is reshaping the governance architecture of higher education worldwide [1]. For local undergraduate universities, which operate under tighter constraints and differ widely in funding, digital infrastructure, and faculty digital literacy, the digital-intelligence transformation is not a technical upgrade but a deep restructuring of governance that reaches into decision structures, administrative processes, and multi-actor relations. National policy now sets data-driven modernization of education governance as an explicit goal, yet a practical puzzle remains: many institutions have poured resources into information systems and data platforms while their governance structures and decision-making have hardly changed—a condition best described as “technology suspension”. Technology empowerment evidently does not transmit into governance reform automatically; the intervening links and boundary conditions remain to be identified.

Existing work has documented the diffusion of digital technologies in university administration and the use of learning analytics in institutional decision-making [2], but three gaps persist: digital transformation and governance reform are usually treated as parallel rather than coupled phenomena; organizational change intensity as the internal transmission belt has rarely been identified empirically; and boundary conditions such as teacher digital literacy are seldom brought into a unified model. Addressing these gaps, this study integrates the resource-based view, dynamic capabilities theory, and complex adaptive systems theory into a moderated mediation framework and asks three questions: What is the effect of DIE on GOV, and which internal mechanism carries it? Under what boundary conditions is the effect amplified? How do the three subsystems develop in coordination over time? It builds and tests a mediation–moderation model of "technology empowerment–organizational change–governance outcome", and distils four actionable pathways for administrators.

2. Literature Review and Hypotheses

2.1. Theoretical background

Digital-intelligence empowerment (DIE) denotes an institution's capacity to strengthen its core functions through digital infrastructure, data platforms, and intelligent technologies, going beyond earlier "informatization" by emphasizing data connectivity, intelligent integration, and organizational agency [3]. The resource-based view holds that such complementary technology-and-people assets are valuable, rare, and hard to imitate, and thus a source of competitive advantage [4]; dynamic capabilities theory adds that institutions reconfigure their resource base through sensing, seizing, and transforming routines [5], which justifies treating organizational change intensity (OCI) as the mediator. Educational governance reform (GOV) denotes a university's deliberate change in how it steers itself at the levels of structure, process, and relations [6]. Digital technologies can advance such reform by narrowing access gaps, reducing information asymmetry, and strengthening transparency and accountability, yet technology can equally be absorbed by existing inertia and become an electronic shell over unchanged processes, so the intervening mechanism must be examined.

2.2. Hypotheses

Research on the technology–organization–environment framework and on digital government transformation shows that technology empowerment directly reshapes governance structures and processes [7], so we expect DIE to affect GOV positively (H1). Digital transformation is first of all organizational change: how far an organization rebuilds routines, redistributes authority, and re-socializes its members decides whether technological potential becomes governance reality [8], so DIE should raise change intensity (H2), and the greater that intensity, the more readily the new rules, processes, and collaborative relations on which reform depends can be established and stabilized (H3). Together these imply a transmission chain from technology empowerment to governance outcomes (H4). Technology affordance theory holds that the value of technology depends on users' competence rather than on the technology itself [9]: teacher digital literacy (TDL) is thus not a direct antecedent of governance outcomes but a boundary condition for affordance actualization, and should positively moderate the DIE–GOV link (H5). Finally, complex adaptive systems theory treats interacting subsystems as evolving together through continuous feedback [10]: DIE, GOV, and governance effectiveness form three interlinked subsystems whose coordinated development can be captured by the coupling coordination degree model [11]; because the coupling index discriminates poorly in balanced samples, H6 is deliberately restricted to the temporal trend of

composite development. Finally, governance reform should also raise governance effectiveness (H7).

H1. Digital-intelligence empowerment positively affects educational governance reform.

H2. Digital-intelligence empowerment positively affects organizational change intensity.

H3. Organizational change intensity positively affects educational governance reform.

H4. Organizational change intensity mediates the relationship between DIE and educational governance reform.

H5. Teacher digital literacy positively moderates the relationship between DIE and educational governance reform.

H6. The composite development level of the DIE, GOV, and governance effectiveness subsystems (province-level objective panel indices) rises significantly over time.

H7. Educational governance reform positively affects governance effectiveness.

2.3. Conceptual model

Figure 1 presents the hypothesized model. DIE is the exogenous driver, OCI the mediator, TDL the moderator, and GOV the focal outcome, which in turn affects governance effectiveness; DIE, GOV, and governance effectiveness are further tracked over time as objective provincial composites (they share names with the survey latent variables but differ in measurement).

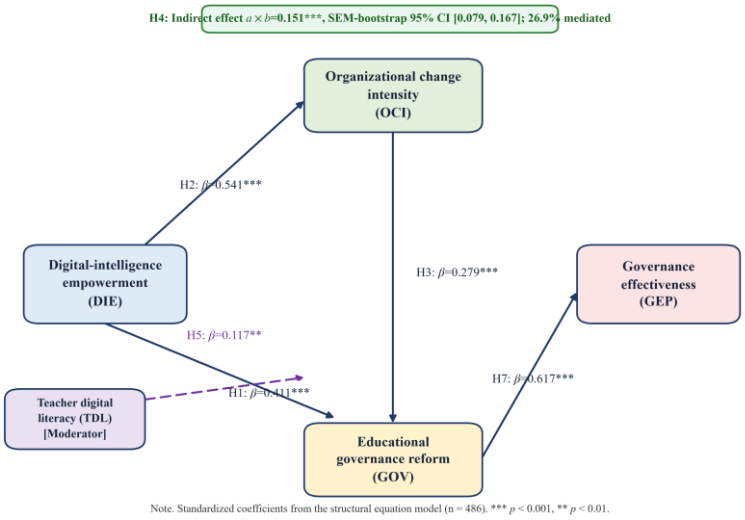


Figure 1: Theoretical model and hypothesized relationships.

3. Research Design

3.1. Data and measures

Two data sources are combined. The first is a structured questionnaire: 156 local undergraduate (non-“Double First-Class”) universities were drawn within a 3 × 4 stratified frame of region (east, central, west) and institutional type, with questionnaires directed to administrators, faculty, and support staff in roughly a 2:5:2 ratio. Fieldwork ran from March to June 2025: of 540 questionnaires distributed, 512 were returned and 26 removed for patterned responding or key missing values, leaving 486 valid responses (90.0% valid-response rate). Respondents missing fewer than 3% of items were imputed with construct means and those missing more than 10% were dropped altogether; the study was approved by the university ethics committee (EDU-IRB-2025-0147), and all respondents gave informed consent. Respondents were 51.2% male and on average

40.76 years old (SD = 7.84), comprising 27.6% administrators, 57.0% faculty, and 15.4% support staff, with institutional-type and regional distributions closely mirroring the stratified frame. The second source is a balanced panel of 31 provinces and 217 observations for 2019–2025, aggregated from annual operating statistics of the 156 universities (sampling frame from the Ministry of Education's list of undergraduate institutions) and drawn from education statistics, provincial bulletins, and universities' information-disclosure pages. Panel indicators include per-student informatization funding, platform coverage, and the number of data-sharing interfaces; provincial values are enrollment-weighted averages, and the few missing values (under 2%) are filled by linear interpolation. Substantive constructs were measured on 7-point Likert scales with items adapted from established instruments in digital transformation, public governance, and learning analytics [3][6][9]; some of these originate in smart-city governance and learning analytics research and were transferred to the university setting after semantic adaptation and localized revision. Control variables are gender, age, role, institutional type, region, and enrollment size.

3.2. The coupling coordination degree model

To characterize coordinated development of the three subsystems, a four-step model is built: (1) the subsystem indices U_1 (DIE), U_2 (GOV), and U_3 (governance effectiveness) are synthesized from the provincial panel by the entropy method, avoiding subjective weighting; (2) the coupling degree $C = 3(U_1U_2U_3)^{(1/3)}/(U_1+U_2+U_3)$ captures the strength of association; (3) the comprehensive coordination index $T = 0.34U_1 + 0.33U_2 + 0.33U_3$ treats the subsystems as equally important; and (4) the coordination degree $D = \sqrt{(C \times T)}$ combines association and level on a 0–1 scale with an eight-grade classification. Because the coupling formula approaches 1 as the subsystem indices converge, C loses discriminating power in balanced samples; D is therefore read mainly as a composite-level measure, and H6 is tested as a trend in composite development.

3.3. Analytical strategy

The empirical work proceeds in four layers: descriptive statistics with reliability and validity testing; maximum-likelihood SEM with institution-level cluster-robust standard errors; effect decomposition with 5,000 bootstrap resamples for mediation and standardized interaction regression with simple slopes and Johnson-Neyman analysis for moderation [12]; and coupling coordination analysis supported by Mann-Kendall tests and Sen's slope. Robustness checks cover institution-level aggregated OLS, region fixed effects with provincial clustering, models with and without controls, the Harman single-factor and marker-variable diagnostics, a nested-model chi-square test of discriminant validity, and coupling quadrants under three thresholds.

4. Results

4.1. Measurement quality

Items showed approximate normality (skewness below 1.2, kurtosis below 1.5), and Cronbach's α ranged from 0.902 to 0.942 across the five constructs, with no item deletion raising α. Prerequisites for EFA were met (KMO = 0.935; Bartlett's $\chi^2 = 13022.0$, $p < 0.001$), and principal component analysis with promax rotation extracted five factors explaining 64.82% of the variance. CFA showed good fit ($\chi^2/df = 1.12$, CFI = 0.995, TLI = 0.994, RMSEA = 0.016); all standardized loadings exceeded 0.76 ($p < 0.001$), composite reliability ranged from 0.848 to 0.925, and AVE from 0.572 to 0.611, so convergent validity is adequate. Discriminant validity also holds: every √AVE value in the Fornell-Larcker matrix exceeds the inter-construct correlations in its row and

column, and the HTMT ratios involving TDL stay between 0.01 and 0.10, far below the 0.85 threshold.

4.2. Structural model and hypothesis testing

The SEM fits the data well ($\chi^2/df = 1.12$, CFI = 0.994, TLI = 0.994, RMSEA = 0.016); standardized path estimates appear in Table 1. DIE significantly predicts GOV ($\beta = 0.411$, $p < 0.001$), supporting H1; DIE predicts OCI ($\beta = 0.541$, $p < 0.001$, $R^2 = 0.293$), supporting H2; OCI predicts GOV ($\beta = 0.279$, $p < 0.001$), supporting H3; and GOV predicts governance effectiveness ($\beta = 0.617$, $p < 0.001$, $R^2 = 0.380$), supporting H7, with the GOV equation explaining 37.1% of its variance.

Table 1: Path estimates of the structural model (N = 486).

Hypothesis / path	Standardized β	SE	z	p	Sig.
H1: DIE → GOV	0.411	0.062	6.63	<0.001	***
H2: DIE → OCI	0.541	0.055	9.84	<0.001	***
H3: OCI → GOV	0.279	0.059	4.73	<0.001	***
H7: GOV → GEP	0.617	0.052	11.87	<0.001	***

Note. All path coefficients are standardized, with z = β/SE; *** p < 0.001, ** p < 0.01, * p < 0.05.

4.3. Mediation analysis

The direct and indirect effects are both significant and carry the same sign, so OCI partially mediates the DIE–GOV link (indirect effect 0.151, 95% CI [0.079, 0.167]; 26.9% of the total effect; Table 2), supporting H4. The mediation interpretation also withstands a series of prerequisite checks: OCI and GOV correlate only 0.457 at the zero order; the five-factor model improves on the merged four-factor model by $\Delta\chi^2 = 620.15$ ($\Delta df = 4$, $p < 0.001$); the Harman single-factor model fits poorly (CFI = 0.471, RMSEA = 0.168); and marker-variable correlations stay below 0.18, so common method bias is not a serious threat.

Table 2: Bootstrap tests of mediation (5,000 resamples, within the SEM framework).

Effect type	Point estimate	95% CI	Significance
Total effect (c)	0.561	—	p < 0.001, significant
Direct effect (c′)	0.411	—	p < 0.001, significant
Indirect effect (a × b)	0.151	[0.079, 0.167]	CI excludes zero, significant
Proportion mediated	26.9%	—	Partial mediation

Note. All estimates are obtained within the structural equation modelling framework; the confidence interval for the indirect effect comes from 5,000 bias-corrected bootstrap resamples.

4.4. Moderation analysis

To test H5, the independent and moderating variables were standardized and an interaction term constructed. The interaction is significant ($b = 0.117$, $t = 3.00$, $p = 0.003$, $\Delta R^2 = 0.017$), while the main effect of TDL is non-significant ($b \approx 0.001$, $p = 0.979$), consistent with its role as a moderator rather than a direct antecedent. Simple slopes rise monotonically with literacy—0.395, 0.511, and 0.628 at −1 SD, the mean, and +1 SD—and Johnson-Neyman analysis places the significance boundary at −2.54 on the standardized moderator, with 98.97% of observed literacy values (range [−3.39, 3.02]) to the right of it. Within the observed range, the marginal effect of DIE is therefore positive and rises with literacy (Figure 2): literacy acts as an amplifier rather than a threshold.

Although TDL correlates only weakly with the governance constructs at the zero order, its non-significant main effect alongside a significant moderation path is precisely the pattern expected of a moderator.

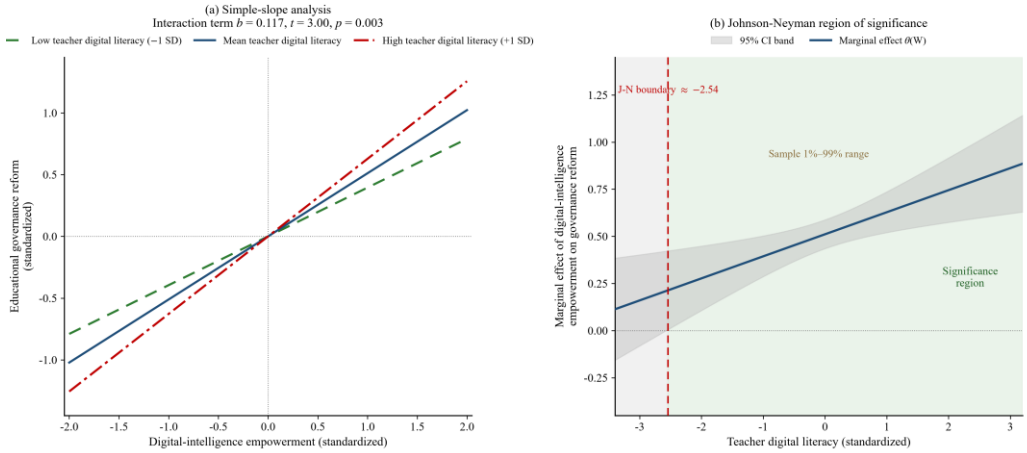


Figure 2: Moderating effect of teacher digital literacy (simple slopes).

4.5. Coupling coordination analysis

Applied to the 31 provinces for 2019–2025, the diagnostics show that C is nearly constant (mean 0.994, SD 0.007, coefficient of variation 0.007), so we do not read "high coupling" as strong interdependence and instead test trends in T and D (Table 3). All three subsystem indices and T rise significantly and monotonically (Mann-Kendall Z = 3.004, p = 0.003; Sen's slope 0.071), and relative dispersion across the subsystems falls from 0.170 in 2019 to 0.100 in 2025 (Z = −2.703, p = 0.007), so overall improvement comes with greater balance. D rises from 0.599 (barely coordinated) to 0.886 (well coordinated), supporting H6 in its restricted form; since D correlates 0.997 with T but only 0.319 with C, the rise chiefly reflects a higher overall level rather than an improved coupling structure. Lagged correlations and panel Granger tests lend partial support to "technology leads, organization follows" ($U_1 \rightarrow U_2$: F = 4.125, p = 0.044), but with N = 31 and T = 7 these results are read as descriptive rather than causal. Spatially, eastern coastal provinces entered well-coordinated status by 2024–2025 while some western provinces remain intermediately coordinated, suggesting that investment alone cannot close regional gaps.

Table 3: Evolution of subsystem indices, the coupling degree, and the coordination degree (national averages, 2019–2025).

Year	U_1 DIE	U_2 GOV	U_3 GEP	Coupling degree C	Coordination degree D	Coordination grade
2019	0.342	0.371	0.384	0.988	0.599	Barely coordinated
2020	0.408	0.445	0.449	0.992	0.655	Primarily coordinated
2021	0.486	0.518	0.510	0.994	0.707	Intermediately coordinated
2022	0.560	0.597	0.576	0.995	0.757	Well coordinated
2023	0.633	0.677	0.641	0.996	0.803	Well coordinated
2024	0.701	0.753	0.706	0.995	0.845	Well coordinated
2025	0.780	0.826	0.765	0.996	0.886	Well coordinated

Note. U_1, U_2, and U_3 are subsystem indices synthesized by the entropy method; $D = \sqrt{(C \times T)}$, with $T = 0.34U_1 + 0.33U_2 + 0.33U_3$; D is computed province by province and then averaged nationally.

4.6. Robustness checks

Six checks support the core findings: institution-level aggregated OLS reproduces the paths (DIE b = 0.292, t = 4.21; OCI b = 0.498, t = 7.08; both $p < 0.001$); region fixed effects with provincial cluster-robust errors leave every core path stable; results hold with and without the six controls (DIE b = 0.387, t = 8.82; OCI b = 0.264, t = 6.02); the Harman test and the marker-variable technique rule out serious common method bias; the nested-model test confirms discriminant validity; and coupling quadrants are broadly consistent under median, mean, and tercile thresholds. Because the released micro data lack respondent-to-institution identifiers, ICC(1) and r_wg cannot be reported; cluster-robust standard errors serve as a conservative substitute.

5. Discussion

5.1. Theoretical contributions

The individual-level mechanism evidence and the system-level trend evidence complement each other but differ in construct definition and level. First, DIE shapes governance reform both directly and, more strongly, indirectly through OCI: the 26.9% mediated share confirms that technology alone does not reform governance; the conversion runs through organizational change. Second, the moderation by teacher literacy adds a boundary condition to technology affordance theory: the marginal effect is positive and significant across 98.97% of the observed range, so literacy acts as an amplifier rather than a threshold, revising both infrastructural determinism and the literacy-threshold view. Third, the study brings composite development analysis into higher education governance research, showing that in balanced data C degenerates to a near-constant while D is driven mainly by T; future applications should therefore report the variation of C first.

5.2. Practical pathways

Four pathways follow for local undergraduate universities. Infrastructure first: prioritize network, computing, and data-center capacity, dismantle barriers among academic, personnel, finance, and research systems, and adopt data connectivity as an acceptance criterion to avoid new islands. Process reengineering: pair technology deployment with administrative redesign—streamlining approvals, cutting redundancy, and clarifying cross-departmental authority—and lock the changes in through formal rules, since failing to raise change intensity forfeits roughly 26.9% of the potential benefit. Multi-agent collaboration: establish joint governance bodies such as data governance committees, in which faculty, administrators, and students hold substantive data access rights. Data-driven decision-making: institutionalize literacy training—systematic courses, practice communities, and inclusion in appraisal—covering administrators and frontline faculty alike. For regions with lower coordination, support should be tied to change-management capacity rather than hardware provision alone.

5.3. Limitations and future research

Several limitations remain. The survey is cross-sectional, so multi-wave tracking would strengthen causal identification; the context is a single country, so cross-national comparison is a natural extension; DIE is measured perceptually, so platform logs could provide triangulation; only teacher literacy is tested as a moderator; and the reliability of institution-level aggregation (ICC(1), r_wg) awaits respondent identifiers. The CCD model also loses discriminating power in balanced data, which we offset with trend and dispersion measures. These gaps define the agenda for further

work; none of them, however, unsettles the mechanism identified here.

6. Conclusion

Grounded in the resource-based view, dynamic capabilities theory, and complex adaptive systems theory, this study builds and tests an integrated model of how digital-intelligence empowerment shapes educational governance reform in local undergraduate universities. At the individual level, DIE affects reform directly ($\beta = 0.411$, $p < 0.001$) and indirectly through organizational change intensity (0.151, 95% CI [0.079, 0.167]; 26.9% of the total effect), and teacher digital literacy amplifies the effect across virtually the whole observed range. At the system level, the composite development index and coordination degree of the three subsystems rise monotonically over 2019–2025 (D: 0.599 → 0.886; Mann-Kendall $Z = 3.004$, $p = 0.003$) while the coupling degree stays nearly constant, so "coupling coordination" here chiefly reflects gains in composite development. Together the evidence discloses an amplification–mediation–coordinated advancement mechanism and yields four sequenced pathways—infrastructure-first, process reengineering, multi-agent collaboration, and data-driven decision-making—offering evidence-based guidance for governance transformation.

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