

# Shaping Innovation in Education: Transformational Leadership, Knowledge Management, and a Dual PLS-SEM–NCA Approach

CONFIGURANDO INNOVACIÓN EN EDUCACIÓN: LIDERAZGO TRANSFORMACIONAL Y GESTIÓN DEL CONOCIMIENTO, CON ENFOQUE DUAL PLS-SEM—NCA

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## Abstract

**Purpose:** To examine how transformational leadership influences innovation in higher education through a dual analytical approach (PLS-SEM and Necessary Condition Analysis), considering the mediating role of knowledge management capabilities.

**Methodology:** A postpositivist paradigm with a quantitative, cross-sectional design. Structured surveys were distributed to university professors in Lima (Peru), yielding 235 valid responses. The study examined direct and indirect relationships among transformational leadership, knowledge management capabilities (acquisition, sharing, and application), and innovation.

**Results:** Transformational leadership influences innovation indirectly via knowledge sharing and knowledge application. The direct effect is not supported, and knowledge acquisition is not significant. NCA shows that transformational leadership, knowledge sharing, and knowledge application constitute necessary conditions for high innovation.

**Implications:** The findings refine Leadership–Knowledge–Innovation theory by demonstrating that leadership drives innovation primarily through capability-based mechanisms. Practically, higher education institutions should strengthen structures that promote knowledge sharing and application among faculty.

**Originality:** Empirical evidence is provided through the integration of PLS-SEM and NCA, offering a more comprehensive understanding by combining average effects and structural constraints. This dual approach highlights how leadership and knowledge processes jointly shape innovation, a critical priority in higher education.

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## Resumen

**Propósito:** Examinar cómo el liderazgo transformacional influye en la innovación en la educación superior mediante un enfoque analítico dual (PLS-SEM y Análisis de Condiciones Necesarias, NCA), considerando el papel mediador de las capacidades de gestión del conocimiento.

**Metodología:** Se adoptó un paradigma postpositivista con un diseño cuantitativo y transversal. Se aplicaron encuestas estructuradas a profesores universitarios en Lima (Perú), obteniéndose 235 respuestas válidas. Se analizaron relaciones directas e indirectas entre el liderazgo transformacional, las capacidades de gestión del conocimiento (adquisición, intercambio y aplicación) y la innovación.

**Resultados:** El liderazgo transformacional influye en la innovación de forma indirecta a través del intercambio y la aplicación del conocimiento. El efecto directo no es respaldado y la adquisición de conocimiento no resulta significativa. El NCA muestra que el liderazgo transformacional, el intercambio y la aplicación del conocimiento constituyen condiciones necesarias para alcanzar altos niveles de innovación.

**Implicaciones:** Los hallazgos refinan la teoría Liderazgo-Conocimiento-Innovación al mostrar que el liderazgo impulsa la innovación mediante mecanismos basados en capacidades. En la práctica, las instituciones de educación superior deben promover el intercambio y la aplicación del conocimiento entre docentes.

**Originalidad:** Se aporta evidencia empírica al integrar PLS-SEM y NCA para explicar cómo el liderazgo y los procesos de conocimiento configuran la innovación.

## INFORMACIÓN ARTÍCULO

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## INTRODUCTION

Innovation (INV) is increasingly essential for Higher Education Institutions (HEIs) to maintain quality and societal relevance in contexts of technological change, evolving pedagogical demands, and growing competition (Bellibas et al., 2024; Fan & Beh, 2024). In this context, INV in HEIs extends beyond technological adoption and refers to systematic changes in teaching practices, research processes, and internal organizational procedures that enhance the institution's capacity to respond to emerging academic and social demands. Such transformations are consistent with the resource-based view, which emphasizes the strategic role of valuable and difficult-to-imitate internal resources (Barney, 1991), and with the knowledge-based view, which identifies the creation, integration, and application of knowledge as primary sources of organizational advantage (Grant, 1996). From this perspective, universities must continuously renew their internal processes by recombining existing knowledge and resources, reflecting Schumpeter (1934) notion of INV as the formation of new combinations and Teece

et al.'s (1997) concept of dynamic capabilities, understood as the ability to integrate and reconfigure competences in changing environments. Consequently, INV in HEIs can be interpreted as an outcome of the institution's capacity to mobilize knowledge and adapt its structures and practices through ongoing reconfiguration of internal capabilities.

Within this setting, transformational leadership (TRL) is frequently examined as a driver of organizational change. Rooted in the work of Burns (1978) and further developed by Bass (1985), TRL refers to a leadership style that articulates a shared vision, promotes intellectual stimulation, and fosters climates supportive of learning. Transformational leaders are therefore expected to create conditions that facilitate innovative outcomes (Harsono et al., 2024; Ha et al., 2025). Some empirical studies report positive associations between TRL and INV across organizational contexts (Gui et al., 2024; Nabi et al., 2023). However, findings are not consistent. Other studies report non-significant direct effects of TRL on innovation-related outcomes in institutional or highly structured organizational contexts (Aisyah et al., 2025). This pattern suggests that

the influence of leadership on INV in HEIs may operate primarily through organizational mechanisms rather than through a direct path. The issue is especially relevant in HEIs, where professional autonomy, disciplinary specialization, and decentralized structures can limit the immediate translation of leadership actions into innovative practices.

This study addresses this empirical puzzle by examining whether the relationship between TRL and INV in HEIs operates through Knowledge Management (KM) capabilities. Prior research suggests that leadership influences INV largely by shaping organizational knowledge processes (Gui et al., 2024; Nabi et al., 2023). Specifically, we consider Knowledge Acquisition Capability (KAC), Knowledge Sharing Capability (KSH), and Knowledge Application Capability (KAP), consistent with the organizational capability perspective on KM (Gold et al., 2001). From a knowledge-based view, these capabilities represent structured processes through which knowledge is generated, circulated, and utilized as a strategic resource (Grant, 1996). In HEIs, where knowledge processes are shaped by academic cultures, disciplinary specialization, and professional autonomy, KM capabilities are expected to function as the primary mechanisms through which leadership efforts translate into institutional INV (Hoang & Le, 2024; Fan & Beh, 2024).

In addition to this theoretical gap, a methodological limitation characterizes much of the existing research. Most studies rely on structural equation modeling to estimate average effects, thereby adopting a sufficiency logic that addresses whether increases in an antecedent are associated with increases in an outcome (Hair et al., 2022). While informative, this approach cannot determine whether certain factors represent minimum necessary conditions for INV to reach high levels. Necessary Condition Analysis (NCA) offers a complementary perspective by identifying whether the absence of a minimum level of a condition constrains the outcome (Dul et al., 2023). In HEIs, this distinction is critical: even when leadership behaviors are present, INV may remain limited if key knowledge capabilities do not reach baseline levels that allow knowledge to be acquired, circulated, and applied effectively.

This study therefore investigates the TRL–KM–INV nexus in Peruvian HEIs using a dual analytical approach that combines PLS-SEM and NCA. By integrating sufficiency and necessity logics, the research offers three contributions. First, it offers a refined explanation for the mixed evidence on the TRL–INV relationship by positioning KM capabilities as the primary mechanisms through which leadership influences INV. Second, it extends INV research by examining KM capabilities and leadership not only as performance-enhancing factors but as potential boundary conditions. While prior studies could estimate whether leadership and knowledge processes increase innovation on average, they could not determine whether innovation fails to reach higher levels when minimum thresholds of these conditions are absent. By testing this necessity logic, the study clarifies whether innovation in HEIs depends on baseline levels of knowledge capabilities and leadership that enable knowledge recombination and application. Third, it contributes empirical evidence from the Peruvian higher education context, an underrepresented setting in the leadership, knowledge management, and INV literature, and provides guidance for HEI governance on prioritizing knowledge-related capabilities that support sustainable institutional innovation.

## LITERATURE REVIEW

### *Integrated Theoretical Framework*

This study proposes a unified explanatory framework that integrates the Resource-Based View (RBV), the Knowledge-Based View (KBV), and Dynamic Capabilities Theory (DCT). This theoretical synthesis moves beyond fragmented perspectives to clarify the causal chain through which leadership is converted into INV within the professionalized context of HEIs.

RBV provides the foundational logic by conceptualizing TRL and KM capabilities as strategic intangible resources. According to Barney (1991), sustained advantage derives from resources that are valuable, rare, inimitable, and non-substitutable. In HEIs, where infrastructure and curricula tend to standardize, differentiation depends largely on leadership quality and institutional knowledge

However, RBV alone does not explain how such resources are mobilized.

KBV addresses this limitation by identifying knowledge as the most strategically significant resource (Grant, 1996). Universities are archetypal knowledge organizations in which expertise is dispersed across autonomous academics. Their central challenge is not only knowledge creation but the integration of specialized knowledge into organizational processes. In this study, KAC, KSH, and KAP represent the structured mechanisms through which individual expertise becomes an institutional capability.

DCT adds the adaptation logic. Teece et al. (1997) define dynamic capabilities as the ability to integrate, build, and reconfigure competences in changing environments. In HEIs facing technological and pedagogical transformation, KAC, KSH, and KAP function as dynamic processes that enable knowledge recombination. Leadership therefore operates as a catalyst: it activates KM capabilities, which reconfigure institutional knowledge into innovative outcomes (Grant, 1996; Teece et al., 1997).

### ***Transformational Leadership and Innovation***

Transformational Leadership (TRL), rooted in Burns (1978) and Bass (1985), is characterized by idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration. In HEIs—professional bureaucracies where autonomy is high—leadership effectiveness relies on inspiration and intellectual challenge rather than hierarchical control (Bellibas et al., 2024).

Transformational leadership (TRL) fosters innovation (INV) by encouraging experimentation and adaptive thinking that support changes in pedagogical and collaborative practices (Saif et al., 2024). Such an environment also enables educators to adopt emerging instructional approaches, including AI-based tools increasingly present in higher education (Holubnycha et al., 2025). From an RBV perspective, TRL functions as an intangible asset that aligns individual efforts with institutional goals and strengthens internal capabilities (Nabi et al., 2023).

However, evidence in educational settings is mixed. Faculty autonomy and bureaucratic routines can buffer direct leadership effects, suggesting that TRL may influence INV in HEIs both directly and indirectly through organizational knowledge processes (Aisyah et al., 2025). From a theoretical standpoint, leadership is still expected to exert a positive influence on INV. Consequently, we propose:

*H1. Transformational Leadership positively influences Innovation.*

### ***Transformational Leadership and Knowledge Management***

From a KBV perspective, leadership is essential for coordinating dispersed expertise. TRL shapes the knowledge environment that enables institutional learning.

KAC refers to the capacity to identify and obtain relevant knowledge (Gold et al., 2001). Transformational leaders act as boundary spanners, encouraging environmental scanning and openness to new ideas (Huynh et al., 2024; Nabi et al., 2023).

KSH involves systematic dissemination of knowledge across units. TRL builds trust and psychological safety, reducing academic silos and fostering collaboration (Kim & Park, 2020).

KAP concerns the effective use of knowledge in decisions and practices (Gold et al., 2001). Learning-oriented leadership motivates faculty to apply insights in teaching and administration (Gil et al., 2021). Consequently, we propose:

*H2. Transformational Leadership positively influences Knowledge Acquisition Capability.*

*H3. Transformational Leadership positively influences Knowledge Sharing Capability.*

*H4. Transformational Leadership positively influences Knowledge Application Capability.*

### ***Knowledge Management and Innovation***

From the perspectives of the Knowledge-Based View and Dynamic Capabilities Theory, INV is conceptualized as a cumulative process of knowledge transformation rather than a discrete event. In HEIs, this process requires an integrated sequence of capabilities: KAC renews the knowledge base and enhances INV (Nabi et

al., 2023); knowledge sharing (KSH) enables interdisciplinary recombination and collective learning (Nabi et al., 2023); and knowledge application (KAP) translates synthesized knowledge into concrete improvements and innovative outcomes (Ode & Ayavoo, 2019). Together, these capabilities operationalize the conversion of intangible knowledge resources into INV performance. Consequently, we propose:

*H5. Knowledge Acquisition Capability positively influences Innovation.*

*H6. Knowledge Sharing Capability positively influences Innovation.*

*H7. Knowledge Application Capability positively influences Innovation.*

### **Mediations**

While TRL is often linked to INV, theoretical perspectives suggest that its influence in professional organizations such as HEIs is largely indirect. Leaders shape the organizational context within which knowledge processes unfold.

From a KBV perspective, leaders coordinate the knowledge system that makes INV possible (Grant, 1996). Transformational leaders stimulate intellectual curiosity, encourage collaboration, and legitimize experimentation, thereby influencing how knowledge is acquired, shared, and applied rather than directly generating innovative outputs.

DCT further supports this mechanism. INV requires the recombination and reconfiguration of knowledge resources (Teece et al., 1997). KAC ensures access to new ideas, KSH enables cross-boundary recombination, and KAP converts insights into implemented practices. TRL operates as a higher-level catalyst that activates these processes.

Empirical research aligns with this logic (Gui et al., 2024; Nabi et al., 2023). In HEIs, where INV depends on collective expertise rather

than centralized authority, KM capabilities are therefore expected to transmit leadership influence. Consequently, we propose:

*H8. Knowledge Acquisition Capability mediates the relationship between Transformational Leadership and Innovation.*

*H9. Knowledge Sharing Capability mediates the relationship between Transformational Leadership and Innovation.*

*H10. Knowledge Application Capability mediates the relationship between Transformational Leadership and Innovation.*

### **Necessary Conditions for Innovation**

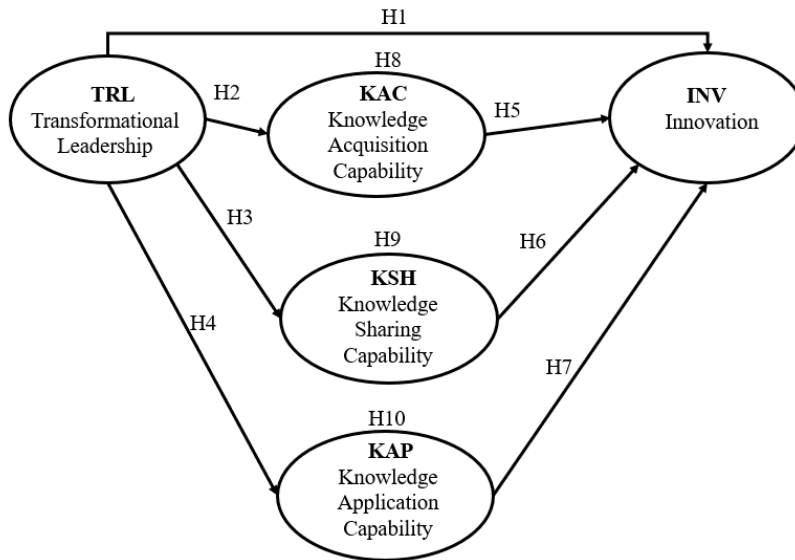
Traditional SEM logic evaluates whether variables increase INV on average. However, INV in HEIs may also depend on minimum enabling conditions. NCA identifies whether the absence of a factor prevents high levels of an outcome (Dul et al., 2023).

From a DCT perspective, INV cannot occur without basic knowledge flows. If an institution lacks the ability to acquire new knowledge (KAC), it cannot renew its knowledge base. Without KSH, expertise remains isolated, preventing recombination. Without KAP, knowledge remains conceptual and does not translate into innovative practices. These capabilities therefore resemble system bottlenecks: below certain thresholds, INV becomes structurally unattainable.

Transformational Leadership may also function as a necessary enabler. Even if KM processes exist formally, their activation depends on leadership that promotes trust, collaboration, and openness to change (Lee et al., 2023).

*H11. Transformational Leadership constitutes a necessary condition for achieving high levels of Innovation.*

*H12. Knowledge Acquisition Capability, Knowledge Sharing Capability, and Knowledge Application Capability constitute necessary conditions for achieving high levels of Innovation.*



**Figure 1.** Conceptual PLS-SEM model: Transformational leadership and innovation with the mediation role of Knowledge acquisition capability, Knowledge sharing capability, and Knowledge application capability. *Source: Own elaboration.*

*Notes:* TRL = Transformational Leadership; KAC = Knowledge Acquisition Capability; KSH = Knowledge Sharing Capability; KAP = Knowledge Application Capability; INV = Innovation. Arrows represent hypothesized relationships among constructs.

## METHODOLOGY

### *Participants and Procedure*

Data were collected from university professors working in HEIs in Lima, Peru, using a non-probabilistic convenience sampling approach complemented by snowball sampling. This strategy is common in organizational research involving specialized professional populations, as it facilitates access to respondents with direct experience in teaching, research, and institutional processes relevant to leadership, knowledge management, and innovation. The questionnaire was administered online via Google Forms and included an informed consent form outlining the study's objectives, voluntary participation, anonymity, and exclusive academic use of the data.

To be eligible be active professors with teaching and/or research responsibilities in a Peruvian HEI. Incomplete or inconsistent questionnaires were excluded. Of 245 responses received, 235 valid cases were retained using complete-case procedures, with no imputation applied. The final

sample included faculty from public and private institutions, representing diverse academic disciplines and ranks. In terms of experience, 28% had 1–10 years, 35% had 11–20 years, 31% had 21–30 years, and 6% had more than 30 years of professional experience. Although the sampling design limits statistical generalization, it is appropriate for theory testing in higher education contexts where knowledgeable respondents are essential. Moreover, the sample size exceeds recommended minimum thresholds for PLS-SEM, supporting the statistical adequacy of the model estimation (Kock & Hadaya, 2018; Hair et al., 2022).

Procedural remedies were applied to mitigate common method bias, including guaranteeing anonymity, ensuring voluntary participation, using validated scales for distinct constructs, presenting variables in separate blocks, and adapting wording for clarity to create psychological separation between predictors and outcomes. Ethical approval was granted by the Ethics Committee of the Graduate Academic Unit at Universidad de Lima (EPG-DAI-003-2024).

## Measures

All constructs were specified as reflective latent variables, consistent with their theoretical conceptualization as underlying phenomena manifested through observable indicators. Transformational Leadership (TRL) was measured using the 7-item scale by Carless et al. (2000) on a 5-point Likert scale. Innovation (INV) was assessed with the 6-item scale by Subramaniam and Youndt (2005) using a 7-point scale. Knowledge Acquisition Capability (KAC) and Knowledge Sharing Capability (KSH) were measured with Chen and Huang's (2009) scale (3 items each, 7-point scale). Knowledge Application Capability (KAP) was measured using the 4-item scale by Huynh et al., (2024) on a 5-point scale. A back-translation procedure, expert review, and pilot testing ensured linguistic and content validity.

Although the constructs were measured using different Likert ranges, this does not affect model estimation. PLS-SEM operates on latent construct scores that are standardized in the structural model through the estimation procedure, which removes scale-range differences at the path coefficient level. The NCA was conducted using these same latent construct scores generated by SmartPLS 4.0. The bottleneck values therefore represent proportional positions within the empirical distribution of each construct, enabling interpretation of minimum required levels while preserving comparability across variables measured with different original scale ranges.

## Data Analysis

Data were analyzed using PLS-SEM in SmartPLS 4.0 to evaluate measurement properties and structural relationships. PLS-SEM was selected due to its suitability for prediction-oriented research, its robustness to non-normal data, and its ability to handle complex mediation structures with moderate sample sizes (Hair et al., 2022). In addition, the objective of this study is variance explanation and mechanism identification rather than covariance structure reproduction. Whereas CB-SEM primarily evaluates global model fit and the consistency of a theoretical covariance matrix with the data, this research focuses on explaining variance in INV and examining indirect capability-based mechanisms. This prediction- and explanation-

oriented purpose aligns more closely with the variance-based logic of PLS-SEM.

All constructs were modeled reflectively. Path significance was assessed using bootstrapping with 10,000 resamples, applying one-tailed tests consistent with the hypothesized positive relationships, and bias-corrected confidence intervals. Collinearity diagnostics showed VIF values below 5.0, indicating no critical multicollinearity. No control variables were included, as the focus was on testing the proposed explanatory mechanisms.

Common method bias (CMB), a potential risk in cross-sectional self-report research (Podsakoff et al., 2003), was addressed through procedural remedies and statistically assessed using the full collinearity VIF approach (Kock, 2015). All VIF values were below 3.3, indicating that CMB is unlikely to threaten the results.

In NCA, the effect size ( $d$ ) indicates the strength of a necessary condition, typically interpreted as small ( $0 < d < 0.10$ ), medium ( $0.10 \leq d < 0.30$ ), or large ( $d \geq 0.30$ ) (Dul et al., 2023). This measure is central for assessing necessity, while accuracy reflects the fit of the ceiling line but is not essential for inference. The analysis should use the CE-FDH method, recommended as more conservative than CR-FDH.

## RESULTS

### Measurement Model Evaluation

Following Hair et al. (2022), outer loadings above 0.70 are desirable, as they indicate that a construct explains at least 50% of an item's variance. While loadings between 0.40 and 0.70 may be retained under certain conditions, their removal is recommended if it significantly improves the construct's reliability or convergent validity. In the initial assessment, most indicators surpassed the 0.70 threshold; however, items INV4, INV6, and TRL7 exhibited insufficient loadings. Consequently, these three indicators were eliminated, and the model was re-estimated. The results confirmed satisfactory internal consistency and composite reliability. All values exceed the recommended threshold of 0.70. Convergent validity was assessed via the Average Variance Extracted (AVE). According to Hair et al. (2022), AVE values should exceed 0.50 to ensure the construct explains more

than half of its indicators' variance. Following the refinement of the model, all constructs achieved acceptable AVE values, ranging from 0.602 to 0.818.

Discriminant validity was assessed using the Fornell–Larcker criterion and the heterotrait–monotrait ratio (HTMT). According to the Fornell–Larcker criterion, the square root of

the AVE for each construct was greater than its correlations with the other constructs, supporting discriminant validity. Additionally, all HTMT values were below the conservative cutoff of 0.85, confirming adequate differentiation between constructs. The full results are presented in Tables 2 and 3.

**Table 1.** Reflective measurement model: Indicator Reliability, Internal Consistency Reliability, and Convergent Validity.

Construct	Item	Loading	Alpha	rho_A	rho_C	AVE
Innovation	INV1	0.923	0.902	0.921	0.933	0.778
	INV2	0.937				
	INV3	0.918				
	INV5	0.736				
Knowledge Acquisition Capability	KAC1	0.816	0.807	0.811	0.886	0.722
	KAC2	0.868				
	KAC3	0.863				
Knowledge Application Capability	KAP1	0.797	0.889	0.896	0.923	0.750
	KAP2	0.885				
	KAP3	0.885				
	KAP4	0.894				
Knowledge Sharing Capability	KSH1	0.927	0.888	0.900	0.931	0.818
	KSH2	0.926				
	KSH3	0.857				
Transformational Leadership	TRL1	0.773	0.869	0.883	0.901	0.602
	TRL2	0.760				
	TRL3	0.790				
	TRL4	0.785				
	TRL5	0.757				
	TRL6	0.788				

Source: Own elaboration.

Notes: TRL = Transformational Leadership; KAC = Knowledge Acquisition Capability; KSH = Knowledge Sharing Capability; KAP = Knowledge Application Capability; INV = Innovation.

Indicator Reliability: Loading = outer loading of each indicator. Internal Consistency Reliability: Alpha = Cronbach's alpha; rho\_A = Dijkstra–Henseler's rho; rho\_C = composite reliability. Convergent Validity: AVE = average variance extracted.

**Table 2.** Discriminant Validity Assessment: Fornell–Larcker Criterion.

	INV	KAC	KAP	KSH	TRL
INV	0.882				
KAC	0.530	0.850			
KAP	0.575	0.589	0.866		
KSH	0.644	0.651	0.726	0.904	
TRL	0.345	0.388	0.400	0.425	0.776

Source: Own elaboration. Note: TRL = Transformational Leadership; KAC = Knowledge Acquisition Capability; KSH = Knowledge Sharing Capability; KAP = Knowledge Application Capability; INV = Innovation.

**Table 3.** Discriminant Validity Assessment: Heterotrait–Monotrait Ratio (HTMT) Matrix of Construct Correlations.

HTMT	INV	KAC	KAP	KSH	TRL
INV					
KAC	0.615				
KAP	0.639	0.689			
KSH	0.710	0.764	0.814		
TRL	0.369	0.450	0.434	0.464	

Source: Own elaboration.

Notes: TRL = Transformational Leadership; KAC = Knowledge Acquisition Capability; KSH = Knowledge Sharing Capability; KAP = Knowledge Application Capability; INV = Innovation.

HTMT = heterotrait–monotrait ratio of correlations.

Values below 0.9 indicate adequate discriminant validity.

**Table 4.** Collinearity Assessment in the Structural Model: Variance Inflation Factors.

	VIF
KAC→INV	1.859
KAP→INV	2.257
KSH→INV	2.578
TRL→INV	1.270
TRL→KAC	1.000
TRL→KAP	1.000
TRL→KSH	1.000

Source: Own elaboration.

Notes: TRL = Transformational Leadership; KAC = Knowledge Acquisition Capability; KSH = Knowledge Sharing Capability; KAP = Knowledge Application Capability; INV = Innovation. Collinearity Assessment: VIF = variance inflation factor. VIF values are reported for each predictor–outcome relationship in the structural model (e.g., KAC → INV). Values below 3.3 indicate absence of multicollinearity issues.

### Structural Model Evaluation

The structural model was evaluated using path coefficients, significance levels obtained through bootstrapping, effect sizes ( $f^2$ ), coefficients of determination ( $R^2$ ), and predictive relevance ( $Q^2$ ). A significance level of  $\alpha < 0.05$  was adopted as the decision criterion.

Following the validation of the measurement model the structural model was assessed to analyze the proposed relationships between the constructs. First, collinearity was examined using VIF values (see Table 4). According to Hair et al. (2022), critical collinearity occurs when  $VIF \geq 5$ , non-critical collinearity may

be present if VIF is between 3 and 5, and it is not considered a problem if  $VIF < 3$ . In Table 4, all VIF values are below 3, indicating that multicollinearity is not a concern for model estimation.

Subsequently, the explanatory power of the endogenous constructs was assessed using the coefficient of determination ( $R^2$ ). The results indicate that the model explains 45.3% of the variance in INV. For the KM capabilities,  $R^2$  values are 0.151 for KAC, 0.160 for KAP, and 0.181 for KSH. According to Hair et al. (2022), the  $R^2$  value for INV represents a moderate level of explanatory power, while those for the KM capability constructs indicate low to moderate explanatory levels.

Predictive relevance was evaluated using the Stone–Geisser  $Q^2$  statistic. All endogenous constructs exhibited  $Q^2$  values greater than zero (INV = 0.109; KAC = 0.136; KAP = 0.149; KSH = 0.168), confirming that the model demonstrates predictive relevance for estimating the dependent constructs.

The structural model results further indicate that not all proposed direct relationships were significant. Specifically, TRL does not have a significant direct effect on INV ( $\beta = 0.047$ ,  $t = 0.729$ ,  $p = 0.466$ ), and thus H1 is not supported. However, TRL shows strong and statistically significant positive effects on all KM capabilities: KAC ( $\beta = 0.388$ ,  $t = 6.896$ ,  $p < 0.001$ ), KSH ( $\beta = 0.425$ ,  $t = 7.489$ ,  $p < 0.001$ ), and KAP ( $\beta = 0.400$ ,  $t = 8.233$ ,  $p < 0.001$ ). Therefore, H2, H3, and H4 are supported.

Regarding the effects of KM capabilities on INV, KSH has a substantial positive effect ( $\beta = 0.396$ ,  $t = 4.889$ ,  $p < 0.001$ ), and knowledge KAP also exerts a significant positive influence ( $\beta = 0.182$ ,  $t = 2.179$ ,  $p = 0.029$ ). Thus, H6 and H7 are supported. In contrast, the effect of KAC on INV is not statistically significant ( $\beta = 0.146$ ,  $t = 1.759$ ,  $p = 0.079$ ). Because the p-value exceeds the 0.05 threshold, H5 is not supported, although the positive coefficient suggests a weak directional tendency.

**Table 5.** Structural Model Results: Direct Effects, Statistical Significance, and Predictive Accuracy of Endogenous Constructs.

Hypothesis	Path	$\beta$	SD	t-Statistic	p-Value	Decision
H1	TRL→ INV	0.047	0.064	0.729	0.466	Not supported
H2	TRL→ KAC	0.388	0.056	6.896	0.000	Supported
H3	TRL→ KSH	0.425	0.057	7.489	0.000	Supported
H4	TRL→ KAP	0.400	0.049	8.233	0.000	Supported
H5	KAC→ INV	0.146	0.083	1.759	0.079	Not Supported
H6	KSH→ INV	0.396	0.081	4.889	0.000	Supported
H7	KAP→ INV	0.182	0.083	2.179	0.029	Supported
Variable	$R^2$	$Q^2$				
INV	0.453	0.109				
KAC	0.151	0.136				
KAP	0.160	0.149				
KSH	0.181	0.168				

Source: Own elaboration.

Notes: TRL = Transformational Leadership; KAC = Knowledge Acquisition Capability; KSH = Knowledge Sharing Capability; KAP = Knowledge Application Capability; INV = Innovation.

Direct Effects: Hypothesis = proposed relationship; Path = structural relationship between constructs;  $\beta$  = standardized path coefficient. Statistical Significance: SD = standard deviation; t-value = t-statistic obtained from bootstrapping; p-value = significance level; Decision = hypothesis testing result (supported/not supported).

Predictive Accuracy of Endogenous Constructs:  $R^2$  = coefficient of determination (explained variance);  $Q^2$  = predictive relevance (Stone–Geisser criterion obtained via blindfolding).

**Mediation Analysis**

The analysis of indirect effects shows that TRL influences INV through selected KM capabilities. Specifically, the indirect effect of TRL on INV through knowledge sharing (KSH) is positive and statistically significant ( $\beta = 0.168, t = 4.072, p < 0.001$ ), thereby supporting H9. Likewise, TRL exerts a significant indirect effect on INV via KAP ( $\beta = 0.073, t = 2.062, p = 0.039$ ), which supports H10.

In contrast, the indirect effect of TRL on INV through KAC is not statistically significant ( $\beta = 0.057, t = 1.594, p = 0.111$ ). Therefore, H8 is not supported.

Overall, these findings indicate that the impact of TRL on INV operates indirectly through KSH and KAP, while KAC does not constitute a significant mediating mechanism in this relationship.

**Table 6.** Mediation Analysis: Indirect Effects and Their Statistical Significance (Bootstrapping Results)

Hypothesis	Mediation Path	$\beta$	SD	t-Statistic	p-Value	Decision
H8	TRL→KAC→INV	0.057	0.036	1.594	0.111	Not supported
H9	TRL→KSH→INV	0.168	0.041	4.072	0.000	Supported
H10	TRL→KAP→INV	0.073	0.035	2.062	0.039	Supported

Source: Own elaboration.

Notes: TRL = Transformational Leadership; KAC = Knowledge Acquisition Capability; KSH = Knowledge Sharing Capability; KAP = Knowledge Application Capability; INV = Innovation.

Indirect Effects: Hypothesis = proposed mediation relationship; Mediation Path = indirect relationship between constructs through a mediator;  $\beta$  = standardized indirect effect.

Statistical Significance: SD = standard deviation; t-value = t-statistic obtained from bootstrapping; p-value = significance level; Decision = hypothesis testing result (supported/not supported).

**Necessary Condition Analysis (NCA)**

The results of the Necessary Condition Analysis (NCA) are reported in Table 7. Following Dul et al. (2023), necessity was evaluated using the effect size of necessity (d), estimated with the CE-FDH (Ceiling Envelopment-Free Disposal Hull) technique, and statistical significance assessed through permutation tests with 10,000 resamples in SmartPLS 4.0. Consistent with established guidelines, a construct is considered a necessary condition when  $d \geq 0.10$  and the permutation test is statistically significant ( $p \leq 0.05$ ).

The findings show clear differences across the antecedent constructs. KAC presents a very small necessity effect ( $d = 0.037$ ) that is not statistically significant ( $p = 0.386$ ). Therefore, KAC does not meet the empirical criteria to be classified as a necessary condition for INV in this model.

In contrast, KAP, KSH, and TRL exceed the recommended necessity threshold under CE-FDH and are statistically significant, indicating that these constructs impose empirical necessity constraints within the CE-FDH estimation framework. Specifically: KAP shows a moderate necessity effect ( $d = 0.208; p < 0.001$ ); KSH also presents a moderate necessity effect ( $d = 0.203; p = 0.001$ ); and TRL displays a moderate necessity effect as well ( $d = 0.191; p = 0.010$ ).

Taken together, these results indicate that while several constructs may contribute to INV from a sufficiency (average-effect) perspective, KAP, KSH, and TRL function as empirically necessary conditions within this dataset. In other words, higher levels of INV cannot be achieved unless minimum levels of these three constructs are in place. KAC, however, does not impose a statistically supported necessity constraint in the present model.

**Table 7.** Necessary Condition Analysis (NCA): Effect Sizes and Statistical Significance (CE-FDH Method)

	Effect size (d)	95% CI	p-value
KAC	0.037	0.078	0.386
KAP	0.208	0.092	0.000
KSH	0.203	0.137	0.001
TRL	0.191	0.146	0.010

Source: Own elaboration.

Notes: TRL = Transformational Leadership; KAC = Knowledge Acquisition Capability; KSH = Knowledge Sharing Capability; KAP = Knowledge Application Capability; INV = Innovation.

Effect Size:  $d$  = effect size of the necessary condition, indicating the strength of the constraint imposed by each predictor on the outcome.

Statistical Significance: CI = confidence interval; p-value = significance level.

CE-FDH = Ceiling Envelopment-Free Disposal Hull method used to estimate necessary condition effects.

To complement the effect size results, a bottleneck analysis was conducted. This analysis identifies the minimum levels of each antecedent required to reach increasing levels of the outcome (INV). Cells labeled NN (Not Necessary) indicate that, at that specific outcome level, the condition does not impose a binding minimum requirement.

Table 8 and Figure 2 provide the bottleneck results of the Necessary Condition Analysis (NCA), illustrating how the requirements for each condition shift across different levels of the outcome. The bottleneck table shows that necessity constraints become more visible as higher levels of INV are targeted. At low levels of INV (0%–10%), no binding constraints are observed for KAP, KSH, or TRL, and only a very low minimum level of KAC is indicated. However, given the non-significant and very small overall effect size of KAC, this early threshold should be interpreted cautiously and not as strong evidence of necessity.

From approximately 20%–40% of INV, KAP and KSH begin to appear as binding conditions, requiring minimum levels to sustain further increases in INV. This pattern is consistent with their statistically supported necessity effects and suggests that the ability to apply knowledge and to share knowledge becomes increasingly critical once INV moves beyond very low levels.

TRL emerges as a clear constraint at moderate-to-high INV levels. From 60% of INV onward, TRL requires progressively higher minimum values, indicating that transformational leadership becomes a limiting factor when organizations attempt to reach more advanced INV performance.

At high INV targets (70%–100%), the minimum required levels of KAP, KSH, and TRL increase, showing that the constraints imposed by these constructs intensify as the desired outcome level rises. This pattern is theoretically consistent with a necessity logic: high INV is structurally unattainable without sufficiently strong leadership and knowledge-based capabilities, even if other favorable conditions are present.

KAC shows relatively stable minimum values across outcome levels and only increases at the maximum INV level. However, in light of its non-significant necessity effect, this pattern should be interpreted as a descriptive boundary rather than robust statistical evidence of a true necessary condition.

Overall, the bottleneck analysis reinforces the core NCA findings: KAP, KSH, and TRL represent the most critical necessity constraints for achieving medium-to-high and high levels of INV, whereas KAC does not demonstrate a statistically supported necessity role. These results highlight that some antecedents do not merely improve INV on average but instead define minimum thresholds below which higher INV performance cannot occur.

**Table 8.** Necessary Condition Analysis (NCA): Bottleneck Levels Required for Innovation

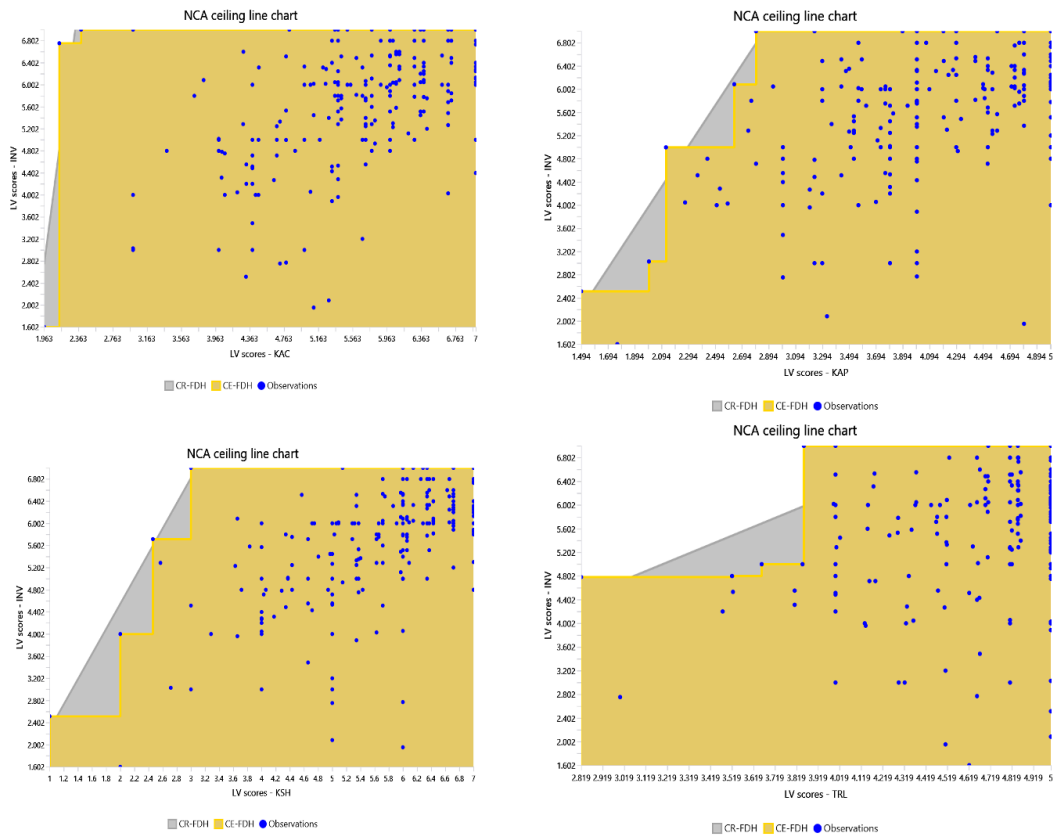
	INV	KAC	KAP	KSH	TRL
0.00%	1.602	2.139	NN	NN	NN
10.00%	2.142	2.139	NN	NN	NN
20.00%	2.682	2.139	2.000	2.000	NN
30.00%	3.221	2.139	2.127	2.000	NN
40.00%	3.761	2.139	2.127	2.000	NN
50.00%	4.301	2.139	2.127	2.461	NN
60.00%	4.841	2.139	2.127	2.461	3.657
70.00%	5.381	2.139	2.637	2.461	3.853
80.00%	5.920	2.139	2.637	3.000	3.853
90.00%	6.460	2.139	2.800	3.000	3.853
100.00%	7.000	2.393	2.800	3.000	3.853

Source: Own elaboration.

Note: TRL = Transformational Leadership; KAC = Knowledge Acquisition Capability; KSH = Knowledge Sharing Capability; KAP = Knowledge Application Capability; INV = Innovation.

Bottleneck Levels: Values indicate the minimum level of each condition required to achieve a given level of innovation (INV). Higher percentage levels represent increasing desired levels of the outcome.

NN = no necessary condition identified at the specified outcome level.



**Figure 2.** Ceiling Lines for Innovation Based on Necessary Condition Analysis (NCA). Source: Own elaboration. Note: TRL = Transformational Leadership; KAC = Knowledge Acquisition Capability; KSH = Knowledge Sharing Capability; KAP = Knowledge Application Capability; INV = Innovation.

Ceiling lines represent the upper boundary of the data and indicate necessary conditions for achieving higher levels of innovation.

## DISCUSSION

The relationship between TRL and INV in HEIs remains empirically inconsistent. By integrating sufficiency logic (PLS-SEM) with necessity logic (NCA), the findings offer a better understanding of how leadership contributes to innovation in professionalized academic contexts.

### *Transformational Leadership as an Indirect Enabler*

The structural results show that TRL does not exert a significant direct effect on INV. This aligns with prior research indicating that leadership influence in educational and professional bureaucracies is often indirect, filtered through organizational mechanisms rather than directly translated into performance outcomes (Aisyah et al., 2025). HEIs are characterized by academic autonomy, disciplinary specialization, and decentralized structures, which limit the immediate impact of leadership behaviors on INV outputs. In line with the Knowledge-Based View, leadership contributes by shaping the organizational conditions under which knowledge processes unfold (Grant, 1996).

Consistent with this perspective, TRL shows strong and significant effects on all three KM capabilities (KAC, KSH, and KAP), supporting evidence that transformational leaders foster learning climates, collaboration, and knowledge-oriented behaviors (Kim & Park, 2020; Hoang & Le, 2024). In other words, transformational leaders act as catalysts that activate the institutional knowledge environment rather than direct producers of innovation.

### *Core Mechanisms*

Only KSH and KAP exert significant positive effects on INV, whereas KAC does not. This distinction is theoretically meaningful in HEIs, which are inherently knowledge-rich organizations; the main challenge is enabling knowledge circulation across academic

boundaries and embedding it into practices (Fan & Beh, 2024). KSH facilitates interdisciplinary recombination and collective learning (; Nabi et al., 2023), while KAP translates knowledge into improved teaching, research, and organizational routines (Ode & Ayavoo, 2019).

The mediation results reinforce this interpretation: TRL influences INV indirectly through KSH and KAP, but not via KAC. Leadership thus supports innovation primarily by enhancing the circulation and practical application of knowledge rather than merely encouraging knowledge acquisition. This mechanism helps explain why prior studies report mixed direct effects of TRL on INV (Gui et al., 2024; Nabi et al., 2023), showing that leadership impacts are largely process-mediated in knowledge-intensive settings.

### *Necessity Conditions Perspective*

PLS-SEM assesses average effects, but NCA reveals that TRL, KSH, and KAP also function as necessary conditions for achieving higher INV levels. In contrast, KAC does not meet the empirical threshold for necessity. Insufficient levels of TRL, KSH, or KAP structurally constrain INV potential in HEIs, regardless of other favorable conditions.

This approach provides inferences beyond traditional SEM: while SEM indicates that KSH and KAP predict INV, NCA shows that these capabilities (and TRL) establish minimum thresholds below which high innovation cannot occur (Dul et al., 2023). From a Dynamic Capabilities perspective, without baseline capacity to share and apply knowledge, recombination and reconfiguration cannot achieve the levels required for advanced INV (Teece et al., 1997). High INV is therefore not only a matter of incremental improvement but also of ensuring foundational capability levels are met.

### *Integrated Interpretation*

Together, the results position TRL as a higher-order enabler that activates knowledge processes, which in turn foster INV in higher education settings. TRL strengthens the organizational climate, promotes collaboration, and supports learning-oriented behaviors (Kim

& Park, 2020; Hoang & Le, 2024). Among KM capabilities, KSH and KAP play a dual role: they explain variance in INV under sufficiency logic and act as structural bottlenecks under necessity logic, highlighting their critical role in achieving advanced innovation outcomes.

## CONCLUSIONS

The relationship between TRL and INV in HEIs has produced inconsistent empirical evidence, suggesting that the mechanisms linking leadership to INV remain insufficiently understood. By examining KM capabilities as mediating processes and by integrating sufficiency and necessity perspectives, this research clarifies how leadership becomes relevant to innovation in knowledge-intensive contexts. The findings indicate that leadership influence in HEIs is structurally indirect, operating through knowledge-based capabilities rather than through a direct effect on INV outcomes.

### *Theoretical Implications*

Three theoretical contributions emerge from these findings.

First, it refines the Leadership–Knowledge–Innovation framework by differentiating the roles of KM capabilities. While prior research often treats KM as a unified construct, the findings show that KSH and KAP constitute the operative mechanisms linking TRL to INV, whereas KAC does not play a decisive role in HEIs. This distinction aligns with the Knowledge-Based View, highlighting that in knowledge-rich academic environments, the critical constraint is not access to knowledge but the institution’s ability to circulate and enact knowledge effectively (Grant, 1996; Kim & Park, 2020; Hoang & Le, 2024).

Second, TRL is repositioned as a dynamic meta-capability. Rather than serving as a direct driver of performance, TRL enables the processes through which knowledge is recombined and embedded in teaching, research, and organizational routines. This perspective helps explain why prior TRL–INV studies in HEIs report mixed direct effects: leadership influence is largely mediated by knowledge-oriented

capabilities (Kim & Park, 2020; Hoang & Le, 2024).

Third, the integration of PLS-SEM and NCA contributes methodologically and theoretically by incorporating a constraint-based perspective. While SEM results show that KSH and KAP increase INV on average, NCA demonstrates that TRL, KSH, and KAP also function as necessary conditions for achieving higher INV levels (Dul et al., 2023). This shifts the theoretical focus from identifying “drivers of INV” to recognizing the minimum capability thresholds that make higher levels of innovation feasible in HEIs.

### *Practical Implications*

For HEI governance, the results indicate that leadership development initiatives should be closely integrated with mechanisms that strengthen KSH and KAP. INV capacity depends on whether knowledge moves across disciplinary and organizational boundaries and is translated into teaching, research, and administrative practices. Investments in collaborative platforms, interdisciplinary structures, and routines that embed knowledge into action are therefore central.

The necessity findings further suggest that management should focus not only on improving average performance but also on preventing capability deficits. Units operating below minimum levels of leadership support or knowledge-process capability can constrain the INV potential of the institution. Addressing structural bottlenecks in KSH and application is thus as important as promoting excellence among already high-performing units.

Overall, INV in HEIs emerges from the institutionalized capacity to share and apply knowledge under enabling leadership conditions. TRL matters not as a direct INV engine, but as the catalyst that activates the knowledge-based capabilities that make INV possible and, beyond certain thresholds, feasible.

Furthermore, TRL and KM capabilities function as necessary conditions for higher INV levels. HEIs must therefore ensure that these variables operate above minimum thresholds to avoid structural limitations on INV performance.

### Limitations and Future Research

First, the cross-sectional design limits causal inference. Although the theoretical model assumes that TRL shapes KM capabilities, which in turn influence INV, the temporal sequencing of these processes cannot be empirically verified in the present design. Longitudinal studies are needed to examine how leadership behaviors gradually build KSH and KAP over time to translate into INV outcomes. Such research would allow testing whether the indirect effects observed here strengthen, weaken, or change from across different stages of organizational development.

Second, this research focused on KM capabilities as the primary processes linking TRL to INV. While theoretically justified, INV in HEIs is likely shaped by additional individual, team, and contextual factors. Future research could incorporate constructs such as individual and collective creativity, psychological empowerment, learning orientation, collaborative climate, or digital capability to examine whether leadership also operates through cognitive, motivational, or socio-cultural pathways. Such extensions would help determine whether knowledge processes are the dominant mechanisms or part of a broader constellation of mediators translating leadership into INV outcomes.

Finally, the integration of PLS-SEM and NCA demonstrates the value of combining sufficiency and necessity logics, yet this dual-method approach remains underutilized in leadership and INV research. Future studies could extend this approach to examine whether other leadership styles, organizational cultures, or structural variables also operate as necessary conditions. Such work would contribute to a broader shift from identifying “drivers” of INV to understanding the boundary conditions and minimum requirements that make INV feasible.

### Conflicts of Interest

The authors declare no conflicts of interest.

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### Authors' contributions:

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