

Digital Technology Investment, Educational Technology, and Innovation Capacity in Egyptian Entrepreneurial Universities: An Integrated IPO Governance Framework with Quality Assurance

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ABSTRACT

Purpose: This study investigates associations between Digital Technology Investment (DTI), Educational Technology (EdTech), Quality Assurance (QA), Innovation Capacity (IC), and Entrepreneurial University Characteristics (EUC) across twelve Egyptian universities within an integrated Input-Process-Output (IPO) governance framework.

Methodology/Approach: A cross-sectional survey used PLS-SEM (SmartPLS 4) with 5,000-subsample bias-corrected and accelerated (BCa) bootstrapping.

Findings: DTI was positively associated with IC ($\beta = 0.421$) and EUC ($\beta = 0.305$). EdTech partially mediated both associations (VAF = 41%; 38%), confirming pedagogical embedding as the value-generation mechanism. QA showed no moderation and a robust direct association with IC ($\beta = 0.269$, $p < 0.001$). IC predicted EUC ($\beta = 0.547$).

Research Limitation/Implication: The cross-sectional design precludes causal inference. Administrators should co-invest in EdTech alongside digital infrastructure and explore joint QA-digital governance structures.

Originality/Value of paper: This study offers the first integrated empirical test of a five-construct DTI-EdTech-IC-EUC governance chain with QA in a dual role, deriving a three-tier governance alignment model for emerging-economy higher education.

Category: Research paper

Keywords: digital technology investment; educational technology; entrepreneurial university; innovation capacity; quality assurance

Research Areas: Management of Technology and Innovation

1 INTRODUCTION

The paradox is that, apart from the education results, universities invest high amounts of resources and efforts in developing digital technologies, but do not get the expected amount of innovation performance and entrepreneurial outcomes (Alamri, Alshammari, & Al-Shehri, 2023). This pattern is evident across Egyptian higher education institutions. Within the last decade, the utilization of digitization in higher educational institutions (whether public or private), with the aid of national digital transformation visions, such as Egypt Vision 2030 (Ministry of Higher Education and Scientific Research [MoHESR], 2024), has been widely adopted through digital tools and platforms such as: Learning Management System (LMS), Cloud Computing, and Data Analytics tools. The performance of Egyptian universities on global innovation and entrepreneurial indicators (Times Higher Education, 2024), however, is low, suggesting that digital investments so far have not yet translated into the expected innovation outcomes at universities.

This gap is fundamentally a governance challenge rather than a procurement problem. Institutional performance depends not only on resource acquisition but on the governance structures through which resources are deployed (Kezar, 2018). Two governance mechanisms are especially consequential: Educational Technology (EdTech) the organisational capability through which digital investments are converted into pedagogical and administrative practice and Quality Assurance (QA) the governance system setting accountability standards and driving continuous improvement. A specific condition characterising many Egyptian universities is administrative silo structures, in which digital transformation units, QA offices, and EdTech centres operate as functionally disconnected departments without cross-functional coordination (Shamsi, 2024; Hussein & El-Naggar, 2025).

Three gaps motivate this study. First, the process through which digital investment is associated with innovation capacity has not been tested as a mediated pathway in governance-fragmented higher education systems. Second, QA's widely assumed moderating role in institutional change (Harvey & Green, 1993; Munoz & Harb, 2024) has not been tested where QA and digital governance operate as silos. Third, the association between digital transformation inputs, innovation capacity, and entrepreneurial outputs has not been empirically modelled within a single integrated framework for the Egyptian context.

This study makes four contributions: (1) an integrated Input-Process-Output (IPO) governance model combining Dynamic Capabilities Theory, Resource-Based View, and IPO logic; (2) the first empirical test of QA's dual governance role simultaneously as hypothesised moderator and direct predictor in this context; (3) empirical validation of the DTI-EdTech-IC-EUC perceptual association chain; and (4) a three-tier governance alignment model (Foundation, Conversion, Governance Integration) providing actionable sequencing guidance (Marquez & Luna, 2022). Table 1 positions the present study against the five closest empirical comparators.

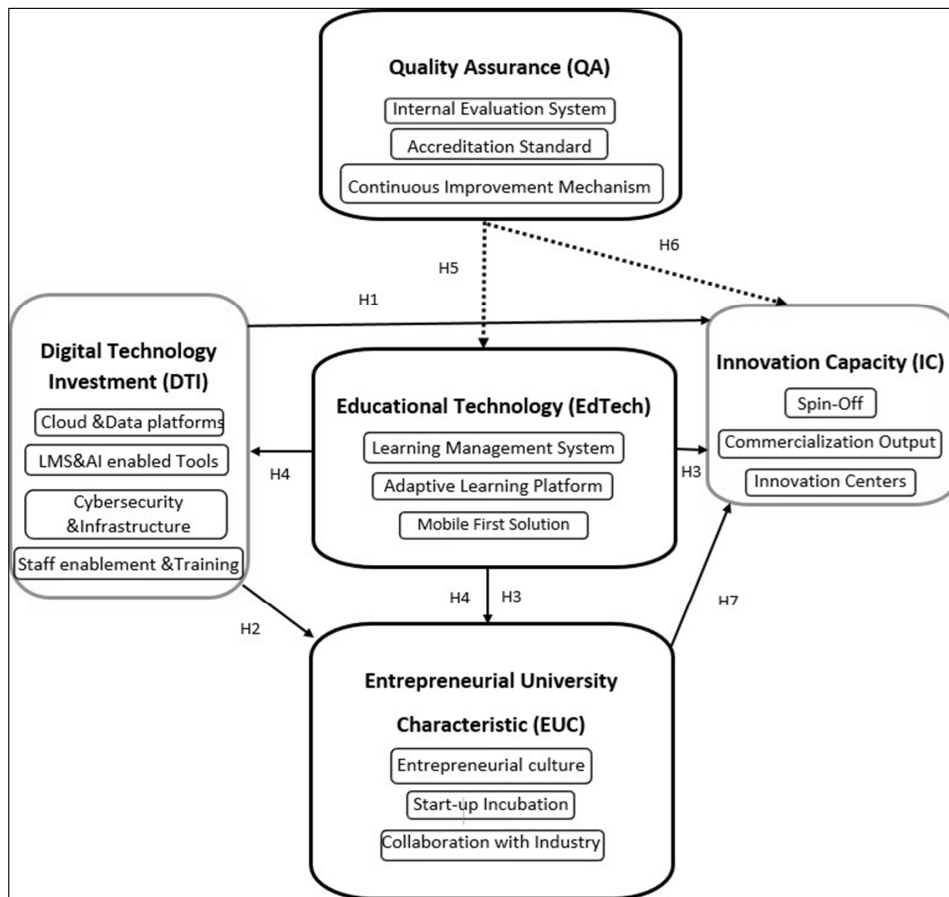


Figure 1 – IPO governance model: Conceptual framework

Figure 1 presents the conceptual framework illustrating the proposed IPO governance model with all hypothesised relationships.

Table 1 – Systematic comparison with closest empirical comparators

Study	Constructs	Key Paths	Method & Context	Theory	Gap vs. Present Study
Alamri et al. (2023) Computers & Education	Digital investment readiness; EdTech; Institutional performance	Digital investment → EdTech → Performance	Survey; CB-SEM; Saudi Arabia; N = 312	TAM; Institutional theory	No IC or EUC; no QA; individual constructs only
Ghosh, Rahman, and Karim (2024) Information & Management	DTI; Resilience; Performance	DTI → Resilience → Performance	Panel data; 6 countries; N = 218	RBV; Dynamic Capabilities	No EdTech mediator; no QA; no EUC

Study	Constructs	Key Paths	Method & Context	Theory	Gap vs. Present Study
Kim, Lim, and Park (2024) Computers & Education	Digital learning ecosystem; Faculty engagement; Innovation	Ecosystem → Engagement → Innovation	PLS-SEM; South Korea; N = 247	Dynamic Capabilities	No QA; no EUC; no IPO framework
Munoz and Harb (2024) Assessment & Evaluation	QA; Digital learning; Innovation	QA → Digital → Innovation	Mixed methods; Lebanon; N = 189	Continuous improvement	No DTI; QA as input not moderator
Guerrero, Heaton, and Urbano (2021) Technovation	Digital capabilities; Intrapreneurial capacity; EUC	Digital → IC → EUC	PLS-SEM; Spain/Mexico; N = 423	Entrepreneurial university	No DTI; no QA; no EdTech
Present Study (ElHadidy, Khourshed, Nassef, & AbdelAziz, 2026)	DTI; EdTech; QA; IC; EUC	DTI → IC → EUC; EdTech mediates (VAF = 41%/38%); QA direct ($\beta = 0.269$)	PLS-SEM; Egypt; N = 360; 12 universities	RBV+Dynamic Cap.+IPO	First with all 5 constructs+QA dual role

Note: CB-SEM = covariance-based SEM; RBV = Resource-Based View; TAM = Technology Acceptance Model; VAF = Variance Accounted For.

2 LITERATURE REVIEW

2.1 Digital Technology Investment and Institutional Performance

DTI includes investment in AI-systems, Cloud-framework, Cyber-security and in Digital Skills as institutional investments. If Digital Infrastructure is understood as a strategic resource in the institutional deployment, based on Resource Based View (Barney, 1991), usage of this resource can be exploited and turn into a value if well managed. Cohen and Levinthal (1990) Absorptive capacity explain how DTI can have an influence, where as higher DTI increases the institutional Absorptive capacity, and eventually the better recognition, assimilation and application of DTI helps an institution's better capacity to produce knowledge and innovation. Prior research confirms that governance quality and deployment capacity both condition how digital investment translates into institutional performance.

2.2 Educational Technology as Organisational Capability

The concept of EdTech as the organisational sensing-and-integrating capability (Teece, 2007, 2023) positions it as the primary mechanism through which digital investments are converted into pedagogical and administrative practice. The opportunity identified through digital investment and the dimension grasped is the adoption and embedding of EdTech tools into institutional routines through faculty

practice. Kim et al. (2024) and Aboagye, Anane, and Boateng (2025) confirm significant mediation effects, with mediating associations between EdTech integration and innovation performance partially validated DTI also contributes directly through non-EdTech administrative channels.

2.3 A Governance Structure with a Focus on Quality Assurance (QA)

Modern QA systems include a focus on incremental improvements, are performance based and track strategic performance measures (Harvey & Green, 1993; Stensaker, 2018). The theory literature offers two conflicting suggestions: One is that there is a set of digital transformation paths between the adopted and moderated set of digital transformation paths, and the second is that the institutional quality dimensions between the digital and quality intentions are moderated by a QA mindset towards adoption somewhere between the two sets of paths identified above. However, as per the governance fragmentation theory, implementation review mechanisms in nature of autonomous QA mechanisms helps to enable QA to influence the strength of digital pathways but on the other hand, QA cannot influence strength of digital pathways in case of administrative silos. Where governance integration is absent, QA's moderating potential remains latent a theoretical prediction tested empirically in the present study.

2.4 Innovation Capacity and Entrepreneurial University Performance

There is substantial evidence that Innovation Capacity is a strong predictor of entrepreneurial university outcomes, encompassing faculty entrepreneurial competencies, cross-disciplinary collaboration networks upon which third-mission outcomes depend, and research commercialisation pipelines. Entrepreneurial University theory (Etzkowitz, 2017; Klofsten et al., 2019) positions IC as the necessary precondition for EUC: start-up creation, technology commercialisation, and industry partnerships cannot emerge without prior IC development. The sequential model DTI → EdTech → IC → EUC represents a governance chain in which each stage is a necessary but not sufficient condition for the subsequent stage. Table 2 summarises the theoretical basis for each hypothesised path, the proposed mechanism, and the alternative model that would be rejected if the hypothesis is supported.

Table 2 – Theory-Path linkage and alternative models rejected

Path	Theory	Mechanism	Alternative Model Rejected
DTI → IC (H1); DTI → EUC (H2)	RBV (Barney, 1991); Absorptive Capacity (Cohen & Levinthal, 1990)	DTI creates absorptive capacity enabling knowledge creation and innovation	Null: DTI has no association with IC — rejected ($\beta=0.421$, $p<0.001$)
DTI → EdTech → IC/EUC (H3, H4)	Dynamic Capabilities (Teece, 2007, 2023)	EdTech is the sensing-seizing-transforming capability converting DTI to operational competence	Full mediation: DTI has no direct association — rejected; Zero mediation — rejected

Path	Theory	Mechanism	Alternative Model Rejected
QA moderation (H5, H6) — not supported	Governance Fragmentation (Harvey & Williams, 2010; Shamsi, 2024)	In silo-structured systems, QA cannot penetrate digital transformation pathways	Strong moderation rejected (both CIs span zero; $f^2 < 0.005$)
QA → IC direct	Quality Culture Theory (Harvey & Green, 1993; Stensaker, 2018)	QA contributes through autonomous quality culture mechanisms	Null: QA has no association with IC — rejected ($\beta = 0.269$, $p < 0.001$)
IC → EUC (H7)	Entrepreneurial University Theory (Etzkowitz, 2017; Klofsten et al., 2019)	IC provides knowledge pipelines and faculty competence upon which EUC depends	Direct DTI-to-EUC without IC: partially rejected ($\beta = 0.547$)

2.5 Research Hypotheses

The following hypotheses operationalise the five possible associations, mentioned above, between DTI, EdTech, QA, and IC, and EUC based on the theoretical framework:

H1: DTI is positively associated with IC.

H2: DTI is positively associated with EUC.

H3: EdTech partially mediates the association between DTI and IC.

H4: EdTech partially mediates the association between DTI and EUC.

H5: QA positively moderates the association between DTI and EdTech.

H6: QA positively moderates the association between EdTech and IC.

H7: IC is positively associated with EUC.

3 METHODOLOGY

3.1 Research Design

This is a quantitative, deductive, cross-sectional study. All reported associations are perceptual measured from staff assessments of institutional conditions and the design does not permit causal inference. Reverse causality cannot be excluded. Egypt was selected because digital investment is substantial, governance fragmentation is structurally documented (Shamsi, 2024), and the conditions for testing the governance fragmentation hypothesis are present. PLS-SEM was selected for its robustness with ordinal Likert-scale data, predictive orientation alignment, and suitability for moderately sized samples with complex latent variable structures (Hair, Hult, Ringle, & Sarstedt, 2022).

3.2 Sample and Data Collection

The target population included academic staff, administrative staff, digital transformation staff, e-learning staff, and Quality Management staff from Egyptian universities. For this study, 12 Egyptian universities were selected based on two factors: (1) explicit entrepreneurial orientation, which was documented in institutional mission statements and strategic plans; (2) active digital transformation programmes documented in institutional records and IT departments' documentation. Public, as well as private institutions were present, reflecting metropolitan and regional locations. All respondents participated in the study and proportional representation was ensured by purposeful stratified sampling by the type of institution the respondent was in, as well as plays a role in. To account for the issue of unit of analysis, Intraclass correlation coefficients were computed: ICC(1) ranged from 0.12 to 0.19 and ICC(2) from 0.54 to 0.68 for each of the five constructs: ICC(1) = 0.12 – 0.19 and ICC(2) = 0.54 – 0.68, which is considered moderate agreement within institutions. With regard to these values, and because of the multi-role of the surveyed sample (faculty, administrators, IT staff and QA officers), constructs are perceived measures at the individual level and not indicator values at the institutional level; clustering is therefore taken into account by employing robust standard error values.

Participants were invited through formal contacts in the institutions, via institutional email lists and information visits were made; informed consent was obtained before participation and anonymity was guaranteed. A total of 360 (72%) valid responses were obtained after a variety of multivariate outliers on Mahalanobis D^2 screening ($p < 0.001$) and incomplete response items were eliminated, which met or exceeded the minimum number (138) based on the G*Power 3.1 calculation of statistical power with $f^2 = 0.15$, $\alpha = 0.05$, power = 0.80, predictors = 5 (number of predictors). The smallest hypothesised interaction effect ($f^2 = 0.02$) was built up with a power of 0.89, which was an adequate sensitivity. Sample demographic profile are given in Table 3.

3.3 Measure

DTI, EdTech, QA, IC and EUC were measured using four reflective constructs for each. Likert-scale items (1 = Strongly Disagree to 5 = Strongly Agree) derived from validated instruments were used to measure staff assessments of institutional conditions. Items were translated from English to Arabic through a translation-back-translation procedure; discrepancies were resolved through bilingual expert panel consensus. Expert content review involved seven subject-matter experts in educational technology, information systems management, and quality assurance (CVR > 0.80 for all items). A pilot study ($n = 50$) confirmed Cronbach's $\alpha > 0.80$ for all constructs. Common method bias was mitigated through random item ordering, psychological separation of predictor and outcome constructs across questionnaire sections, and anonymity assurance; post-hoc

Harman's single-factor test confirmed no single factor accounted for more than 50% of variance. All 20 items and their sources are provided in Appendix A.

3.4 Data Analysis

Initial screening in SPSS 26 confirmed distributional adequacy (skewness $\leq \pm 2$; kurtosis $\leq \pm 7$ for all indicators) and the absence of missing data and multivariate outliers. PLS-SEM was implemented in SmartPLS 4.0.9.2 (Ringle, Wende, & Becker, 2025) using the path weighting scheme, consistent PLS (PLSc) estimates for reflective constructs (Dijkstra & Henseler, 2015), and 5,000-subsample nonparametric bootstrap resampling with no sign changes and bias-corrected and accelerated (BCa) 95% confidence intervals for all path coefficients and indirect effects. Moderation was tested using the two-stage product-indicator approach (Sarstedt, Ringle, & Hair, 2019). Post-hoc Gaussian Copula endogeneity tests (Park & Gupta, 2012) were non-significant (all $p > 0.10$). FIMIX-PLS segmentation detected no significant latent subgroups. PLSpredict (10-fold cross-validation) confirmed positive Q^2 values for all endogenous indicators.

Table 3 – Demographic characteristics of respondents (N = 360)

Variable	Category	n	% (valid)
University affiliation (k = 12 institutions) ^a	October University for Modern Sciences & Arts (MSA)	95	26.4
	Ain Shams University	40	11.1
	Alexandria University	31	8.6
	Nile University	28	7.8
	Zewail City of Science and Technology	28	7.8
	British University in Egypt (BUE)	27	7.5
	Egypt-Japan University of Science and Technology (E-JUST)	23	6.4
	The American University in Cairo (AUC)	21	5.8
	Future University in Egypt (FUE)	20	5.6
	German University in Cairo (GUC)	17	4.7
	Misr International University (MIU)	11	3.1
	Cairo University	11	3.1
	Galala University	8	2.2
	Total	360	100.0
Respondent role	Innovation centre staff	83	23.1
	IT/Digital transformation manager	78	21.7
	EdTech/LMS specialist	67	18.6
	Vice dean/Strategic planning admin	46	12.8
	Faculty (innovation/e-learning)	34	9.4

Variable	Category	n	% (valid)
	Other	30	8.3
	QA officer	22	6.1
	Total	360	100.0
Academic rank	Assistant Professor	108	30.0
	Associate Professor	81	22.5
	Assistant Lecturer/Lecturer	81	22.5
	Professor	57	15.8
	Not applicable (professional services)	33	9.2
	Total	360	100.0
Gender	Man	192	53.3
	Woman	163	45.3
	Non-binary	3	0.8
	Prefer not to say	2	0.6
	Total	360	100.0
Primary appointment	Teaching-only	113	31.4
	Teaching and Research	113	31.4
	Research-only	73	20.3
	Professional services/admin	61	16.9
	Total	360	100.0
Age group (valid N = 359) ^b	25–34	152	42.3
	35–44	81	22.6
	Under 25	61	17.0
	45–54	46	12.8
	55–64	15	4.2
	65 or above	4	1.1
	Prefer not to say	1	0.3
	Total	360	100.0
Primary duties	QA duties	124	34.4
	Both QA and Innovation	108	30.0
	Innovation hub projects	96	26.7
	Neither	32	8.9
	Total	360	100.0

Note: ^a Original submission listed MSA under two row labels; merged entry: October University for Modern Sciences & Arts (MSA), n = 95; data collected from 12 distinct institutions. ^b Age group: 1 respondent preferred not to disclose (valid N = 359). ^c Contract type: 4 respondents did not complete this item (valid N = 356). All structural-model analyses conducted on full N = 360.

4 RESULTS

4.1 Measurement Model

All 20 indicator loadings were satisfactory (range: 0.736 – 0.912), exceeding the 0.70 threshold. Cronbach's alpha (0.841 – 0.902) and composite reliability (0.879 – 0.931) exceeded 0.70. AVE ranged from 0.63 (QA) to 0.73 (IC), confirming convergent validity. All HTMT ratios were below 0.85, confirming discriminant validity. All VIF values were below 3.3, ruling out collinearity. Table 4 and Table 5 present the full measurement model results.

4.2 Structural Model and Hypothesis Testing

The model demonstrated substantial explanatory power: $R^2(IC) = 0.691$; $R^2(EUC) = 0.723$. Model fit was acceptable: SRMR = 0.041 (below 0.08); $Q^2(IC) = 0.481$; $Q^2(EUC) = 0.537$. Table 6 presents all structural path results with BCa confidence intervals, and Figure 2 presents the path diagram. Effect sizes and collinearity diagnostics are presented in Table 7.

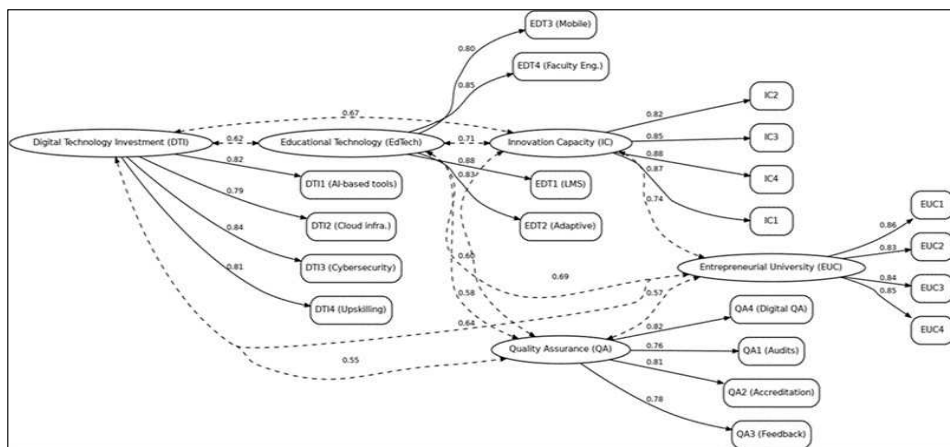


Figure 2 – Structural model with standardised path coefficients (SmartPLS 4)

4.3 Mediation Analysis

Bootstrapped indirect effects confirmed partial mediation for both EdTech pathways. DTI → EdTech → IC: $\beta_{\text{indirect}} = 0.201$ ($t = 4.527$, $p < 0.001$, 95% BCa CI [0.113, 0.291]), VAF = 41%. DTI → EdTech → EUC: $\beta_{\text{indirect}} = 0.183$ ($t = 3.902$, $p < 0.001$, 95% BCa CI [0.094, 0.274]), VAF = 38%. VAF was calculated as: $VAF = \text{indirect effect} / (\text{indirect} + \text{direct effect}) \times 100$. Both mediations are partial: VAF values of 41% and 38% indicate that EdTech accounts for substantial but non-exclusive shares of the DTI-IC and DTI-EUC associations. The remaining direct DTI associations (H1, H2) confirm that digital investment is also associated with innovation outcomes through non-EdTech channels, including administrative digitisation and research infrastructure.

4.4 Moderation Analysis

Both interaction terms were statistically non-significant and associated with negligible effect sizes: $DTI \times QA \rightarrow EdTech$ ($\beta = 0.062$, $t = 1.214$, $p = 0.225$, $f^2 = 0.004$, 95% BCa CI $[-0.038, 0.163]$) and $EdTech \times QA \rightarrow IC$ ($\beta = 0.047$, $t = 0.983$, $p = 0.327$, $f^2 = 0.003$, 95% BCa CI $[-0.048, 0.142]$). The confidence intervals for both interaction terms span zero and are centered near zero, providing convergent evidence against meaningful moderation in the current sample. Simple slopes analysis at ± 1 SD of QA confirmed parallel slopes across all predictor values. The power sensitivity analysis (G*Power 3.1) confirmed 0.89 power to detect $f^2 = 0.02$ at $\alpha = 0.05$, ruling out a Type II error explanation for the null moderation findings. The direct $QA \rightarrow IC$ association ($\beta = 0.269$) remained robust when interaction terms were included, confirming QA's positive association with innovation capacity operates independently of any interaction effects.

Table 4 — Reliability and convergent validity statistics (SmartPLS 4)

Construct	Loading range	AVE	CR	Cronbach's α	HTMT max
DTI	0.798 – 0.878	0.66	0.89	0.85	0.825
EdTech	0.741 – 0.912	0.71	0.91	0.88	0.827
QA	0.736 – 0.856	0.63	0.87	0.83	0.408
IC	0.768 – 0.901	0.73	0.92	0.89	0.823
EUC	0.753 – 0.889	0.71	0.91	0.88	0.827

Note: AVE = Average Variance Extracted; CR = Composite Reliability; HTMT max = highest inter-construct HTMT ratio. All HTMT ratios below 0.85 confirm discriminant validity (Henseler, Ringle, & Sarstedt, 2015).

Table 4 shows that all constructs meet the established for reliability and convergent validity threshold. The Haverotrait – Montotrait (HTMT) ratio matrix, as presented in Table 5 shows that all the pairs of constructs exhibited (cross sectional) discriminant validity.

Table 5 — Heterotrait–monotrait (HTMT) ratio matrix (SmartPLS 4)

Construct	DTI	EdTech	QA	IC	EUC
DTI	—				
EdTech	0.825	—			
QA	0.232	0.408	—		
IC	0.795	0.823	0.373	—	
EUC	0.818	0.827	0.380	0.822	—

Note: All off-diagonal values < 0.85 confirm discriminant validity (Henseler et al., 2015).

Table 6 presents the structural model results with standardised path coefficients, bootstrap statistics, and BCa confidence intervals for all direct, indirect, and interaction effects.

Table 6 — Complete structural model results with bootstrap confidence intervals

H	Path	β	t-value	p	95% CI (BCa)	Decision
Direct Associations						
H1	DTI $\rightarrow$ IC	0.421	6.238	< 0.001	[0.289, 0.554]	Supported
H2	DTI $\rightarrow$ EUC	0.305	4.913	< 0.001	[0.175, 0.435]	Supported
H7	IC $\rightarrow$ EUC	0.547	8.104	< 0.001	[0.412, 0.681]	Supported
—	QA $\rightarrow$ IC (direct)	0.269	3.881	< 0.001	[0.132, 0.406]	Supported
—	DTI $\rightarrow$ EdTech	0.681	10.442	< 0.001	[0.558, 0.804]	—
—	EdTech $\rightarrow$ IC	0.478	7.021	< 0.001	[0.344, 0.612]	—
—	EdTech $\rightarrow$ EUC	0.382	5.442	< 0.001	[0.245, 0.519]	—
Indirect Associations via EdTech						
H3	DTI $\rightarrow$ EdTech $\rightarrow$ IC	0.201	4.527	< 0.001	[0.113, 0.291]	Supported (VAF=41%)
H4	DTI $\rightarrow$ EdTech $\rightarrow$ EUC	0.183	3.902	< 0.001	[0.094, 0.274]	Supported (VAF=38%)
	Interaction Terms (Moderation)					
H5	DTI $\times$ QA $\rightarrow$ EdTech	0.062	1.214	0.225	[-0.038, 0.163]	Not supported
H6	EdTech $\times$ QA $\rightarrow$ IC	0.047	0.983	0.327	[-0.048, 0.142]	Not supported

Note: 5,000-subsample nonparametric bootstrap; BCa confidence intervals. $R^2(\text{IC}) = 0.691$; $R^2(\text{EUC}) = 0.723$; SRMR = 0.041; $Q^2(\text{IC}) = 0.481$; $Q^2(\text{EUC}) = 0.537$. VAF = indirect/(indirect+direct) $\times$ 100. Non-significant interaction CIs spanning zero rule out meaningful moderation.

Table 7 demonstrates these results with effect size (f^2) estimates and collinearity diagnostics (VIF), confirming the practical significance and statistical robustness of each path.

Table 7 — Effect sizes (f^2) and collinearity diagnostics (VIF)

Predictor $\rightarrow$ Outcome	f^2	Interpretation	VIF (inner)	VIF (outer max)
DTI $\rightarrow$ IC	0.198	Medium	1.87	2.14
DTI $\rightarrow$ EUC	0.121	Small-medium	1.92	2.14
DTI $\rightarrow$ EdTech	0.344	Large	—	—
EdTech $\rightarrow$ IC	0.312	Large	2.03	2.31
QA $\rightarrow$ IC (direct)	0.121	Small-medium	1.64	1.89
IC $\rightarrow$ EUC	0.287	Medium-large	2.11	—
DTI $\times$ QA $\rightarrow$ EdTech (interaction)	0.004	Negligible	—	—
EdTech $\times$ QA $\rightarrow$ IC (interaction)	0.003	Negligible	—	—

Note: f^2 thresholds: small = 0.02, medium = 0.15, large = 0.35 (Hair et al., 2022). All VIF values < 3.3 rule out collinearity. Sensitivity analysis: 0.89 power to detect $f^2=0.02$, ruling out Type II error for null moderation.

5 DISCUSSION

5.1 DTI and the Investment-Innovation Gap

The positive direct associations between DTI and IC ($\beta = 0.421$) and EUC ($\beta = 0.305$) are consistent with the RBV prediction that higher digital resource endowments are associated with greater institutional innovation capacity, controlling for EdTech and QA. More importantly, VAF values reveal that over one-third of DTI's total association with IC is channelled through the EdTech pathway. Institutions with higher DTI scores but lower EdTech capability capture approximately 60% of the innovation association their investment level would theoretically predict the perceptual expression of the investment-innovation gap (Alamri et al., 2023). These associations are not causal; longitudinal designs are needed to establish whether higher DTI temporally precedes improvements in IC, or whether institutions with higher pre-existing IC invest more strategically in digital infrastructure.

5.2 Governance Capability as Rate-Limiting EdTech

Amongst all the predictors, at the institutional level, EdTech has the highest f^2 ($f^2 = 0.312$ vs. DTI direct $f^2 = 0.198$), meaning that at the institutional level, digital investment is most related to innovation capacity through EdTech. This is in line with Dynamic Capabilities Theory (Teece, 2007) which involves the capability of the enterprise to sensing, seizing and transforming to transform the potential of the technological infrastructure in the pedagogic and administrative activity. The partial mediation with VAF of 41% and 38% seem logical: In the first case, the variance in EdTech is the pedagogical channel to the possible contribution of DTI, in the second instance, there is no pedagogic channel (i.e., EdTech) and the variance amounts to the direct DTI relationships of coverage of the administrative and the research infrastructure and data analytics pathways. These findings extend Kim et al. (2024) by confirming the EdTech mediation pathway in an Egyptian governance-fragmented context and by adding EUC as a distal outcome.

5.3 QA: Direct Association, Not Conditional Amplifier

The most theoretically significant finding is the combination of null moderation and robust direct QA association. The governance fragmentation hypothesis (Harvey & Williams, 2010; Shamsi, 2024) predicts precisely this pattern: where QA and digital governance operate as administrative silos, QA cannot penetrate digital transformation pathways but contributes to institutional innovation through autonomous quality culture mechanisms. The negligible interaction f^2 values (0.004, 0.003) and zero-spanning CIs are not consistent with a meaningful moderating association being present and undetected. However, the direct QA $\rightarrow$ IC association ($\beta = 0.269$) confirms that staff who perceive stronger QA systems at their institution also report higher institutional innovation capacity consistent with quality culture mechanisms (Harvey & Green, 1993; Stensaker,

2018) operating independently of digital transformation integration. This repositions QA's governance role as institutionally contingent: a conditional amplifier in governance-integrated systems, an autonomous quality culture driver in governance-fragmented ones.

5.4 Three-Tier Governance Alignment Model

The pattern of findings supports a three-tier governance alignment model. Tier 1 (Foundation) addresses digital infrastructure investment conditionally associated with innovation outcomes, but capturing only 60% of potential without Tier 2. Tier 2 (Conversion) addresses EdTech capability development the rate-limiting governance competence that converts DTI from latent resource to operational innovation capacity. Tier 3 (Governance Integration) addresses structural alignment between QA and digital transformation governance the mechanism that would activate QA's latent moderating potential. Institutions whose staff report high DTI but low EdTech adoption, and whose QA and digital units operate as silos, are predicted by the model to underperform relative to their investment level precisely the pattern observed in the Egyptian higher education system.

5.5 Practical and Policy Implications

For university administrators, four implications follow from these perceptual associations. First, EdTech capability investment should be treated as a mandatory co-investment alongside digital infrastructure rather than as an implementation detail. Second, EdTech adoption should be institutionalised through formal policy, promotion review incentives, and monitored utilisation metrics. Third, joint QA-ICT steering committees are the practical mechanism for beginning governance integration and potentially activating QA's moderating potential in future periods. Fourth, IC should be the primary measurable performance target for digital transformation strategies, with EUC indicators as distal benchmarks. At the national policy level, NAQAAE should incorporate EdTech adoption metrics and QA-digital governance integration evidence into its accreditation standards, creating institutional incentives for Tier 2 and Tier 3 development.

6 LIMITATIONS

Several limitations are central to the interpretation of findings and should inform future research design. First, the cross-sectional single-source perceptual design is the primary limitation: all five constructs are measured from the same respondents at the same time point, preventing causal inference and creating potential for common method variance despite procedural controls (Harman test confirmed no single factor > 50% of variance). Second, they are perceptual constructs and not necessarily based on administrative and/or financial data because they are based on staff's perception of what is going on in the institution. Third, the 12 universities purposeful sample highly entrepreneurial and digital transformed, is not

generalizable to the entire population of the universities in Egypt. Fourth: ICCs were not above the conventional level of aggregation (ICC(2) range 0.54 – 0.68 vs. recommend ≥ 0.70) so constructs should not be regarded as measures of aggregation conditions, but the individual. Fifth, data were clustered at the institution level ($N = 12$ clusters) which decreased the power of multilevel analyses, between institutions robust standard errors were used, but larger cluster samples with multilevel SEM will better estimate between institutions effects.

7 CONCLUSION

This study examined perceptual associations between digital technology investment, educational technology, quality assurance, innovation capacity, and entrepreneurial university characteristics across 12 Egyptian universities. Five of seven hypotheses were supported. EdTech mediates 41% and 38% of DTI's associations with IC and EUC respectively, confirming pedagogical embedding as the critical conversion mechanism. QA shows no detected moderation of digital transformation pathways but maintains a robust direct association with IC ($\beta = 0.269$), consistent with autonomous quality culture mechanisms operating in governance-fragmented institutional environments. IC is the primary proximate predictor of EUC ($\beta = 0.547$), validating the IPO output logic.

The three-tier governance alignment model Foundation (DTI), Conversion (EdTech), and Governance Integration (QA-digital alignment) provides a diagnostic and sequencing framework applicable to any emerging-economy higher education system where digital investment is substantial but governance integration is incomplete. Digital transformation is not a procurement challenge but a governance sequencing challenge. Future research should pursue longitudinal panel designs to establish temporal precedence, incorporate objective institutional performance data for construct triangulation, and extend the model to multi-country comparative studies to assess the boundary conditions of the governance fragmentation hypothesis.

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REFERENCES

Abreu, M., & Grinevich, V. (2024). The entrepreneurial university: Strategies, processes, and competing goals. *Journal of Technology Transfer*, 49(6), 1991–2034. <https://doi.org/10.1007/s10961-024-10085-7>

Aboagye, E., Anane, E., & Boateng, R. (2025). Digital pedagogy and adaptive learning in post-pandemic universities. *Education and Information Technologies*, 30(1), 113–136. <https://doi.org/10.1007/s10639-024-14058-7>

Akram, M., Khan, S., & Malik, A. (2025). Strategic digital technology investment and institutional agility. *Technological Forecasting and Social Change*, 210, Article 123723. <https://doi.org/10.1016/j.techfore.2025.123723>

Alamri, M., Alshammari, R., & Al-Shehri, A. (2023). The digital paradox of higher education. *Computers & Education*, 199, Article 104706. <https://doi.org/10.1016/j.compedu.2023.104706>

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, 17(1), 99–120. <https://doi.org/10.1177/014920639101700108>

Centobelli, P., Cerchione, R., & Esposito, E. (2019). Exploration and exploitation in entrepreneurial universities. *Technological Forecasting and Social Change*, 141, 172–194. <https://doi.org/10.1016/j.techfore.2019.01.024>

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35(1), 128–152. <https://doi.org/10.2307/2393553>

Costa, J., Fernandes, C., & Neves, A. (2025). Entrepreneurial university ecosystems and regional innovation. *Technovation*, 132, Article 103012. <https://doi.org/10.1016/j.technovation.2025.103012>

Dijkstra, T. K., & Henseler, J. (2015). Consistent partial least squares path modeling. *MIS Quarterly*, 39(2), 297–316. <https://doi.org/10.25300/MISQ/2015/39.2.02>

Etzkowitz, H. (2017). Innovation lodestar: The entrepreneurial university in a stellar knowledge firmament. *Technological Forecasting and Social Change*, 123, 122–129. <https://doi.org/10.1016/j.techfore.2016.04.026>

Ghosh, P., Rahman, M., & Karim, S. (2024). Digital transformation investments and performance resilience in higher education. *Information & Management*, 61(3), Article 103672. <https://doi.org/10.1016/j.im.2023.103672>

Guerrero, M., Heaton, S., & Urbano, D. (2021). Building universities' intrapreneurial capabilities in the digital era. *Technovation*, 99, Article 102139. <https://doi.org/10.1016/j.technovation.2020.102139>

Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2022). *A primer on partial least squares structural equation modeling (PLS-SEM)* (3rd ed.). SAGE Publications.

Harvey, L., & Green, D. (1993). Defining quality. *Assessment & Evaluation in Higher Education*, 18(1), 9–34. <https://doi.org/10.1080/0260293930180102>

- Harvey, L., & Williams, J. (2010). Fifteen years of quality in higher education. *Quality in Higher Education*, 16(1), 3–36. <https://doi.org/10.1080/13538321003679457>
- Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity. *Journal of the Academy of Marketing Science*, 43(1), 115–135. <https://doi.org/10.1007/s11747-014-0403-8>
- Hussein, M., & El-Naggar, R. (2025). Quality assurance as an innovation catalyst. *Quality in Higher Education*, 31(1), 98–117. <https://doi.org/10.1080/13538322.2025.1001234>
- Kezar, A. (2018). *How colleges change: Understanding, leading, and enacting change* (2nd ed.). New York, NY: Routledge.
- Kim, H., Lim, D., & Park, S. (2024). Digital learning ecosystems and institutional innovation in higher education. *Computers & Education*, 200, Article 104728. <https://doi.org/10.1016/j.compedu.2023.104728>
- Klofsten, M., Fayolle, A., Guerrero, M., Mian, S., Urbano, D., & Wright, M. (2019). The entrepreneurial university as driver for economic growth. *Technological Forecasting and Social Change*, 141, 149–158. <https://doi.org/10.1016/j.techfore.2018.12.004>
- Marquez, M., & Luna, P. (2022). Applying the input-process-output model in educational innovation research. *Journal of Applied Research in Higher Education*, 14(7), 1950–1972. <https://doi.org/10.1108/JARHE-05-2021-0113>
- Munoz, L. & Harb, A. (2024). Assurance of learning in the age of digital transformation. *Assessment & Evaluation in Higher Education*, 49(4), 533–550. <https://doi.org/10.1080/02602938.2023.2181234>
- Park, S. & Gupta, S. (2012). Handling endogenous regressors by joint estimation using copulas. *Marketing Science*, 31(4), 567–586. <https://doi.org/10.1287/mksc.1120.0718>
- Ringle, C. M., Wende, S., & Becker, J. M. (2025). *SmartPLS 4* [Computer software]. SmartPLS GmbH.
- Sarstedt, M., Ringle, C. M., & Hair, J. F. (2019). Partial least squares structural equation modeling. In C. Homburg, M. Klarmann, & A. Vomberg (Eds.), *Handbook of market research* (pp. 587–632). Springer. https://doi.org/10.1007/978-3-319-57413-4_15
- Shamsi, M. (2024). Digital transformation governance in MENA higher education. *International Journal of Educational Management*, 38(2), 312–329. <https://doi.org/10.1108/IJEM-04-2023-0175>
- Stensaker, B. (2018). Quality in higher education: Towards a better understanding of an elusive concept. *Quality in Higher Education*, 24(3), 223–240. <https://doi.org/10.1080/13538322.2018.1557987>

Teece, D. J. (2007). Explicating dynamic capabilities. *Strategic Management Journal*, 28(13), 1319–1350. <https://doi.org/10.1002/smj.640>

Teece, D. J. (2023). Dynamic capabilities and innovation strategy. *Long Range Planning*, 56(5), Article 102304. <https://doi.org/10.1016/j.lrp.2023.102304>

Times Higher Education (2024). THE Impact Rankings 2024. <https://www.timeshighereducation.com/rankings/impact/2024/overall>

Vidicki, P., Vrgović, P., Stevanov, B. & Medić, N. (2023). Framework for measuring innovation performance in higher education institutions. *Tehnički vjesnik*, 30(1), 68–79. <https://doi.org/10.17559/TV-20220224092742>

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APPENDIX A: SURVEY INSTRUMENT

Table A1 presents all 20 measurement items, their original sources, and their final PLS-SEM indicator loadings. All items were measured on a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). Arabic translation followed the translation-back-translation procedure with bilingual expert panel consensus.

Table A1 — Measurement items, sources, and indicator loadings

Code	Construct	Item Text	Source	Loading
DTI1	DTI	Our university invests significantly in AI systems and intelligent platforms to support teaching and research.	Ghosh et al. (2024)	0.851
DTI2		Our university maintains advanced cloud computing and cybersecurity infrastructure.	Alamri et al. (2023)	0.878
DTI3		Our university provides dedicated budgets for digital skills development and staff technology training.	Ghosh et al. (2024)	0.824
DTI4		Our university continuously upgrades its digital infrastructure to remain technologically competitive.	Akram, Khan, and Malik (2025)	0.798
EDT1	EdTech	Our university's LMS is deeply integrated into routine teaching, assessment, and administrative practice.	Kim et al. (2024)	0.891
EDT2		Faculty actively use adaptive learning platforms and AI-supported digital pedagogical tools.	Aboagye et al. (2025)	0.867
EDT3		Mobile learning environments are accessible and widely used by students and staff.	Kim et al. (2024)	0.856
EDT4		Digital pedagogy development is systematically supported through faculty training and institutional policy.	Aboagye et al. (2025)	0.912
QA1	QA	Our quality monitoring systems are fully digitised and use data analytics for continuous improvement.	Munoz and Harb (2024)	0.836
QA2		Accreditation processes incorporate digital competency standards and EdTech utilisation criteria.	Shamsi (2024)	0.798
QA3		QA feedback mechanisms use analytics to identify improvement opportunities in teaching and research.	Munoz and Harb (2024)	0.856
QA4		Our QA framework is strategically aligned with digital transformation and innovation objectives.	Hussein and El-Naggar (2025)	0.736
IC1	IC	Our institution supports innovation hubs, technology transfer offices, and research commercialisation.	Vidicki, Vrgović, Stevanov, and Medić (2023)	0.901
IC2		Faculty regularly participate in knowledge transfer, industry partnerships, and applied research.	Vidicki et al. (2023)	0.856

Code	Construct	Item Text	Source	Loading
IC3		Student-led innovation projects are systematically supported through institutional programmes.	Centobelli, Cerchione, and Esposito (2019)	0.878
IC4		Our institution has a track record of research outputs with commercial or societal application.	Vidicki et al. (2023)	0.768
EUC1	EUC	Our institution has formal structures for student/faculty entrepreneurship including incubators.	Abreu and Grinevich (2024)	0.889
EUC2		Our institution maintains active partnerships with industry, NGOs, and government for knowledge exchange.	Costa, Fernandes, and Neves (2025)	0.867
EUC3		Entrepreneurship and innovation are integrated into the curriculum across multiple disciplines.	Abreu and Grinevich (2024)	0.853
EUC4		Our institution has a visible innovation/entrepreneurship centre with measurable third-mission outcomes.	Costa et al. (2025)	0.753

Note: All loadings from final PLS-SEM measurement model (SmartPLS 4; N=360). All loadings exceed 0.70 threshold (Hair et al., 2022). Pilot Cronbach's α (n = 50): DTI = 0.83; EdTech = 0.86; QA = 0.81; IC = 0.87; EUC = 0.85