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SMART RESEARCH FOR IMPACT: CATALYSING AI IN SHAPING A SUSTAINABLE FUTURE

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Smart Research for Impact:
Catalysing AI in Shaping a Sustainable Future

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Message from the Dean

Assalamualaikum Warahmatullahi Wabarakatuh and warm greetings.

It is my pleasure to welcome all distinguished participants to the 4th International Postgraduate Research Symposium (INPOS 2025). We are delighted to host this event at Amari Hotel, Penang, bringing together postgraduate researchers, academics, and practitioners from various institutions and disciplines.

The theme for this year, *"Smart Research for Impact: Catalysing AI in Shaping a Sustainable Future,"* underscores the growing significance of artificial intelligence in driving innovative, responsible, and sustainable research. As AI continues to reshape industries and societies, this symposium provides a timely platform to explore how intelligent technologies can elevate research quality, enhance decision-making, and support long-term sustainability goals.

INPOS 2025 serves as a vital platform for participants to share insights, broaden their perspectives, and establish meaningful academic and professional connections. I encourage all attendees to engage actively, exchange ideas, and take advantage of the diverse discussions and opportunities presented over the next two days.

I wish to extend my sincere appreciation to the Postgraduate Student Society (PGSS) and the organizing committee for their dedication in ensuring the success of this symposium. Their collective efforts have made INPOS 2025 a valuable and enriching experience for all.

Thank you, and I wish everyone a productive and inspiring symposium.

Professor Dr. Noor Hazlina Ahmad
Dean
School of Management

About the Symposium

INPOS @USM is a distinctive international symposium that serves as a premier platform for engaging with leading experts in top-tier, highly cited and internationally recognised research methodology. It provides scholars and researchers with an opportunity to deepen their understanding of the true essence of research, its rigour, relevance and impact.

The 4th International Postgraduate Symposium 2025 (INPOS 2025), proudly organised by the School of Management, Universiti Sains Malaysia, in collaboration with Universitas Padjadjaran, took place on 18–19 November 2025. The symposium brought together postgraduate students, researchers and academics to exchange ideas, share experiences and deliberate on contemporary management and research issues at both local and global levels.

Under the theme "Smart Research for Impact: Catalysing AI in Shaping a Sustainable Future," INPOS 2025 highlighted the transformative potential of Artificial Intelligence (AI) in advancing sustainability, innovation and sustainable development. Researchers are encouraged to go beyond conventional thinking, explore new frontiers of knowledge and adopt innovative methodologies. This includes interdisciplinary collaboration, leveraging emerging technologies such as Artificial Intelligence (AI) and translating academic findings into practical applications, policies and solutions that benefit society.

INPOS 2025 strengthened appreciation for scientific rigour, real-world relevance and long-term research impact, while fostering a shared understanding among researchers from diverse backgrounds. The symposium underscored the role of academia in driving societal advancement, economic growth, technological breakthroughs and sustainable development by cultivating innovative scholarship and comprehensive education.

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Table of Contents

Re-specifying IFRS 17 Implementation as Disclosure Governance: Positioning AI as Algorithmic Assurance in Insurance Reporting Infrastructures

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Abstract

Accounting and insurance research commonly frames IFRS 17 implementation as a problem of actuarial modelling complexity—cash-flow estimation, discount-rate calibration, and Contractual Service Margin (CSM) computation—implicitly treating modelling stability as the primary route to reporting stability. However, early post-adoption debates increasingly surface persistent issues of disclosure quality, comparability, traceability, and enforcement consistency, especially under institutional and technological constraints. We conduct a PRISMA-guided synthesis of 117 Scopus-indexed publications (2020–2025), complemented by an interpretive practitioner triangulation with IFRS 17 implementation personnel at Hamilton Prima Indonesia. Using thematic coding that distinguishes between measurement-centric and disclosure-centric framings, we examine how IFRS 17 implementation challenges are problematised and how AI is positioned within the reporting architecture. Across the corpus, disclosure and governance concerns appear more persistently than stand-alone modelling difficulties. In parallel, AI is more often articulated as a layer of algorithmic assurance—supporting anomaly detection, explainability, audit trails, and compliance monitoring—than as an engine for actuarial optimisation. Taken together, the findings re-specify IFRS 17 implementation as a socio-technical disclosure governance problem in which representational stability depends on organisational and institutional infrastructures rather than computational sophistication alone. This re-positioning clarifies AI's most plausible role in IFRS 17 contexts: strengthening traceability and interpretive accountability within reporting infrastructures under constraint, rather than primarily enhancing modelling precision.

Keywords: IFRS 17; disclosure governance; insurance reporting infrastructure; socio-technical systems; algorithmic assurance; explainability; institutional constraints; representational stability

Introduction

Since its mandatory adoption on 1 January 2023, IFRS 17 has not only changed the measurement of insurance liabilities but has also reconfigured the reporting infrastructure through which insurers produce, justify, and circulate accounting representations. Implementing IFRS 17 typically requires extensive redesign of data pipelines, actuarial–accounting interfaces, and control routines, alongside new requirements for traceability, comparability, and disclosure coherence across time and organisational units (Deloitte, 2022; EFRAG, 2018). In this sense, IFRS 17 implementation is not merely a technical exercise of valuation; it is an organisational challenge of sustaining accountable representations within a socio-technical reporting system.

A prevalent strand of the literature nevertheless problematises IFRS 17 implementation primarily as a matter of actuarial and computational complexity—cash flow estimation, discount rate calibration, and the operationalisation of Contractual Service Margin (CSM) dynamics under the Building Block Approach (Carlehed, 2023; Yousuf et al., 2020). In parallel, research on artificial intelligence (AI) in insurance often highlights predictive modelling, automated valuation routines, and simulation capabilities enabled by machine learning and deep learning (Acosta-Prado et al., 2024; Mishra et al., 2024; Pattnaik et al., 2024). Read together, these streams invite an implicit expectation that improving modelling sophistication—potentially through AI—provides a primary route to "solving" IFRS 17 implementation.

This expectation becomes questionable when viewed through the lens of disclosure governance. Across jurisdictions, prior work continues to raise concerns about disclosure quality, comparability, enforcement consistency, and reporting heterogeneity—issues that are not reducible to modelling precision alone (Adamek-Hyska & Pacud, 2025; Bradbury & Kim, 2024). In emerging-market contexts, institutional constraints and uneven governance infrastructures further complicate the stabilisation of transparent and comparable reporting practices (Omotoso et al., 2022; Wahyuni et al., 2023). These observations suggest a different organising problem: IFRS 17 implementation may hinge less on computational optimisation and more on the capacity to produce representational stability—that is, reporting outputs that remain traceable, interpretable, and auditable as assumptions, systems, and organisational responsibilities evolve.

If IFRS 17 is approached as a socio-technical disclosure governance architecture, AI's role is also at risk of being mis-specified. Rather than functioning mainly as a modelling enhancer, AI may be positioned more plausibly as an assurance layer that strengthens audit trails, anomaly detection, explainability, and compliance monitoring within reporting infrastructures (Černevičienė & Kabašinskas, 2024; Owens et al., 2022). The question, then, is not whether AI "improves IFRS 17" in general, but how the scholarly literature problematises IFRS 17 implementation and how AI is positioned within the accountability arrangements of insurance reporting.

Against this background, we ask two interrelated questions. First, how does the early post-adoption literature (2020–2025) predominantly frame IFRS 17 implementation challenges across jurisdictions: as measurement-centric modelling complexity or as disclosure-centric governance instability? Second, how are AI applications positioned within these framings, particularly in relation to traceability, interpretability, and assurance functions within reporting infrastructures?

To address these questions, we conduct a PRISMA-guided systematic synthesis of 117 Scopus-indexed publications (2020–2025) (Grames et al., 2022; Schreiber & Cramer, 2024), complemented by interpretive practitioner triangulation with IFRS 17 implementation personnel at Hamilton Prima Indonesia. Using thematic coding that distinguishes between measurement-centric and disclosure-centric problematisations, we examine the distribution of implementation framings and the corresponding positioning of AI within the reporting architecture. The inference is bound to how the scholarly record conceptualises challenges and AI roles during the early adoption period, rather than to causal claims about AI effectiveness in practice.

This study contributes in three ways. Theoretically, it re-specifies IFRS 17 implementation as a problem of socio-technical disclosure governance and representational stability, conditioning modelling-centric interpretations that treat computational sophistication as a sufficient basis for reporting stability. Methodologically, it integrates systematic synthesis with practitioner triangulation to sharpen the distinction between measurement work and governance work in IFRS 17 implementation. Substantively, it repositions AI primarily as algorithmic assurance—supporting explainability, anomaly detection, and traceability—thereby clarifying AI's most defensible role within insurance reporting infrastructures under institutional constraint.

Literature Review

IFRS 17 as Measurement Work

A substantial body of research approaches IFRS 17 implementation as a problem of actuarial modelling and computational work. Within this orientation, the core challenges revolve around cash-flow estimation, discount-rate calibration, risk adjustment, and the operationalisation of the Contractual Service Margin under the Building Block Approach (Ewelt-Knauer et al., 2018; Yousuf et al., 2020; Carlehed, 2023). Implementation burdens are therefore articulated as data quality, parameter instability, assumption updates, and system integration (Basu & Grace, 2022; Owais & Dahiyat, 2021).

In this framing, organisational disruption is largely interpreted as a consequence of technical re-engineering. Stability is expected to follow once modelling routines become robust and computational processes are standardised. Research on artificial intelligence in insurance often aligns with this view, emphasising predictive optimisation, automation of actuarial routines, and enhanced simulation capacity through machine learning and deep learning

techniques (Acosta-Prado et al., 2024; Mishra et al., 2024; Pattnaik et al., 2024). Technological sophistication is thus positioned as a pathway toward modelling reliability and, implicitly, improved reporting outcomes.

Here, IFRS 17 is treated primarily as a measurement regime, and reporting appears as the output layer of actuarial computation.

IFRS 17 as Disclosure Governance

A second stream of research shifts attention from modelling precision to the organisational and institutional conditions that sustain stable disclosure practices. Studies of IFRS adoption continue to document concerns regarding comparability, enforcement consistency, and reporting heterogeneity across jurisdictions (Adamek-Hyska & Pacud, 2025; Bradbury & Kim, 2024). In emerging markets, uneven regulatory capacity and infrastructural limitations complicate the translation of formal standards into coherent disclosure routines (Omotoso et al., 2022; Wahyuni et al., 2023; Puławska & Strzelczyk, 2025).

Within this orientation, IFRS 17 is better understood as a governance architecture that organises reconciliation processes, assumption traceability, narrative disclosures, and audit interfaces. Stability depends not solely on modelling precision but on the capacity to produce representations that remain interpretable, auditable, and comparable as they circulate across organisational units and regulatory environments.

AI research intersecting with this perspective foregrounds anomaly detection, explainability, compliance monitoring, and audit trail reinforcement (Bin-Nashwan et al., 2025; Owens et al., 2022; Sharbek, 2024). Rather than extending actuarial optimisation, AI is a mediating mechanism that strengthens governance and transparency within reporting infrastructures.

Conceptual Tension and Research Gap

Read together, these two orientations reveal a conceptual tension. The measurement-centric view implicitly associates modelling stability with reporting stability: once computational routines are refined, reliable reporting is presumed to follow. The disclosure-oriented view suggests that reporting stability is contingent upon organisational and institutional infrastructures that sustain interpretive coherence and accountability.

This tension raises a question that has not been systematically examined: how does the early post-adoption literature predominantly problematise IFRS 17 implementation, and how is AI positioned within these problematisations? By distinguishing measurement work from governance work, the present study addresses this gap. It provides the analytical basis for re-specifying IFRS 17 implementation as a question of representational stability under institutional constraint.

Methodology

Research Design

This study adopts a conceptual systematic review to examine how IFRS 17 implementation and AI applications are problematised in the scholarly literature. Rather than aggregating empirical outcomes or conducting bibliometric mapping, the objective is to analyse the interpretive structures through which implementation challenges are articulated. The review follows PRISMA 2020 procedures to ensure transparency in search and selection (Grames et al., 2022; Schreiber & Cramer, 2024), but its analytical logic is interpretive rather than statistical.

The unit of analysis is not IFRS 17 performance outcomes, but the problem definition embedded within each publication. Specifically, the review differentiates between two recurring framings:

1. Measurement-centric framing, in which implementation is articulated primarily as actuarial and computational modelling work.

2. Disclosure-centric framing, in which implementation is articulated as a matter of governance, traceability, comparability, and institutional coordination.

This design enables inference regarding how the scholarly record conceptualises IFRS 17 implementation during the early post-adoption period (2020–2025). It does not support causal claims regarding AI effectiveness nor empirical generalisations about operational realities across insurers. The claims are therefore bound to patterns of problematisation within the selected corpus.

Literature Search and Corpus Construction

The literature search was conducted in Scopus on 22 August 2025. Scopus was selected for its broad coverage of peer-reviewed journals across accounting, finance, management, and information systems. The search was restricted to English-language publications from 2020 to 2025, covering the preparation, transition, and early post-adoption phases of IFRS 17.

Search strings combined terms related to IFRS 17 implementation and AI in insurance reporting contexts. After applying subject-area and temporal filters, 117 publications met the inclusion criteria. The corpus includes journal articles, book chapters, and conference papers indexed within the selected database.

The review does not claim to be exhaustive across all databases or grey literature. Instead, it aims to capture the dominant peer-reviewed academic discourse within a clearly defined timeframe. This boundary is consistent with the study's focus on scholarly problematisation rather than practitioner narratives or regulatory guidance.

Coding and Analytical Procedure

Analysis proceeded through a structured interpretive coding process.

First, each publication was examined to identify how IFRS 17 implementation was articulated as a problem. Rather than relying solely on keyword frequency, coding focused on the primary locus of difficulty described in the study. Articles were categorised as measurement-centric when implementation challenges were framed predominantly in terms of actuarial modelling, computational complexity, parameter estimation, or system integration. Articles were categorised as disclosure-centric when challenges were framed primarily in terms of governance routines, transparency, comparability, auditability, enforcement, or institutional coordination.

Second, AI-related discussions were coded according to their functional positioning. AI was classified as a modelling enhancement when discussed as improving predictive accuracy, automating valuation, or increasing simulation capacity. AI was classified as governance-assurance when associated with anomaly detection, explainability, compliance monitoring, traceability, or audit reinforcement.

Coding decisions were documented in an extraction table that recorded conceptual justification for each classification. Where studies contained overlapping themes, the dominant framing was determined by the explicit research problem and the argumentative emphasis. To enhance reliability, coding criteria were applied consistently across the corpus, and ambiguous cases were re-examined iteratively to ensure conceptual coherence.

Interpretation focused on identifying recurring patterns in how implementation was problematised and how AI was positioned within reporting infrastructures. Frequency counts were used only as heuristic indicators of distribution, not as statistical claims of dominance.

Practitioner Triangulation

To contextualise the literature-based synthesis, a semi-structured group interview was conducted with three practitioners involved in the implementation of the IFRS 17 system at Hamilton Prima Indonesia. The interview explored how implementation challenges are experienced in practice and how AI tools are operationally deployed.

The purpose of this triangulation was not validation through statistical corroboration but interpretive grounding. Practitioner narratives were used to assess whether the measurement-centric and disclosure-centric framings identified in the literature resonated with organisational experience. This step reduces the risk of purely discursive abstraction while maintaining the study's primary focus on scholarly problematisation.

Validity and Boundaries of Inference

The study's conclusions concern the distribution of interpretive framings within the selected corpus. They do not establish empirical dominance of disclosure or modelling challenges across all jurisdictions, nor do they evaluate the technical performance of AI systems.

Transparent inclusion criteria and explicit coding logic support credibility. Confirmability is strengthened through documented classification rationales. Dependability arises from the consistent application of framing criteria across the entire dataset.

By distinguishing measurement work from governance work and modelling enhancement from algorithmic assurance, the methodology provides an analytical foundation for re-specifying IFRS 17 implementation as a question of representational stability within socio-technical reporting infrastructures.

Results

1. Framing IFRS 17 Implementation in the Scholarly Record

Analysis of the 117 publications indicates a patterned differentiation in how IFRS 17 implementation is problematised. Across the corpus, two recurrent framings are identifiable: measurement-centric articulations focused on actuarial modelling and computational complexity, and disclosure-centric articulations concerned with governance, comparability, enforcement, and interpretive coherence.

While modelling challenges—such as discount-rate calibration, cash-flow estimation, and CSM operationalisation—are consistently discussed, they are frequently embedded within broader discussions of reporting transparency, traceability, and institutional coordination. In a substantial portion of the corpus, implementation difficulty is articulated not solely in terms of computational refinement but in terms of sustaining coherent and auditable disclosures across organisational and regulatory contexts (Adamek-Hyska & Pacud, 2025; Bradbury & Kim, 2024; Puławska & Strzelczyk, 2025).

In this sense, disclosure and governance concerns are more persistently foregrounded as systemic constraints than modelling refinement alone. Measurement work often appears as a necessary technical condition, but not as a sufficient explanation for reporting instability. This pattern suggests that, within the scholarly discourse examined, modelling stability is frequently articulated as contingent upon institutional and governance arrangements.

This interpretive distribution does not imply that actuarial modelling challenges are negligible. Rather, it indicates that they are rarely positioned as the sole or foundational bottleneck of implementation. Instead, the literature repeatedly situates implementation within broader concerns about comparability, enforcement capacity, and infrastructural coordination—particularly in emerging-market contexts (Omotoso et al., 2022; Wahyuni et al., 2023).

2. Positioning AI within IFRS 17 Debates

A parallel differentiation emerges in the positioning of artificial intelligence. AI applications associated with predictive optimisation and modelling automation are present in the corpus (Acosta-Prado et al., 2024; Mishra et al., 2024; Pattnaik et al., 2024). However, discussions of AI more frequently emphasise anomaly detection, explainability, compliance monitoring, and audit trail reinforcement (Černevičienė & Kabašinskas, 2024; Owens et al., 2022; Sharbek, 2024).

In many studies, AI is articulated as strengthening transparency and accountability within reporting systems rather than exclusively enhancing actuarial forecasting accuracy. References to explainable AI, regulatory oversight, and fraud detection often intersect with discussions of disclosure reliability and governance vulnerability. It suggests that AI is commonly positioned as an infrastructural support mechanism within reporting architectures.

Deep learning applications explicitly framed around CSM optimisation appear comparatively less central within the corpus than AI applications tied to governance and assurance functions. As with the implementation framing, this does not negate the technical relevance of modelling enhancement but indicates that AI's conceptual salience in the literature extends beyond computational optimisation.

3. Integrative Pattern: Conditional Modelling Stability

When the two strands are considered together, a coherent interpretive pattern emerges. Measurement-centric accounts emphasise the refinement of actuarial computation, while disclosure-centric accounts foreground the organisational and institutional conditions under which representations remain stable, interpretable, and auditable.

Across the corpus, modelling precision is frequently discussed as necessary but not sufficient for reporting stability. The articulation of implementation challenges often shifts from technical modelling tasks to issues of reconciliation, assumption traceability, enforcement consistency, and narrative coherence. In parallel, AI is positioned less as a stand-alone optimisation engine and more as a mechanism supporting validation, monitoring, and explainability within reporting infrastructures.

Practitioner triangulation aligns with this pattern. Interview participants emphasised reconciliation processes, disclosure consistency, and assumption tracking as recurring implementation concerns. AI tools were described primarily as validation and interpretive support mechanisms rather than as predictive optimisation systems. While limited in scope, this triangulation reinforces the interpretive distinction identified in the literature.

Taken together, these results indicate that, within the early post-adoption scholarly record, IFRS 17 implementation is frequently articulated as a matter of disclosure governance and infrastructural coordination. AI is correspondingly positioned as an assurance-oriented arrangement within socio-technical reporting systems.

Discussion

Reconsidering the Implementation Problem

The results invite a reconsideration of how IFRS 17 implementation is problematised in the scholarly record. While modelling-centric accounts remain prominent, the synthesis indicates that implementation challenges are frequently articulated in terms of disclosure governance, interpretive coherence, and institutional coordination. The presumed linkage between modelling sophistication and reporting stability may be less straightforward than often implied.

Rather than positioning IFRS 17 solely as a valuation framework requiring computational refinement, the literature frequently situates implementation within broader concerns about reconciliation routines, assumption traceability, comparability, and enforcement stability. In this light, reporting stability appears contingent upon governance arrangements and infrastructural coordination as much as upon actuarial modelling precision.

The contribution of this study is therefore conceptual rather than empirical: it clarifies that IFRS 17 implementation can be understood as a socio-technical reporting problem in which representational stability—defined as the sustained interpretability, traceability, and auditability of accounting outputs—depends on organisational and institutional infrastructures.

Repositioning AI within Reporting Infrastructures

A parallel reconsideration concerns the positioning of AI. Across the reviewed corpus, AI is frequently discussed not only in relation to predictive optimisation but also in connection with anomaly detection, explainability, compliance monitoring, and audit reinforcement. This pattern suggests that AI's conceptual role extends beyond modelling enhancement toward supporting governance and accountability functions within reporting systems.

If IFRS 17 is approached as a reporting infrastructure that organises data flows, assumptions, and disclosures across organisational boundaries, AI appears less as a stand-alone optimisation engine and more as a mediating arrangement that reinforces transparency and validation processes. The notion of AI as "algorithmic assurance" captures this positioning: AI systems contribute to stabilising reporting practices by enhancing traceability and interpretive clarity rather than solely by increasing predictive accuracy.

This reframing does not diminish the importance of modelling sophistication. Instead, it conditions its role within a broader governance architecture. Modelling stability may be necessary, but the literature suggests it is rarely considered sufficient to ensure reporting coherence.

Implications for Research on Information Infrastructures and Governance

Beyond insurance reporting, these findings speak to ongoing debates in research on socio-technical systems and information infrastructures. Standards such as IFRS 17 function not only as technical measurement prescriptions but as organising devices that reshape accountability relations, data architectures, and interpretive practices within and across organisations.

By distinguishing between measurement work and governance work, the study highlights how technological interventions—such as AI—are embedded within existing infrastructures rather than operating independently of them. This perspective aligns with research that views digital technologies as mediating accountability arrangements and organisational coordination, rather than simply optimising technical processes.

Accordingly, the re-specification advanced here contributes to a more nuanced understanding of how computational tools interact with institutional and organisational structures in complex reporting environments.

Boundary Conditions and Alternative Interpretations

The analysis is bound to the early post-adoption period (2020–2025) and to the selected Scopus-indexed corpus. It therefore captures patterns of scholarly problematisation rather than definitive operational hierarchies of implementation challenges. As IFRS 17 matures, refinements to modelling or institutional adaptation may alter the relative salience of different framings.

An alternative interpretation is that the prominence of disclosure governance themes reflects publication tendencies within accounting research rather than substantive implementation dynamics. While this possibility cannot be excluded, practitioner triangulation indicates that reconciliation stability, assumption tracking, and disclosure coordination are experienced as ongoing organisational challenges alongside modelling tasks. This convergence suggests that governance concerns are not merely discursive artefacts but resonate with implementation practice.

A second alternative is that modelling complexity remains primary but becomes less visible once embedded within systems. The present study does not adjudicate this possibility empirically; rather, it demonstrates that within the scholarly record examined, modelling stability is rarely articulated as independently sufficient for reporting stability.

Taken together, the discussion narrows the interpretation of IFRS 17 implementation and AI integration. The early post-adoption literature frequently frames implementation as a matter of disclosure governance and infrastructural coordination, with AI positioned as an assurance-oriented mediator within reporting systems. This re-specification clarifies the conceptual basis for understanding technological integration in insurance reporting, without extending claims beyond the interpretive evidence synthesised.

Conclusion

This study examined how IFRS 17 implementation challenges and AI applications are problematised in the early post-adoption scholarly record through a conceptual systematic synthesis of 117 publications complemented by practitioner triangulation. The analysis identifies a patterned differentiation in which disclosure governance, comparability, and institutional coordination are more persistently foregrounded than stand-alone actuarial modelling refinement. In parallel, AI is frequently articulated as supporting assurance, explainability, and monitoring functions within reporting systems rather than solely enhancing predictive computation.

These findings clarify the limits of an exclusively modelling-centric interpretation of IFRS 17 adoption. Within the literature examined, reporting stability is rarely articulated as deriving solely from computational precision; instead, it is situated within broader organisational and institutional infrastructures that sustain traceability, interpretability, and auditability. Modelling sophistication appears necessary, but not independently sufficient, for stabilising reporting practices.

Taken together, the study re-specifies IFRS 17 implementation as a socio-technical disclosure governance issue and positions AI as an assurance-oriented mediator embedded within reporting infrastructures. By clarifying how implementation problems and technological roles are conceptualised in the scholarly discourse, the analysis contributes to ongoing debates on information infrastructures, digital governance, and the organisational mediation of accounting standards.

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An Exploration into AI-based Augmentation for Shrimp Disease Handling: Affordance Perspective

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Abstract

Indonesia's vast marine resources position it as a key player in advancing the blue economy through sustainable ocean utilization. In particular, shrimp aquaculture plays a critical role in supporting national export performance and the livelihoods of small-scale farmers across coastal regions of Indonesia. Despite the importance of shrimp farming for aquaculture activities, shrimp disease reporting and monitoring remains a challenge that threatens shrimp populations and the livelihoods of small-scale farmers. Recent advancements in artificial intelligence (AI) present augmentation opportunities for shrimp disease handling. This study explores the prospect of AI-based augmentation from the lens of affordance theory, by seeking to identify the emerging and perceived affordances that can inform the design of AI-driven disease reporting and monitoring systems for small-scale shrimp farmers in Indonesia. Drawing on qualitative data from in-depth interviews with Indonesian small-scale shrimp farmers and relevant stakeholders, thematic coding was applied to identify enabling and constraining constructs which are further analyzed to examine the existence of affordance, information about affordance, and the perception of affordance that is suitable to support the shrimp farmers' need in reporting and monitoring disease. This study contributes originality by extending affordance theory to AI-enabled aquaculture systems in Indonesia, advancing scholarship on digital transformation within the blue economy.

Keywords: Affordance, AI, Artificial Intelligence, Aquaculture, Augmentation, Shrimp Disease

Introduction

Indonesia, as a maritime nation, maintains substantial potential in its marine and oceanic resources to advance in the blue economy. With its vast aquatic territory, Indonesia holds immense opportunities to foster blue economic growth through the optimal utilization of its marine resources. The fisheries sector contributed 4.76%, equivalent to roughly 290.6 trillion rupiah to Indonesia's Gross Domestic Product (GDP) in 2023, a twofold increase from 2010 (Kementerian Kelautan dan Perikanan Indonesia, 2024).

Indonesia occupies a strategic position in the global development of the blue economy (Hendarman et al., 2024). Aquaculture, one of the sectors that notably enhances the prosperousness of coastal communities, has been increasingly seen as a major contributor for the blue economy. One of the aquaculture activities commonly in Indonesia is brackish water shrimp culture. Shrimp farming is a cornerstone of the aquaculture sector in Indonesia, with exports valued at USD 1,997.49 million in 2022 (Kementerian Kelautan dan Perikanan Indonesia, 2024).

Shrimp aquaculture in Indonesia presents both a significant economic opportunity and a series of persistent challenges that threaten its long-term viability. Specifically, it remains vulnerable to systemic and unanticipated disease outbreaks that threaten shrimp stock, dangering the economic stability for farmers, in particular the small-scale communities (Delphino et al., 2022). Tackling the problem of disease reporting and continually monitoring outbreak likelihood among small-scale shrimp farmers who depend heavily on traditional methods is therefore vital for achieving food security (SDG 2).

The wave of digital innovation, in particular the increasing development in AI, arguably paves the way to augment shrimp disease handling in many ways. AI adoption has generally been found at various usages in aquaculture (Aung et al., 2025). Nevertheless, limited scholarly attention has been devoted to the reporting and surveillance of shrimp diseases. Existing research and technological applications in shrimp aquaculture predominantly emphasize water quality monitoring (Blancaflor & Baccay, 2022; Nguyen et al., 2024) and the utilization of DNA-based technologies for disease treatment (Yang et al., 2024), rather than systematic disease reporting and monitoring mechanisms. Additionally, as we aim for sustainable farming for small scale farmers, their dependence on conventional techniques leaves them particularly exposed to disease outbreaks and economic instability.

Introducing context-aware, open, and easily accessible digital solutions for shrimp disease handling offers a viable pathway to enhance the sustainability and resilience of this sector (Kotlarsky et al., 2023; Pan et al., 2022). To fulfil this need, it is necessary to assess how the technology solutions afford the shrimp disease handling. That is, we need to understand what small scale farmers can do with the AI-based solutions to augment shrimp disease reporting and monitoring work, hence AI augmentation. Understanding these affordances is important because the intended AI-based disease reporting solution as the technical object needs to clearly catch the possibilities for goal-oriented action afforded to shrimp farmers (Anderson & Robey, 2017). Adopting the affordance framework by (Bernhard et al., 2013), this study

aims to explore the AI-based shrimp augmentation by posing the following research question: How could emerging and perceived affordances be identified to design a contextual AI-oriented shrimp disease reporting and monitoring solution?

The next section of this paper is structured as follows. Section two discusses the existing literature on technology adoption in shrimp aquaculture and AI augmentation affordance, followed by research methodology in section three. Section four and five will explore the results of the data analysis and the conclusion respectively.

Literature Review

Shrimp Farming Challenges

Shrimp aquaculture has become an essential pillar of Indonesia's economic development, offering significant growth potential while also presenting multifaceted challenges that demand strategic and sustainable management (Kumar et al., 2021). Despite its promising prospects, the sector continues to encounter major obstacles, including environmental degradation, recurring disease outbreaks that jeopardize shrimp populations, and socio-economic vulnerabilities stemming from global market volatility that directly impact local farmers (Bhassu et al., 2024; Bosman et al., 2021).

Indonesian shrimp farming is continuously threatened by key viral diseases, including White Spot Syndrome Virus (WSSV) and Infectious Myonecrosis Virus (IMNV), among the more than twenty viral pathogens reported globally (Seibert & Pinto, 2012). Equally problematic are endemic bacterial infections, notably Vibrio parahaemolyticus and Vibrio alginolyticus, which are common in regions like Pangandaran, West Java (Herawati et al., 2025). The presence of high pathogenic loads often results in acute outbreaks, manifesting as symptoms like "red disease," prompting the frequent practice of early harvesting to minimize immediate losses. This pattern of early harvest is a clear consequence of inadequate proactive disease management and poor monitoring practices.

Despite official efforts by the World Organization for Animal Health (WOAH) and the Network of Aquaculture Centres in Asia-Pacific (NACA) to provide biosecurity awareness materials, such as localized leaflets on viral diseases, the adoption of standardized monitoring and reporting protocols at the farm level remains weak (NACA-WOAH, 2022). This operational fragility is compounded by a social dimension: farmers, particularly those from diverse socio-economic backgrounds, often forgo rigorous, standardized practices—including eco-certification—in favor of visually observing and imitating the successful cultivation methods of their neighbors (Lee et al., 2025). This reliance on anecdotal success instead of objective, data-driven diagnostics inhibits the collection of pre-symptomatic data.

Many shrimp farmers—particularly those operating on a small scale or using traditional practices—struggle to accurately identify diseases due to limited scientific guidance and insufficient formal education. As a result, they often depend on conventional techniques or informal knowledge, which can lead to misdiagnosis. The situation is further

exacerbated by restricted access to diagnostic services and the scarcity of analytical tools, with recent studies highlighting that farmers in remote regions of Indonesia face significant barriers to utilizing laboratory facilities. In addition to these technical constraints, small-scale farmers commonly encounter financial pressures, including high operational expenses and limited capital, which hinder their ability to effectively manage day-to-day aquaculture activities (Primartono & Agus Prasetio, 2024).

On AI Augmentation

The significant adoption and role ofAI are often seen to follow divergent paths on its impact to humans, namely augmentation and automation. The construct Augmentation is viewed as a human-centric operation benefiting and complementing humans, often used to contrast with Automation that leans toward replacing them. Augmentation is frequently conceptualized through a mechanistic lens, viewing the collaboration between humans and artificial intelligence (AI) as an integrated system for enhancing productivity. This perspective encompasses ideas such as human–AI configurations (Grønsund & Aanestad, 2020), the fusion of human and AI capabilities into cohesive operational entities (Rai & Sarker, 2019), the treatment of humans and AI as interdependent elements within a hybrid framework (Dellermann et al., 2019), and the importance of constructing, refining, stabilizing, and maintaining these human–AI structures to ensure their effective functioning (Baptista et al., 2020).

While task augmentation with AI is commonly portrayed as a synergistic collaboration between humans and intelligent systems aimed at improving specific outcomes, the operationalization of such enhancement differs considerably across various domains. A metanarrative study has been conducted to elucidate the degree to which AI may augment humans' role. Four overarching narratives that characterize AI-based augmentation were identified: (1) augmentation of the human body, (2) augmentation of cognitive capabilities, (3) augmentation of work processes, and (4) augmentation of overall performance (Baer et al., 2025).

Technology Affordance Theoretical Foundation

Approximately four decades ago, Gibson (1979) introduced the notion of affordances, referring to the range of possible actions that an environment or object enables for a given actor (Gibson, 1979). Since its inception, this concept has been widely adopted and reinterpreted across multiple academic fields, including Information Systems (IS) research (Strong et al., 2014). Within the IS domain, affordance theory offers a valuable framework for examining the relational and socio-technical dynamics involved in the design, implementation, and utilization of information technologies (Ostern et al., 2020). Within the field of Information Systems (IS), numerous scholars have adopted the affordance perspective to better explain how users interact with and derive consequences from technological artifacts.

Reflecting this relational perspective, affordance is conceptualized as emerging from the interaction between technological systems and organizational contexts. Hence, affordances are viewed as the potential actions or behaviors that enable goal-directed actors to achieve specific, tangible outcomes through their engagement with technological artifacts (Bygstad et al., 2016). In this context, affordances are understood as the range of potential actions or opportunities that an artifact presents to particular groups of users engaged in goal-directed activities (Markus & Silver, 2008). Fundamentally, the concept emphasizes that affordances do not exist solely within the intrinsic characteristics of an object. Rather, affordances are relational phenomena and arise through the dynamic interaction between an object and an individual using the object for a specific goal. This theoretical lens holds substantial relevance in understanding technology adoption. User engagement in adopting technological systems is influenced by the interplay between opportunities and constraints inherent in such technologies (Majchrzak & Markus, 2012).

While the notion of technology affordance has been viewed at both individual and organizational level, literature still mainly focuses on the actualization part of the affordance. Only few addresses and examine the precondition that activates the potential into action. (Bernhard et al., 2013) propose the general framework of affordances. The central premise of the framework differentiates affordance existence, affordance perception, and affordance actualization as three distinct constructs. The outcomes of affordance actualization are largely shaped by affordances that are perceived by users. A user's perception of an affordance arises through their interaction with a given object, during which the affordance becomes apparent. Moreover, the quality and accessibility of information surrounding the emerging affordance play a crucial role in influencing the way it is recognized and perceived by the user. Given the study is at the exploration on how shrimp farmers perceive disease reporting and monitoring technology provide affordances to meet their goals, a specific investigation on affordance existence and perception is instrumental to ensure proper actualization of the affordances.

Methods

This study employed an interpretive qualitative case study approach (Klein & Myers, 1999) to investigate the perceived and emerging affordance transmitted by the digital object. The interpretive paradigm emphasizes understanding human behavior through the examination of social interactions and contextual experiences, allowing researchers to uncover how individuals construct and sustain their social realities (Newman, 2014). This methodological stance is particularly relevant here, as small-scale farmers' involvement through digital technology is understood to emerge from socially mediated interactions between users and the technological systems they engage with (Creswell, 2009; Recker, 2021).

To identify affordance perception, information about affordance, and affordance existence, this study employs semi-structured interviews as the primary data collection method. Interviews are a well-established and widely used qualitative research technique within the social sciences. The semi-structured format was selected to encourage participants to critically reflect on their experiences and articulate challenges related to digital

technology adoption for disease monitoring and reporting. The interview process was conducted by a team of two seasoned researchers: one serving as the lead interviewer and the other providing support through note- taking and supplementary probing. The interviewers' subject-matter expertise and familiarity with qualitative interviewing techniques were crucial to ensuring the depth and effectiveness of the data collection process.

Data Collection & Analysis

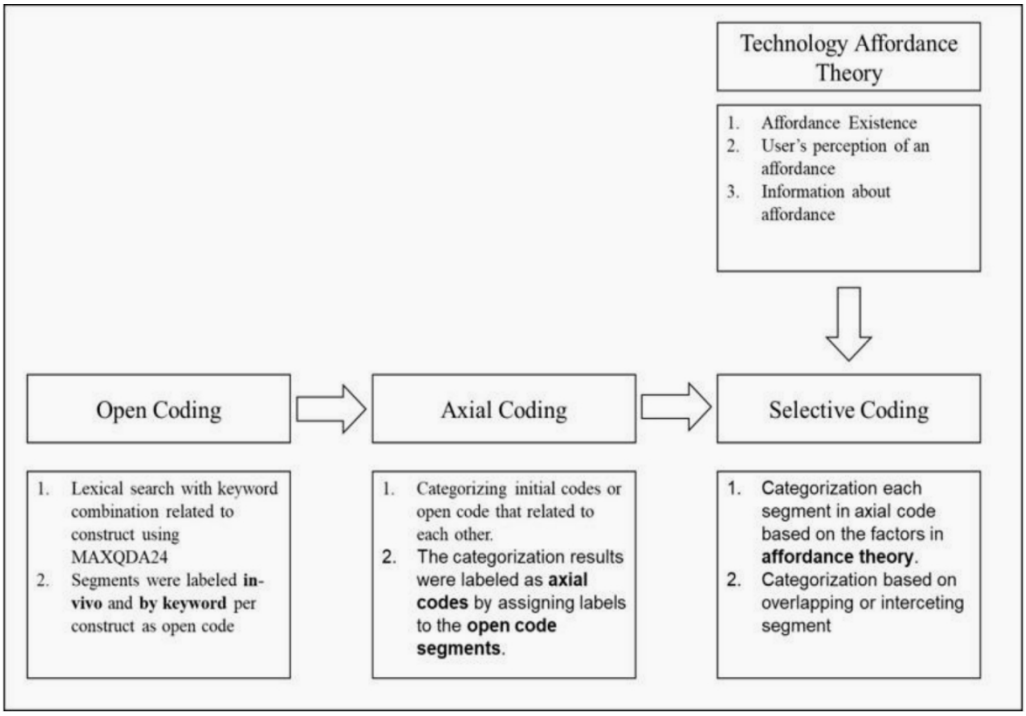
Data were collected using a combination of interviews, observations, and document reviews to enhance evidence triangulation and enrich the scope of insights obtained. The use of semi-structured interviews enabled participants to articulate their perspectives and experiences freely, while still maintaining alignment with the key themes under investigation. Table 1 below provides the demographic profile of the informants. The study involved 16 informants selected through purposive sampling to capture diverse roles within the shrimp aquaculture ecosystem. In qualitative research, sampling adequacy is determined by data saturation rather than statistical representativeness. Interviews were conducted until thematic convergence was observed and no substantially new insights emerged, indicating that the findings had reached saturation. The initial interview protocol was developed from existing theoretical concepts in the literature and was iteratively refined throughout the research process to incorporate emerging themes and newly identified ideas.

All interview recordings were transcribed, anonymized, and examined through a multi-coder analytical procedure. This multi-coder strategy was employed to minimize individual bias during text interpretation, with each transcript undergoing several iterative rounds of analysis. Given the exploratory nature of the research, all key themes and factors were inductively derived from the interview data. This framework served as a foundation that was progressively refined and expanded whenever new themes, challenges, or disease reporting related issues emerged.

Table 1. Demographics of Informants

Demographic Characteristic	Number	Percentage (%)
Job's Role		
Owner	3	18,8%
Expert	2	12,5%
Technicians	2	12,5%
Farm operator	4	25%
Employee	5	31,3%
Location		
Cirebon	6	37,5%
Pangandaran	1	6,25%
Sukabumi	1	6,25%
Pelabuhan Ratu	1	6,25%
Jakarta	1	6,25%
Indramayu	2	12,5%
Pangandaran	4	25%

Figure 1. Stage of Qualitative Data Analysis



The interview transcripts were analyzed through a three-stage coding process – open coding, axial coding, and selective coding–using MAXQDA 2024 to enhance transparency and minimize researcher bias. During the open coding stage, all interview transcripts were reviewed line by line to identify key concepts and recurring ideas guided by preliminary node structure. In order to ensure comprehensive data capture, a third researcher performed multiple iterative readings and codings ofthe transcripts. After each iteration, the coding framework and excerpts were refined to improve conceptual clarity. Subsequently, two other researchers independently re-coded the data using the revised structure and then collaboratively reviewed all nodes, consolidated overlapping categories and further delineated nuanced issues (e.g., by subdividing nodes where appropriate). Finally, the entire research team jointly revisited every transcript to verify that all relevant insights were accurately represented and systematically coded.

Both in-vivo and keyword coding techniques were used to preserve informants' expressions and identify terms related to enabling and constraining constructs. In the axial coding stage, open codes were compared and classified into broader subcategories based on conceptual relationships. Selective coding then synthesized these subcategories into core categories that explained the overarching patterns and interconnection within the data based on the general affordance framework of Bernhard et al., (2013). Analytic rigor was ensured through researcher triangulation, audit trails within MAXQDA, and member checking, these procedures enhanced the credibility, dependability, and confirmability of the findings which aligns with the trustworthiness criteria proposed by Lincoln & Guba (1986).

MAXQDA performed a search and labelling process on statements within the interview documents, resulting in two types of findings: Segments and Documents. A segment refers to a portion of text or statement identified within the interview transcript that is marked and coded for analysis, regardless of the respondent's document source. A document, on the other hand, represents a respondent's full transcript or document that contains at least one instance of a categorical code based on the model proposed by Bernhard et al., (2013), regardless of the frequency of occurrences. For example, a value of "2" indicates that two documents contain a specific category from Bernhard's model, even if each document includes more than one coded segment. Each segment identified during the open coding stage was categorized according to the factors according to Bernhard's model construct. This categorization was carried out by identifying overlapping or intersecting segments between the encouraging and challenging constructs and the constructs of Bernhard's model.

Findings

Farmers' Needs in Digital Technologyfor Disease Management

A total of 14 from 16 interview transcripts were analyzed in a three-stage qualitative coding process–open, axial, and selective coding–following grounded theory principles (Corbin & Strauss, 2008). Two transcripts were excluded due to limited relevance to central research questions. During the axial coding stage, numerous initial codes were identified and subsequently classified into eight overarching constructs: Product, Security, Information, Economics, Utility, Approach, Knowledge, and Demographic. Among those categories, Information, Product, and Security emerged as the most frequently discussed constructs, each appearing in nine interview transcripts. Economics became the second most frequently discussed construct by appearing in five interview transcripts, while Demographic was the least represented construct (see Figure 2).

Analysis of interview transcripts also explore the context of the statements reflecting factors that encourage farmers to adopt digital technologies. As presented on Figure 2, eight thematic constructs emerged from coded documents: Product (28,9%); Security (22,2%); Information (17,8%); Economics (11,1%); Approach (4,4%); Utility (8,9%); Knowledge (4,4%); and Demographic (2,2%). Among these constructs, Product is the most influential construct in shaping farmers' motivation to adopt digital technology. Twenty coded segments across six interview transcripts highlighted expectations for user-friendly and reliable technologies. The sub-constructs include products meeting performance expectations, tailored design for end users, symptom exploration feature, designed for ease of use, and availability of training programs. These findings emphasize that farmers prioritize tangible functionality and local adaptability over abstract technological sophistication. This resonates with previous studies showing that usability and perceived compatibility are critical to digital technology adoption among small-scale farmers (Aubert et al., 2012).

Figure 2. Identification of Digital Technology Adoption Enabling Constructs

Construct	Sub-Construct	Frequency	Percentage
Product	Explore the symptom by algorithmic	13	28,9%
	Product can work as expected		
	Training program		
	User friendly		
	Tailored to user need		
Security	Data confidentiality	10	22,2%
	Data security		
	Ensuring data protection		
Information	information about shrimp	8	17,8%
	Information of disease		
	Information of disease treatment		
	Quality of information		
Economics	Cost efficient	5	11,1%
	Reduce failure cost		
	Middleman for right price		
Approach	Taking friend to solve problem of the application	2	4,4%
	Curiosity of new technology		
Utility	Using image / video to identification of disease	4	8,9%
	The equipment is considered reliable/works as intended/produces the results promised		
	Product considered as useful as expected		
Knowledge	-	2	4,4%
Demographic	-	1	2,2%
TOTAL		**45**	**100%**

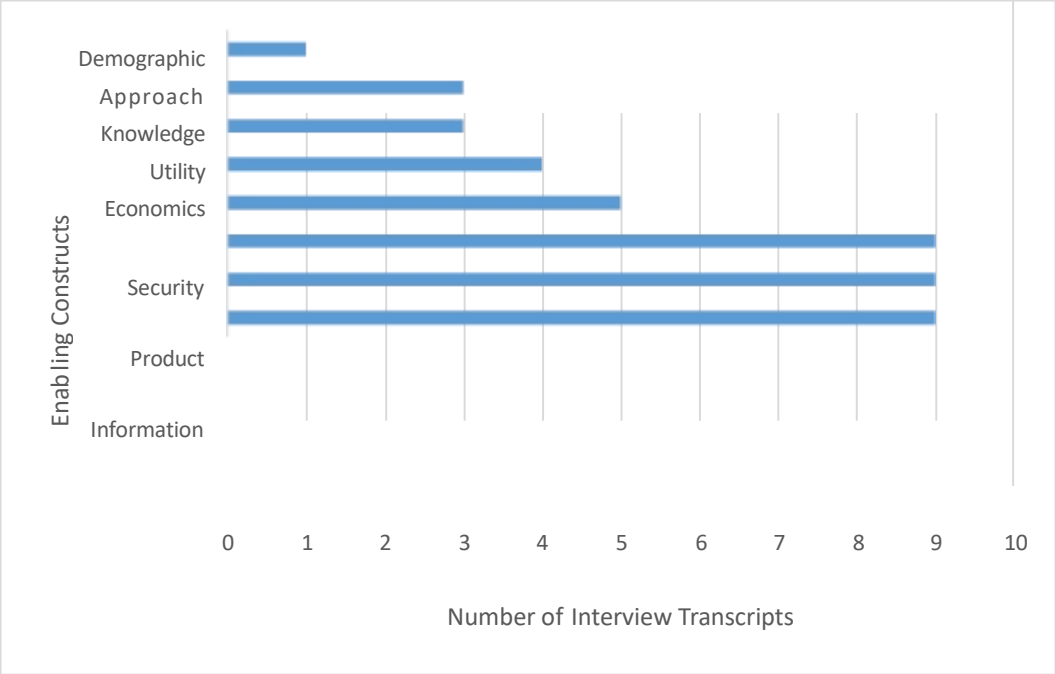
The second most prominent construct, Security, consisted of three enabling sub-construct: data confidentiality, data security, and ensuring data protection. These three sub-constructs appeared in fifteen coded segments across six interview transcripts. This finding indicates that while farmers are open to digital innovation, trust and perceived data safety remain as critical determinants of technology acceptance (Adnan et al., 2025). Following closely, Information, became the third most frequently discussed construct as it was mentioned in fourteen segments across six interviews. Farmers pointed out the need for relevant information about disease, quality of information, disease treatment, and shrimp. This finding suggests that the availability and reliability of information are central to farmers' willingness to use new digital technologies.

The Economics construct covers cost efficiency, reducing failure-related losses, and better price transparency through fewer intermediaries. These sub-constructs appeared in a total of six coded segments across four interview transcripts. The farmers signify that economic considerations also play a role in supporting their willingness to adopt digital technologies. Specifically, they expect digital technology to help lower operational costs, minimize production losses due to disease outbreaks, and improve market access by providing more transparent pricing information. These findings demonstrate that perceived financial benefits are key motivators for small-scale fish farmers in evaluating new technologies. Similar study supports this finding by emphasizing the significance of financial consideration in adopting technologies (Tey & Brindal, 2012).

As the fifth construct, Utility was identified in five coded segments across three interview transcripts which consist of three sub-constructs related to the practical use of digital technologies. The next construct, Approach, was mentioned in four segments across two documents which consisted of two sub-constructs. The last two constructs–Knowledge and Demographic–did not include any sub-constructs. The number of interview transcripts referencing each enabling constructs identified is presented in Figure 3.

Overall, these findings suggest that small-scale fish farmers are not resistant to digital technology adoption per se, but require solutions that are affordable, secure, practical, and contextually relevant. The discussion points to a "functionality–trust–affordability triad" as the foundation for designing AI-based aquaculture tools that are suitable for small-scale fish farmers (Gumbi et al., 2023; Iliopoulos et al., 2025; Yeo & Keske, 2024).

Figure 3. Number of Interview Transcripts Referencing Each Enabling Construct



Challenges to Technology Adoption

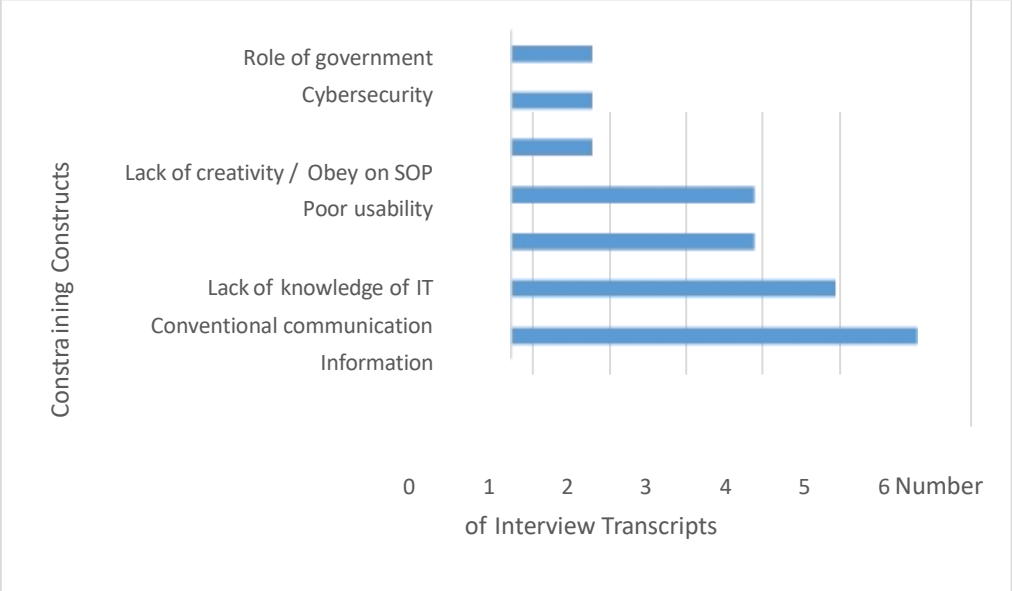
A total of nine out of sixteen interview transcripts were analyzed through three stages of qualitative coding to identify the main challenges in implementing digital technologies among small-scale fish farmers. The remaining eight documents were excluded due to their lack of relevance to the research question. During the open coding process, twelve initial challenges were identified. These challenges were later refined through axial and selective coding, resulting in seven final constructs representing the key challenges faced by farmers with regards to technology adoption. The distribution of these final constructs is presented in Figure 4.

Figure 4. Identification of Digital Technology Adoption Constraining Constructs

Construct	Sub-Construct	Frequency	Percentage
Information	Uncomfortability in Sharing Data	9	37,5%
	Recording Data Manually		
	Availability of data		
Lack of knowledge of IT	-	5	20,8%
Conventional communication	Direct communication preference	4	16,7%
	Uncomfortability with social media		
Poor usability	-	3	12,5%
Lack of creativity / Obey on SOP	-	1	4,2%
Cybersecurity	-	1	4,2%
Role of government	-	1	4,2%
TOTAL		**24**	**100,00**

The analysis revealed that Information-Related Challenges were the most frequently mentioned construct (37.5%), followed by Lack of knowledge of Information Technology (IT) (20.8%), Conventional Communication preferences (16,7%), and Poor Usability (12.5%). The least mentioned challenges were Lack of Creativity, Cybersecurity concerns, and Limited Government Involvement, each representing 4.2% of the total segments. The number of interview transcripts referencing each constraining constructs identified is presented in Figure 5.

Figure 5. Number of Interview Transcripts Referencing Each Constraining Construct



Information construct consists of three sub-constructs derived from the open coding stages, namely Discomfort in Sharing Data, Manual Data Recording Practices, and Availability of Data. This construct was referred to in nine segments across five documents, indicating that farmers struggle with both trust and infrastructure in managing digital information. As the third construct, Conventional Communication includes two sub-constructs: Preference for Direct Communication and Discomfort on social media. This construct appeared in four segments across four documents, reflecting a strong reliance on traditional interpersonal interaction rather than digital tools.

The remaining identified sub-constructs–Lack of IT Knowledge, Poor Usability, Lack of Creativity or Adherence to SOPs, Cybersecurity, and the Role of Government–did not generate additional sub-constructs. These domains stood independently, representing specific and discrete barriers that could not be clustered under broader classification such as Information or Conventional Communication. Overall, these findings suggest that information management, digital literacy, and communication habits are the primary constraints in the adoption of AI and related technologies by small-scale fish farmers. Limited government support and low emphasis on cybersecurity further indicate that institutional and policy frameworks remain underdeveloped for promoting digital transformation in the aquaculture industry (Toonen et al., 2025).

Discussion

Technology Adoption through the Lens of Affordance Theory

The preceding analysis identified both the enabling and constraining constructs shaping small- scale fish farmers' engagement with digital technologies. In an attempt to deepen the theoretical understanding of these findings, this section interprets the results

through the lens of Affordance Theory (Bernhard et al., 2013). Affordances refer to the possibilities for action that emerge from the relationship between users and technologies within specific contexts. This study adopts three constructs comprising affordance perception, information about affordance, and affordance existence to gain understanding about the extent to which farmers recognize, understand, and expect digital technologies for disease management. As illustrated on Figure 6 and Figure 7, relational analysis was conducted to explore intersections between enabling and constraining constructs respectively from identified interview transcripts and constructs from affordance theory. The darker the color in the tabulation, the higher the number of transcripts referencing both constructs. As seen on Figure 6, interview segments were distributed across three affordance constructs, showing that most farmer statements were associated with information about affordance (49 occurrences), followed by affordance existence (60 occurrences), and affordance perception (35 occurrences). This indicates that while farmers are aware of certain technological potentials, their actual ability to realize those potentials remains uneven and context specific.

Figure 6. Distribution of Enabling Constructs within Affordance Theory Constructs

Code	Affordance perception	Information about Affordance	Affordance existence	Total
Knowledge	2	2	3	7
Utility	-	-	-	-
Using image / video to identification of disease	2	2	2	6
the equipment is considered reliable/works asintended/produce	-	-	1	1
Product considered as useful as expected	-	1	2	3
Approach	-	-	-	-
Taking friend to solve problem of the application	1	2	2	5
Curiosity of new technology	-	-	1	1
Demographic	-	-	1	1
Information	-	-	-	-
information about shrimp	3	3	3	9
Quality of information	1	1	1	3
Information of disease treatment	2	4	4	10
Information of disease	4	5	5	14
Product	-	-	-	-
Explore the symptom by algorithmic	2	3	3	8
Product can work as expected	2	3	4	9
Training program	1	2	2	5
User friendly	-	-	1	1
Tailored to user need	3	5	6	14
Economics	-	-	-	-
Cost efficient	-	-	1	1
Reduce failure cost	-	-	1	1
Middleman for right price	3	4	4	11
Security	-	-	-	-
Data confidentiality	4	5	5	14
Data security	1	1	1	3
Ensuring data protection	4	6	7	17
Total	35	49	60	144

Across the enabling constructs (Figure 6), the information and product-related codes (i.e., information of disease, training program, user-friendly interface) were the most strongly represented constructs within all three affordance constructs. This pattern indicates that when digital tools provide reliable information, intuitive interfaces, and visible feedback mechanisms, farmers are more likely to recognize the affordance being offered. In this sense, information about affordance acts as a bridge between affordance existence and affordance perception by translating the potential of a tool onto a comprehensible and actionable form.

Conversely, the constraining constructs (Figure 7) reveal gaps in affordance perception and informational interpretation. Sub-constructs such as comfortability with social media, manual data recording, and lack of IT knowledge suggests that many farmers face informational and perceptual barriers, even when technological affordances objectively exist. These constraints highlight the importance of socio-cognitive factors such as habits, trust, and familiarity in mediating affordance realization. As (Bernhard et al., 2013) argue, affordances must be both perceived and enacted to generate meaningful outcomes; unrecognized affordance remain inert possibilities.

Figure 7. Distribution of Constraining Constructs within Affordance Theory Constructs

Code System	Affordance existence	Information about affordance	Affordance perception	Total
Role of government	-	-	1	1
Lack of creativity / Obey on SOP	-	1	-	1
Conventional communication	-	-	-	-
Uncomfortability with Social Media	-	3	-	3
Direct communication preference	-	2	-	2
Information	-	-	-	-
Recording Data Manually	-	1	-	1
Uncomfortability Sharing Data	-	2	-	2
Availability of data	-	-	1	1
Poor usability	-	1	1	2
Lack of knowledge of IT	-	1	-	1
Cybersecurity	-	-	1	1
Total	-	11	4	15

Taken together, these patterns demonstrate that technology adoption among small-scale fish farmers depends less on the technological sophistication of digital tools and more on the alignment between affordance communication, user understanding, and contextual relevance. When affordance information is accessible and resonates with farmers' lived practices such as through localized language, peer learning, or visual demonstration, the perceived value of digital tools increases, enhancing the likelihood of sustained use. Thus, strengthening informational transparency and user-oriented design emerges as a critical strategy for promoting digital adoption. Efforts should focus not only on expanding affordance existence, but also on reinforcing affordance perception through effective communication, usability, and context-sensitive training.

In summary, the affordance analysis indicates that while farmers can identify potential technological benefits (perception), the process of translating awareness into action (existence) remains mediated by trust, usability, and contextual relevance. Digital tools that emphasize usefulness, security, and local adaptation are more likely to be actualized in practice.

Realistic AI Solution

Translating the affordance-based findings, a realistic AI model for small-scale fish farmers must bridge the gap between farmers' perceived possibilities for action and the actual technological capabilities available to them. The analysis revealed that the adoption of digital technology among small-scale fish farmers depends on how effective technological possibilities are perceived, understood, and realized in practice. Therefore, realistic AI design should not focus solely on advanced technical performance, but also clarity, visibility, and contextual relevance.

At the foundational level, rule-based systems provide the most straightforward bridge between traditional decision-making practices and AI-based solutions (Misra et al., 2022). As concluded from the analysis on previous sections, farmers are accustomed to following Standard Operating Procedures (SOP) and conditional reasoning, making it more relevant to adopt a rule-based system. Essentially, a rule-based AI can formalize patterns through an "if-then" logic (Pickering et al., 2025), translating local wisdom or knowledge into clear and actionable alerts. In alignment with familiarity–a frequent concern for small-scale farmers–a rule-based system can also be designed to present information in familiar terms so that farmers can easily trace how recommendations are generated. Moreover, a rule-based system can easily be localized to regional farming contexts, making them well-suited for small-scale aquaculture. Building upon this logical foundation, image recognition technology introduces a more intuitive use of AI (Jiang et al., 2025). Traditionally, farmers detect shrimp health issues by analyzing physical symptoms such as changes in color, behavior, or texture that can be early indicators of a disease. Integrating image recognition models into an application can automate this traditional practice, in which farmers will be able to take photos of the shrimp and the AI technology would instantly analyze them for signs of infection. The application would then be able to display results using simple visual indicators to communicate diagnostic information. Complementing these visual and procedural components, Large Language Models (LLMs) introduce an interactive and conversational layer that bridges informational gaps (Zhu et al., 2025). Many small-scale fish farmers, especially those with limited digital literacy, struggle with interpreting technical terms or data dashboards. Allowing users to communicate in natural language, LLMs improve ease of use of the application by translating complex analytical results into accessible, human-like explanations.

Integrating these three AI components from a coherent, context-sensitive ecosystem that aligns closely with the principles of affordance theory. Rule-based reasoning grounds the system in transparent logic that enhances perception; image recognition extends perceptual capacity by visualizing disease cues, while LLMs deepen users' understanding by translating information into meaningful dialogue. Collectively, they bridge the gap between what the technology is capable of and what users believe they can do with it.

Conclusion

This study provides empirical insights into how small-scale fish farmers in Indonesia perceive the opportunities and challenges associated with disease management technology and examine how their adoption behavior can be interpreted through the lens of affordance theory. By applying a qualitative coding framework, the study identified key enabling and constraining factors that influence farmers' technological engagement–ranging from product design and information access to economic feasibility and data security. Findings demonstrate that farmers' willingness to adopt new tools was found to depend not only on functionality, but also on the degree to which technologies are understandable, trustworthy, and relevant to their everyday practices. Furthermore, findings also underscore the need for a user-centered and context-aware AI design in small-scale aquaculture.

From the theoretical perspective, this study contributes to enhancing understanding of technology affordance theory in exploring AI design for the purpose of augmenting the disease mitigation process for small-scale shrimp farmers. The adoption of affordance in aquaculture context is considered rare, therefore, this study provides a nuance perspective on how affordance is identified in a specific context. The three constructs comprising affording perception, information about affordance, and affordance existence provided a nuanced framework for understanding how farmers recognize, interpret, and act upon technological possibilities. The findings showed that while many farmers perceive the potential benefits of digital technology, their ability to translate awareness into meaningful action remains uneven. The gap often results from limited access to clear information, low digital literacy, and the absence of localized feedback mechanisms. To address these challenges, the study proposes a contextualized AI design framework that aligns with farmers' practical needs. Collectively, the design framework embodies the principles of affordance alignment by ensuring what technology can do (existence) is both understood (information) and recognized as useful (perception) by end users.

From a practical perspective, this study underscores three possible AI algorithms to design an aquaculture system for shrimp farmers. The possible algorithms consisting of rule-based systems, image recognition, and LLMs offer realistic solutions to strengthen alignment between technology and user affordances. Although each algorithm has its own merits and faults, the choices allow programmers to focus on experimenting with each possible model. This is to ensure that the designed systems will provide the highest model accuracy. In addition, programmers can pick which models offer the best relevancy towards the needs of shrimp farmers in the disease mitigation context. In addition, the algorithms and its experimentation data can serve as the use case once new diseases emerge. This is important as each shrimp disease's symptoms often overlap with other diseases.

This study has several limitations, thus offering opportunities for future research. Firstly, this research is conducted solely within the Indonesian aquaculture context. While findings offer valuable theoretical contributions, the findings may not easily translate to other geography or industrial settings. Therefore, future study could explore a comparative case study strategy such as preparing comparative research between countries or industries for disease mitigation AI- based design. Secondly, this study depicts a cross-sectional snapshot of AI potentials at a particular time. As digital tools evolve according to user practices, the findings may change when the data is taken at a different time frame. Therefore, longitudinal research could explore how AI design strategies and the choices ofthe algorithms evolves over time.

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Integrating Social Entrepreneurship and Innovation in Project-Based Learning: Empowering Future Change Agents for Sustainable Development

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ABSTRACT

This study examines the impact of a one-day project-based learning (PBL) intervention, "Program Eksplorasi ESD" which is designed to strengthen youth competencies in sustainability, innovation, digital entrepreneurship, and United Nations' Sustainable Development Goals (SDGs) literacy. Grounded in UNESCO's SDGs framework and Malaysia's national agenda for entrepreneurial and future-ready education, the program integrated hands-on activities including a recycling art innovation competition, entrepreneurship and digital workshops, and an SDG Hunt. A survey involving 50 secondary school participants revealed strong engagement and positive learning outcomes, particularly in innovation skills (M = 4.27) and entrepreneurship (M = 3.56), with high instrument reliability (α = 0.90–0.93). Students reported improved creativity, teamwork, ethical thinking, environmental stewardship, readiness to explore entrepreneurial pathways, and increased confidence in digital tools and sustainability-driven business concepts. The findings underscore the value of PBL and non-formal learning models in cultivating youth as proactive, socially responsible change-makers capable of contributing to Malaysia's sustainable and digital economy transition.

Keywords: Innovation, Sustainability, Entrepreneurship, Project-based Learning (PBL), Sustainable Development Goals (SDGs), Education, Youth.

Introduction

UNESCO (2025) emphasizes that sustainable development is both a scientific necessity and an ethical responsibility, highlighting the critical role of Education for Sustainable Development (ESD) in cultivating socially responsible, environmentally conscious, and critically aware citizens. In this context, project-based learning (PBL) emerges as a proactive and experiential pedagogical approach that engages students in analysing real-world challenges, adopting sustainable practices, and developing innovative solutions aligned with the 2030 Agenda for Sustainable Development and its 17 SDGs, thereby equipping learners with the competencies to think critically and creatively, collaborate effectively, communicate proficiently, and contribute meaningfully to global sustainability across personal, community, and ecological spheres (UNESCO, 2025; Cebrián, Junyent, & Mulà, 2021; Chiang & Lee, 2016).

Following the Third Outline Perspective Plan in 2001, which aimed to cultivate a skilled, innovative, and entrepreneurial workforce capable of driving technological advancement and sustainable economic growth toward the nation's Vision 2020 goals, entrepreneurship education was introduced in Malaysia (Roslan et al., 2022). Although entrepreneurship education was initially introduced in Malaysian higher learning institutions in the 1980s, it only gained significant traction around the year 2000, evolving from informal co-curricular training into more strategic national initiative, as well as extra-curricular activities (Roslan et al., 2022). Subsequently, the Ministry of Education has prioritized the development of holistic, entrepreneurial, and balanced graduates as one of the ten key focus areas in the Malaysian Education Blueprint 2015–2025 (Higher Education). Considering the Fourth Industrial Revolution (4IR) and its transformative digital advancements, entrepreneurship education was further redefined to equip learners with the critical skills and innovative mindsets required to thrive in an increasingly dynamic global economy (Roslan et al., 2022).

In Malaysia's higher education landscape, there remains limited exploration of non-formal, informal, and community-based learning in shaping sustainability competencies, even though fostering such competencies across all educational levels remains vital for cultivating sustainability literacy and empowering individuals to act as transformative agents in their professional and personal spheres. Social Entrepreneurship faces challenges of conceptual clarity and limited professional expertise, yet best practices highlight the need for increased awareness initiatives, well-designed curricula, and educator training programs that integrate innovative and practical approaches to Social Entrepreneurship education (Roslan et al., 2022). Recent studies suggest that incorporating sustainability competencies into PBL can effectively advance the achievement of these global goals (Cebrián, Junyent, & Mulà, 2021). Thus, this study examines the impact of an educational intervention based on PBL for sustainable development with designed activities related to social entrepreneurship, leadership, digital skills, creativity, as well as students' knowledge and understanding of the Sustainable Development Goals (SDGs). The learning outcomes for the project are:

i. To increase awareness and practice of SDG principles.
ii. To understand the fundamental concepts of innovation and entrepreneurship.
iii. To apply digital and entrepreneurship skills.

Literature Review

Sustainable Development Goals (SDGs) and Innovation

The United Nations' 2030 Agenda for Sustainable Development presents 17 SDGs aimed at addressing urgent global economic, social, and environmental challenges by 2030 (UNESCO, 2025; Xuan & Lindqvist, 2025). Building upon the Millennium Development Goals, the SDGs focus on five foundational pillars which include people, planet, prosperity, peace, and partnership, to eradicate poverty, promote equitable growth, and ensure long-term sustainability. At the same time, SDGs address environmental, social, and economic dimensions which are increasingly seen as essential learning exposures beginning from an early age (Ilham et al., 2021). Central to this vision, SDG 4 emphasizes inclusive, equitable, and quality education, advocating lifelong learning as a cornerstone for individual and societal advancement. Educational institutions are therefore positioned as transformative agents, responsible for embedding SDGs principles within their curricula to cultivate sustainability-oriented mindsets and practices (UNESCO, 2025).

Within the ASEAN region, countries such as Brunei, Laos, Indonesia, Cambodia, and Malaysia have actively engaged youth in SDGs implementation through diverse educational and skill development initiatives, underscoring their pivotal role as key stakeholders in sustainable progress (Yusof & Ariffin, 2021). In Malaysia, a study by Ilham et al. (2021) revealed that high school students in Kuala Lumpur demonstrate a strong awareness and positive perception of the SDGs, often applying related concepts in practice; however, a persistent gap remains between understanding and sustained action. Furthermore, only a limited number of Malaysian state governments have strategically aligned their development agendas with the SDGs, highlighting the need for more cohesive and actionable integration at both policy and community levels (Yusof & Ariffin, 2021). Integrating SDGs into higher education curricula to better equip students for future challenges, while calling for further research to assess the long-term effects and wider applicability of such educational interventions (Luque-González et al., 2025). Meanwhile, the growing scholarly interest in ESD has focused on exploring, implementing, and evaluating innovative pedagogical approaches and curriculum designs that cultivate sustainability competencies across diverse educational settings. Findings from recent studies highlight the transformative potential of action research, social learning, and project-based learning in enhancing university educators' and students' abilities to think critically and creatively, collaborate effectively, communicate proficiently, and manage projects within real-world constraints while improving overall learning outcomes (Cebrián, Junyent, & Mulà, 2021).

SDG promoting sustainability, which seeks to balance ecological integrity, social equity, and economic prosperity, is essential for addressing escalating global challenges and educating current and future generations to become responsible, informed citizens capable of fostering a harmonious and resilient future for both humanity and the planet (Singha & Singha, 2024). Consequently, social innovation serves as a pivotal strategy for generating adaptive, community-cantered solutions that respond to local challenges with contextual sensitivity and

creativity. There are many sorts of innovation, where social innovation and business innovation are different, yet overlapping concepts. Social innovation can be understood as the development and implementation of new ideas, practices, or structures that address social, cultural, economic, or environmental challenges, ultimately enhancing collective well-being and contributing to a more sustainable and equitable future (Malagón-Castro et al., 2025; Baskaran et al., 2019). Business innovation refers to the pursuit and application of new ideas or processes primarily driven by profit motives, yet often yielding broader societal benefits by enhancing human welfare, expanding consumer choices, and contributing to collective economic and social advancement (Baskaran et al., 2019).

Project-based Learning (PBL), Social Entrepreneurship, and Sustainability

Environmentally oriented education is essential for deepening understanding of sustainability concepts while cultivating awareness and responsible action toward addressing environmental challenges (Islamah et al., 2025; Hnatyuk et al., 2024; Altikolatsi et al., 2021). In line with that, educational institutions are urged to modernize their curricula by adopting experiential, nature-based and environmentally focused approaches such as outdoor lessons, park and river cleanups, and recycling initiatives along tourist routes that actively engage students and foster deeper environmental awareness and responsibility (Hnatyuk et al., 2024; Boeve-de Pauw, 2019). Higher education institutions, particularly universities, have also increasingly embraced their role and initiatives to address growing social inequalities, particularly within the Asian context (Baskaran et al., 2019). Educational strategies that cultivate social innovation and complex thinking are increasingly acknowledged as vital mechanisms for strengthening social cohesion and empowering local leadership in driving sustainable societal transformation (Malagón-Castro et al., 2025).

Consequently, Project-Based Learning (PBL) has been widely acknowledged as an effective pedagogical approach that engages students in sustained, inquiry-driven exploration of authentic, real-world issues and challenges especially when tackling complex environmental issues (Wahid et al., 2024; Singha & Singha, 2024; Cebrián, Junyent, & Mulà, 2021; Chiang & Lee, 2016). Through carefully structured, meaningful projects, learners are immersed in realistic contexts that encourage the integration and application of disciplinary knowledge to complex, practice-oriented problems relevant to their prospective professional domains (Xuan & Lindqvist, 2025; Chiang & Lee, 2016); enhance knowledge construction, critical thinking skills and students' motivation to learn, problem-solving competencies through the adoption of project-oriented instructional strategies (Chiang & Lee, 2016); as well as an effective way in integrates knowledge, skills and values (Cazorla-Montero et al., 2019).

"Social entrepreneurship is a concept of applying business techniques and private sector practices to solve social, cultural or environmental problems sustainably" (Baskaran et al., 2019). It has emerged as a vital driver of inclusive and sustainable economic growth across Asia and beyond, fostering employment, innovation, and community development while contributing to national gross domestic product (GDP), turnover, innovation and sustaining

local communities; while aligning business missions with the UN SDGs through knowledge creation and socially driven problem-solving (Baskaran et al., 2019).

In Malaysia, social entrepreneurship education in higher learning institutions fosters experiential and collaborative learning, where students design and implement small-scale social ventures on campus, cultivating the practical skills, creativity, and competencies essential for success in real-world social enterprise development (Wahid et al., 2024; Roslan et al., 2022; Baskaran et al., 2019). This approach also aims to address complex social challenges innovatively and effectively, leveraging dynamic knowledge mechanisms to continuously transform competencies, skills, attitudes, and knowledge assets in support of sustainable social innovation (Ndou, 2021). While traditionally prioritized for business and management students, entrepreneurship education has increasingly become a critical competence across all educational levels and disciplines, encompassing activities designed to cultivate human capital by enhancing technical, scientific, and business expertise, fostering creative thinking and problem-solving abilities, and developing interpersonal and experiential skills (Ndou, 2021).

Extending beyond economic revitalization, social entrepreneurship rooted in innovation, plays a transformative role in addressing structural issues, fostering social cohesion, and empowering communities toward sustainable development (Malagón-Castro et al., 2025). Thus, education plays an important role in encouraging student participation in social entrepreneurship through problem-based learning, especially in shaping students with positive attitudes, skills, and mindsets for sustainable economic growth (Roslan et al., 2022).

Method

An effective program for developing future social entrepreneurs should cultivate leadership, foster critical and solution-oriented thinking, and equip students with relevant entrepreneurial skills and perspectives that enable them to identify and address real-world social challenges with innovation and purpose (Wahid et al., 2024). The evidence generated can guide academic institutions, NGOs, and government agencies in replicating and scaling social entrepreneurship training across conflict-affected regions, thereby promoting sustainable development grounded in community participation, empowerment, and resilience (Malagón-Castro et al., 2025)

In this study, an online survey was conducted to assess the impact of PBL intervention on participants who joined the “Program Eksplorasi ESD”, which was organized by Green Educator Workgroup (GREW). The online survey was divided into 3 main components which are the respondent demographics, skills assessment and three open-ended questions as reflections. The survey was distributed at the end of the program. For the assessment of skills, 2 skills were assessed using a Likert scale of 1-5; where the instruments were adapted from Liñán and Chen (2009) to measure participants’ entrepreneurship; while innovation instruments are adapted from Cardon et al. (2013). The items were then grouped together according to the skills expected. The values from students' answers were analyzed, while the open-ended questions’ answers were grouped together to get the summary of their reflection

after attending the 1-day program. "Program Eksplorasi ESD" is a 1-day program with 4 different activities designed as PBL, which aims to increase soft skills related to SDGs practice, innovation, entrepreneurship, and digital skills. The workshop was facilitated by educators for better teaching practices and achieving objectives of the program. The details for the activities are:

Activity 1: Recycling Art Innovation Competition

Social Innovation initiatives is the main attraction for the participants, which aim to promote social entrepreneurship and economic inclusion. Participants must invent a ready-to-sell product (innovation) that uses recycled material of either plastic bottles, fabrics, or paper. Products are to be brought during the program for exhibition and explanation, while a video of the invention must be submitted to the organizer before the deadline.

Activity 2: Entrepreneurship Workshop

This activity provided a transformative impact for youth participants by equipping them with essential entrepreneurial mindsets, practical business skills, and sustainability awareness. Through discussion and talk, participants actively engaged in critical and creative thinking, teamwork, communication, marketing and strategic planning.

Activity 3: Digital Workshop

Digital Workshop is a hands-on activity for PBL in line with one of the components of a successful entrepreneur. Participants created their own e-commerce website to sell products, providing a highly impactful platform for cultivating entrepreneurial and technological competencies essential for the digital economy.

Activity 4: SDG Hunt

Station-based games of SDG Hunt was designed to offer a dynamic and experiential platform for participants to meaningfully explore and internalise the 17 SDGs. Through interactive problem-solving tasks, scenario challenges, and collaborative missions at each station, students not only gain conceptual understanding of global sustainability issues but also develop critical soft skills including teamwork, communication, leadership, and creative thinking. The task and aims for each station are different as listed below:

i. "Green Pitch" to pitch green business idea;
ii. "Recycle Relay" as initiatives aligned with the 3R principles;
iii. "Sustainable Logo Design" to promote creative thinking;
iv. "Fun with Word Search" as SDGs awareness action;
v. "SDG Match-UP" as SDGs understanding;
vi. "Flash Quiz SDG" to test knowledge on SDGs current issues;
vii. "Puzzle Efficiency" as problem-solving competencies;
viii. "Disaster Escape" as problem-solving competencies;
ix. "Sign Language" as activity to reduce inequalities;
x. "TT: Sales & Buy" as a marketing strategy.

Analysis & Discussion

This study comprised 36 female and 14 male participants, aged 15 – 20 years old youth, from 20 different secondary schools from Penang, Malaysia. Data analysis was conducted on the results and is displayed in Table 1. The instrument demonstrated high validity and internal consistency, as indicated by a KMO index > 0.80, a p-value < 0.05, and a Cronbach's Alpha of 0.90 for the innovation dimension; and 0.93 for the entrepreneurship dimension.

From the analysis, we can conclude that most of the participants learn and enjoy the innovation competition activity very much, as the overall mean is 4.27. The items included are exciting in inventing products (mean: 4.22); enjoying searching for new ideas (mean: 4.32); motivated in preparing the product (mean: 4.24); and excited participants in the environment (mean: 4.28). It might be the first attempt for the participants to be involved in entrepreneurship intervention, as there is much feedback answering "3" as unsure, and the overall mean demonstrates only 3.56. The instruments intend to measure perception, rather than the level of development; it is also essential for participants to feel knowledgeable, especially in their development as agents of change. This aligns with a study by Malagón-Castro et al. (2025) which mentions that PBL creates conditions and space for authentic participation and collaborative learning. Moreover, at secondary school level, students are still unsure if they are ready to be an entrepreneur or intend to start a business someday, compared to university students who have chosen and have a clear future pathway.

Table 1: Finding of the study

	Item	Mean	Cronbach's Alpha
Innovation	*It is exciting to figure out new ways to solve market needs that can be commercialized.*	4.22	**0.90**
	Searching for new ideas for products to offer is enjoyable to me.	4.32	
	I am motivated to figure out how to make existing products better.	4.24	
	Scanning the environment for new opportunities really excites me.	4.28	
	Overall Mean	**4.27**	
Entrepreneurship	*I am ready to do anything to be an entrepreneur*	3.66	**0.93**
	My professional goal is to become an entrepreneur	3.36	
	I will make every effort to start and run my own business	3.72	
	I am determined to create a business in the future	3.70	
	I have very seriously thought of starting a business	3.36	
	I have the firm intention to start a business some day	3.58	
	Overall Mean	**3.56**	

However, in their personal reflections from the open-ended questions, participants revealed a deeper understanding of ethical entrepreneurship, the positive societal impact of starting a business or online business, marketing strategies, influencer engagement, problem-solving skills, and pathways to becoming a successful entrepreneur (Figure 1 and Table 2). They expressed appreciation of the opportunity and highlighted that the workshop nurtured resilience, adaptability, and responsible decision-making while strengthening their critical thinking by integrating sustainability principles and encouraging social entrepreneurship in response to environmental challenges.

Information and Communication Technology (ICT) represent an advanced evolution of traditional IT, emphasizing the seamless integration of telecommunications and unified communications to enhance users' ability to access, manage, transmit, and utilize information effectively (Din et al., 2020). The rise of Internet technologies has revolutionized knowledge exchange and learning, aligning with the principles of connectivism, which positions educators as facilitators who guide students in independently exploring and constructing knowledge through digital networks and online resources. This hands-on digital entrepreneurship experience not only strengthens digital literacy and innovation capacity but also encourages ethical decision-making, responsible consumption, and sustainable business strategies aligned with contemporary market needs and SDGs (Table 3).

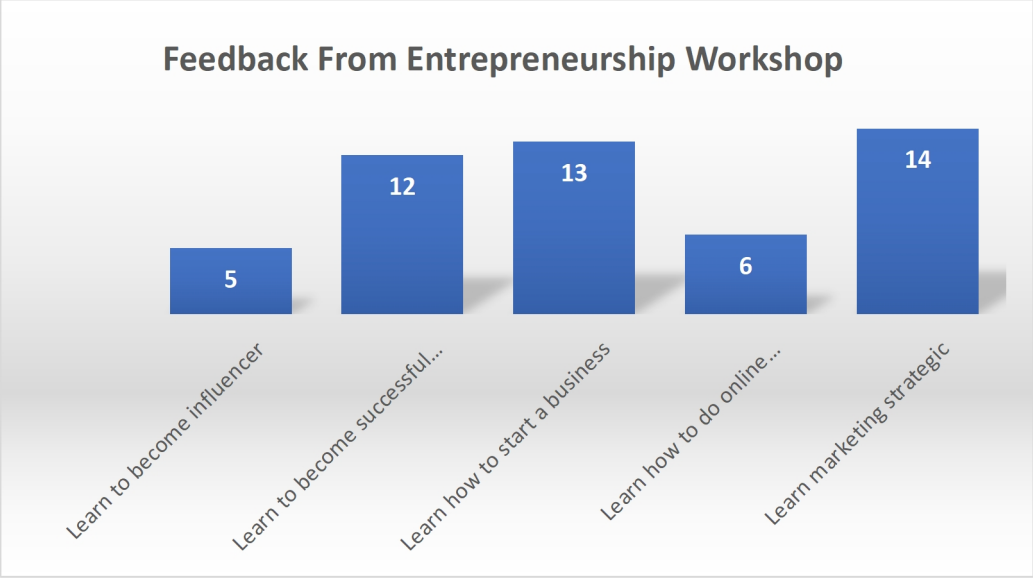

Figure 1: Summary feeback for Entrepreneurship Workshop

Table 2: Students' feedback for Entrepreneurship Workshop

Entrepreneurship Workshop: Is there any improvement or knowledge you learn, regarding entrepreneurship? What do you learn the most?
"I learned how to develop business ideas, manage basic finances, and understand the importance of solving real customer problems."
"It showed me how powerful the digital world can be if used to our advantage and people must be aware of the power of the Internet. Moreover, it showed me that marketing can make a major difference in the business field."
"Yes, I gained a lot of knowledge about entrepreneurship, especially how to identify business opportunities and manage basic finances. What I learned the most was how important innovation and problem-solving are when starting a business."
"I've learnt how to open my own business through online marketing. This helps a lot in case I would like to start a career and I eventually want to follow this path so as to making money. It's important to have a business to show yourself as a way of succeeding in life."
"Yes, I learnt about how most influencer make money by selling their products on social media."

Table 3: Students' feedback for Digital Workshop

Digital Workshop: What do you learn from this activity? Any suggestion to add on for the next program?
"Was very fun and we get to learn how to create our own website which was pretty simple."
"From this activity, I learned how to use digital tools to promote products and improve productivity. I also learned about the importance of digital branding and online customer engagement. For future programs, I suggest including more hands-on digital marketing practice or social media content creation."
"Suggestion: How to manage a digital works and how to use AI."
"Everything was well-organized and informative. Perhaps next time, more group activities or real-life case studies could be included to make the sessions even more engaging."
"In future, can add Quiz as extra activities."

Participants are gaining confidence to participate meaningfully in a technology-driven economic landscape by strengthening information on the importance of social networking, besides designing their own website as a marketing tool. This aligns with study done by Din et al. (2020) which mentioning that social networking, grounded in the collaborative dynamics of Web 2.0 platforms such as Facebook, Instagram, WhatsApp, and YouTube, plays a pivotal role in the business environment by fostering knowledge exchange, enhancing global connectivity, and cultivating innovative thinking that prepares students to navigate and leverage digital networks for entrepreneurial and professional success.

The gamified nature of SDG Hunt fosters intrinsic motivation, enhances engagement, and cultivates a sense of global citizenship, empowering students to recognise their role in contributing to sustainable futures. Ultimately, integrating SDG Hunt activities nurtures a generation equipped with sustainability competencies, problem-solving skills, and a proactive mindset aligned with the transformative agenda of the SDGs. Positive reflections received from participants (Figure 2 and Table 4) on SDG Hunt activities, including encouraging learners to synthesise knowledge, make ethical decisions, and teamwork to propose practical solutions in real-world contexts, thereby strengthening their socio-emotional intelligence, creativity and thinking abilities. Throughout the process in SDG Hunt, students collaborated in teams, enhancing their social and teamwork skills, which are central to PBL. This in line with PBL within the "Working with People" framework which bridges knowledge and action by linking experiential learning to real-world contexts, fostering a balanced development of technical, contextual, and behavioral skills essential for sustainability (Luque-González et al., 2025; Wahid et al., 2024; Singha & Singha, 2024; Cazorla-Montero et al., 2019).

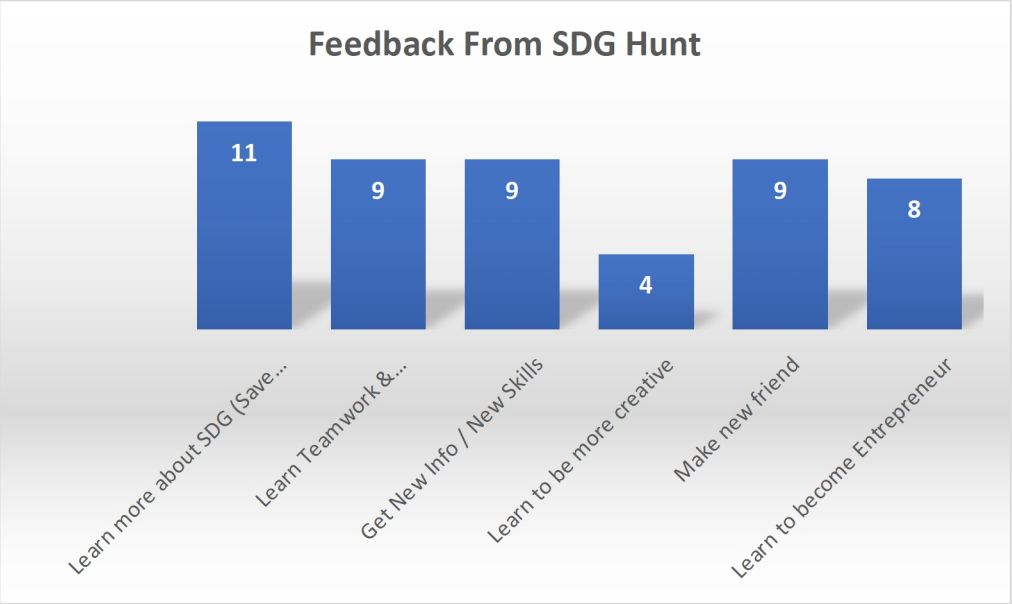

Figure 2: Summary feedback for SDG Hunt

Table 4: Students' feedback for SDG Hunt

SDG Hunt: Do you like the activity? What did you learn from this activity?
"I learned about the 17 Sustainable Development Goals (SDGs) and how they relate to real-life issues. It made me more aware of global problems and how we can take small actions to help."
"This activity was so much fun and challenging at the same time. I enjoyed the station games as well as being able to make new friends throughout the event. Though we were stressed out, we had a wonderful time and managed to win 2nd prize."
"Yes, I really enjoyed the activity. It was interactive and made learning about the Sustainable Development Goals (SDGs) fun and practical. I learned how simple daily actions can contribute to global goals like reducing waste, promoting clean energy, and ensuring quality education."
"I learn to make friends with others even though we don't know each other."
"I love this activity as it triggers my critical thinking skills and also help me found out new information."

One of the unforgetting students' experiences in the station games is business pitching. According to Din et al. (2020), a business pitch is a strategic presentation in which start-up founders engage potential investors (facilitator), to articulate their business vision through a structured dialogue that combines a formal presentation with interactive discussion and critical evaluation, where this element is important as a learning medium in entrepreneurship that helps students to improve self-esteem and communication skills. Meanwhile, "Recycle Relay" as one of the stations in SDG Hunt embedding conceptual understanding of sustainability within meaningful, hands-on environmental practices. Aligned with evidence that experiential learning cultivates stronger environmental responsibility (Islamah et al., 2025), SDG Hunt strategically integrated visual, creative, and collaborative components to accommodate diverse learning styles and foster deeper comprehension. Ultimately, the experience empowered students to view themselves as capable and proactive environmental stewards, equipped with the awareness, agency, and commitment needed to contribute to sustainable transformation at both school and community levels.

Universities widely employ competition activities as a practical platform for aspiring entrepreneurs to challenge themselves and apply their skills to real-world scenarios (Ndou, 2021). These initiatives aim to enhance participants' skills in presenting real cases, identifying and evaluating business opportunities, refining business plans, and securing start-up resources, while immersing participants in action-based learning that simulates the practical process of launching and developing a venture. Recycling Art Innovation Competition that is organized in this program fits the same initiatives' aim, where student's

creativity transforms waste (recycle material) into artistic expressions (art) that related to social entrepreneurship, sharpens critical thinking, and enhances engagement in fostering environment awareness (Hnatyuk et al., 2024; Singha and Singha, 2024; Boeve-de Pauw, 2019).

To equip students for success in the dynamic 21st-century global economy, it is essential to integrate entrepreneurship curricula with innovative, learner-centered teaching and learning approaches. It is recommended that targeted initiatives be implemented to identify effective pedagogical strategies and optimize class sizes, thereby enhancing knowledge acquisition and promoting more meaningful and interactive learning experiences. Overall, activities designed for "Program Eksplorasi ESD" align with curricula as suggested by Roslan et al. (2022); as PBL is one of the effective social entrepreneurship pedagogies (Wahid et al., 2024). According to Intan, Ismail, and Susanah (2024), students' critical thinking skills are enhanced when they actively engage in higher-order cognitive processes such as interpreting, analyzing, evaluating, inferring, explaining, and self-regulating. Within the framework of this PBL, students gradually assumed a more active role in examining and processing information related to environmental issues and the principles of environmental sustainability. Table 5 shows the insights from teachers, revealing positive feedback on students' understanding of environmental challenges and sustainability concepts following their participation in the program. These outcomes indirectly support the development of shared environmental attitudes, values, and cultural norms (Hnatyuk et al., 2024; Altikolatsi et al., 2021), which are essential for advancing the goals of sustainable development.

Table 5: Teachers' feedback for overall program

Overall Program: What is your opinion regarding overall of this program? Anymore comment or suggestion?
"A very good program."
"All great. Looking forward for the coming programs."
"Very good workshop"
"Hope this program will continue in the future."
"Overall, the program was beneficial and insightful, especially in increasing awareness about the importance of recycling practices and the creative use of recycled products. The session successfully highlighted how recycling can be applied in practical ways to reduce waste and promote sustainability, both at school and in our daily lives."

Conclusion & Impact

This study underscores the transformative value of PBL as a catalyst for cultivating sustainability competencies, entrepreneurial mindsets, digital fluency, and SDGs literacy among youth. The findings demonstrate that an integrated one-day program, comprising innovation challenges, entrepreneurship and digital workshops, and station-based SDGs activities, effectively nurtured critical soft skills such as collaboration, communication, ethical reasoning, and creative problem-solving. Participants reported heightened awareness of sustainability issues, improved confidence in digital and entrepreneurial practices, and a deeper appreciation for social responsibility and environmental stewardship. These outcomes affirm the importance of experiential and PBL-based pedagogies in bridging knowledge with action, aligning with UNESCO's vision for education that empowers young people as active contributors to sustainable development.

The program's success carries meaningful implications for education systems seeking to advance the SDGs through youth empowerment and innovative learning models. Beyond enhancing cognitive and technical competencies, the intervention fostered effective and behavioral change, strengthening participants' identity as emerging change-makers capable of applying sustainable business concepts, leveraging digital tools for social impact, and engaging in community-driven solutions. By cultivating agency, systems-thinking, and real-world engagement, this PBL initiative contributes to building a future-ready generation equipped to navigate a dynamic global landscape shaped by the Fourth Industrial Revolution and ecological challenges. Importantly, the study highlights the need for continued integration of non-formal and experiential approaches across educational levels to deepen youth participation in sustainability leadership and social innovation, reinforcing education's pivotal role in shaping resilient, inclusive, and sustainable societies.

While this study offers valuable insights, its limitations also highlight important directions for future research. Expanding the study to larger and more diverse samples across different regions would help validate the applicability of the PBL methodology in varied contexts, while longitudinal studies could assess the durability of its effects over time. Combining self-reported data with additional qualitative and observational approaches such as semi-structured interviews, reflective journals, and participatory focus groups, would provide a more comprehensive understanding of the intervention's long-term impact on participants' lives. Future research should also consider extending the intervention over multiple weeks or structuring it in phases to foster deeper engagement with complex cognitive skills, including critical and innovative thinking, and follow-up assessments three to six months post-intervention, to allow for evaluation of sustainability and impact, particularly in diverse educational contexts.

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Collaborative Innovation and Innovation Performance in Chinese Manufacturing SMEs: The Moderating Role of Technological Uncertainty

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Abstract

This study examines the relationship between collaborative innovation and innovation performance among Chinese manufacturing Small and Medium-sized Enterprises (SMEs), with technological uncertainty serving as a moderating factor. Drawing on the Resource-Based View (RBV) and Dynamic Capabilities Theory, the research explores how collaborative innovation enhances innovation performance under varying levels of technological uncertainty. Using data from 163 SMEs and employing Partial Least Squares Structural Equation Modeling (PLS-SEM), the findings reveal that collaborative innovation has a significant positive effect on innovation performance. Moreover, technological uncertainty moderates this relationship, strengthening the impact of collaborative innovation on innovation outcomes in highly uncertain technological environments. The results highlight the critical role of external collaboration and adaptive capability in improving innovation performance, offering strategic insights for SMEs seeking to sustain competitiveness amid rapid technological change. This study contributes to the growing body of literature on innovation management by elucidating how firms can leverage collaboration to mitigate the challenges of technological uncertainty.

Keywords: Collaborative Innovation; Innovation Performance; Technological Uncertainty; Dynamic Capabilities; Resource-Based View; PLS-SEM; China

Introduction

Manufacturing Small and Medium-sized Enterprises (SMEs) in China operate within a national policy environment that strongly promotes and subsidizes innovation (X. Wang et al., 2023). Despite this strategic emphasis, a substantial implementation gap remains. Industry analyses indicate that the adoption of advanced technologies such as artificial intelligence (AI), big data analytics, and automation remains below 20% among these firms (McKinsey, 2023). As illustrated in Figure VI, this technological lag is further reflected in the limited investment in digital infrastructure, cloud computing, and Industry 4.0 solutions. Such deficiencies in technological competence constrain SMEs' absorptive capacity that the ability to identify, assimilate, and apply external knowledge which is essential for leveraging advanced digital tools and sustaining innovation (Wang, Li, Ding, & Guo, 2025). Foundational IT capability forms the basis for integrating emergent technologies, enabling applications such as AI-driven predictive maintenance (Zhou, Zhou, Nie, & Zheng, 2024) and facilitating entry into Industry 4.0 ecosystems through collaboration with technology providers and academic institutions (Nithyanandam, Munguia, & Marimuthu, 2022).

Parallel to this technological challenge is a persistent collaborative deficit. Empirical evidence shows that only around 10% of Chinese SMEs engage in partnerships with higher education institutions far below the engagement levels of their European counterparts (Du, Wang, & Yin, 2024). This lack of collaboration limits access to external R&D funding, which accounts for less than 10% of total innovation investment, and is exacerbated by perceived barriers such as intellectual property risks (reported by 35% of firms), high partnership costs (25%), and insufficient supportive policies. Consequently, many SMEs lack the institutional frameworks and relational capabilities required for effective collaborative innovation, even though such partnerships are increasingly recognized as essential for enhancing innovation capacity (Zeng et al., 2010).

To address these limitations, this study adopts an integrative theoretical framework that synthesizes the Dynamic Capabilities and Contingency perspectives. From the Dynamic Capabilities viewpoint, collaborative innovation represents a strategic mechanism that enables firms to integrate, build, and reconfigure both internal and external resources to enhance their innovation performance. In this context, innovation performance is not simply an outcome of resource possession, but of a firm's ability to continuously adapt, learn, and co-create value with external partners. Collaborative innovation thus acts as a dynamic capability, translating internal technological and knowledge resources into tangible innovation outcomes.

However, drawing on Contingency Theory, the relationship between collaborative innovation and innovation performance is expected to vary under different levels of technological uncertainty. When technological change is rapid and unpredictable, the benefits of collaboration may intensify, as firms seek diverse external knowledge to mitigate uncertainty and reduce innovation risks. Conversely, excessive uncertainty can hinder coordination, increase transaction costs, and weaken innovation outcomes. Therefore, technological

uncertainty is posited as a moderating variable that conditions the strength and direction of the collaboration–performance relationship.

In summary, this study aims to investigate how collaborative innovation influences innovation performance among Chinese manufacturing SMEs, and how technological uncertainty moderates this relationship. By integrating Dynamic Capabilities Theory and Contingency Theory, the research seeks to provide both theoretical and practical insights into how SMEs can strategically align their internal competencies with external collaborations to achieve superior innovation outcomes in volatile technological environments.

Hypotheses Development

Collaborative Innovation and Innovation Performance

The Dynamic Capabilities Theory emphasizes that a firm's long-term competitiveness depends not only on its possession of valuable resources but also on its ability to integrate, build, and reconfigure these resources to adapt to rapidly changing environments (Teece, Pisano, & Shuen, 1997). Within this framework, collaborative innovation is conceptualized as a dynamic capability that enables firms to effectively coordinate and combine internal knowledge with external expertise to generate novel products, processes, or services. By engaging in joint problem-solving and co-creation with external stakeholders, such as suppliers, customers, universities, and research institutions firms can accelerate knowledge exchange and innovation outcomes (Chesbrough, 2020).

In manufacturing SMEs, collaborative innovation enhances innovation performance by facilitating access to complementary assets, advanced technologies, and diverse knowledge sources that would otherwise remain beyond the firm's internal boundaries (Zeng, Xie, & Tam, 2010). This collaboration allows firms to share risks and costs associated with R&D, thereby improving efficiency and innovation yield (Faems, de Visser, Andries, & Van Looy, 2010). Furthermore, through repeated collaborative interactions, firms enhance their absorptive capacity that the ability to recognize, assimilate, and apply external knowledge (Cohen & Levinthal, 1990)—which directly contributes to improved innovation output and market responsiveness (Feller, Parhankangas, & Smeds, 2020).

Collaborative innovation also strengthens organizational learning and dynamic adaptation. By integrating cross-disciplinary expertise, firms can shorten development cycles, refine existing technologies, and respond rapidly to shifts in customer demand or technological trends (Ritala & Hurmelinna-Laukkanen, 2013). Evidence from recent studies suggests that firms participating in open or collaborative innovation networks exhibit higher levels of both product and process innovation performance (Yun, Zhao, Park, & Shi, 2020). Therefore, collaborative innovation not only acts as a mechanism for knowledge recombination but also serves as a catalyst for continuous renewal and sustained competitiveness in dynamic markets.

Accordingly, the following hypothesis is proposed:

H1: Collaborative innovation has a significant and positive effect on innovation performance.

The Moderating Role of Technological Uncertainty

While collaboration enhances innovation outcomes, its effectiveness can vary depending on external environmental conditions. According to Contingency Theory, the success of organizational strategies and processes depends on their alignment—or "fit"—with contextual factors such as technological turbulence, market dynamism, and environmental uncertainty (Donaldson, 2001). Among these, technological uncertainty represents a particularly salient factor in innovation contexts. It refers to the unpredictability and pace of technological change, which influences both the feasibility and direction of innovation efforts (Jaworski & Kohli, 1993).

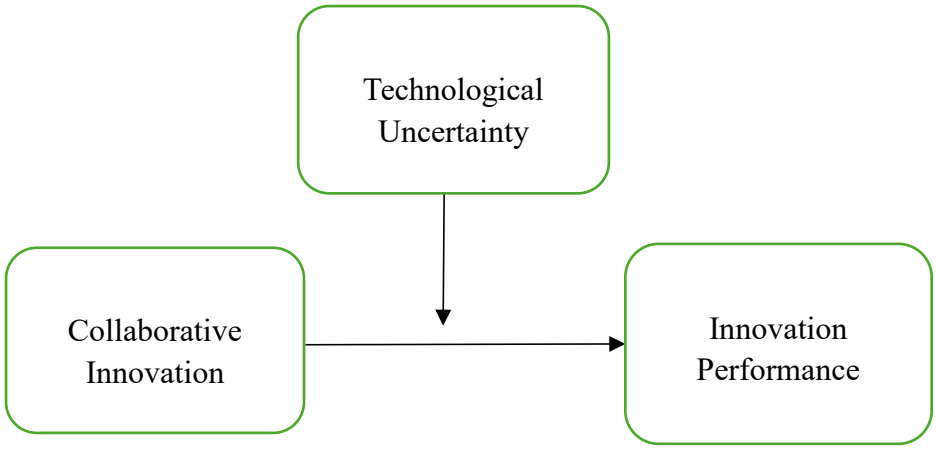
Under conditions of high technological uncertainty, collaborative innovation becomes even more critical, as firms rely on partners to access emerging knowledge, share risks, and experiment with new technological trajectories (Li & Atuahene-Gima, 2001). Collaboration provides a mechanism to pool diverse expertise and rapidly respond to technological disruptions, thereby strengthening the link between collaboration and innovation performance (Lichtenthaler & Lichtenthaler, 2009). Conversely, in low-uncertainty environments, where technologies evolve predictably, firms may depend more on internal capabilities and routines, reducing the relative advantage of collaboration (Song, Berends, van der Bij, & Weggeman, 2007).

However, excessive uncertainty can also complicate collaboration. High technological turbulence may increase coordination costs, heighten the risk of knowledge leakage, and reduce mutual trust among partners (Dittrich & Duysters, 2007). Therefore, the moderating effect of technological uncertainty is complex but generally positive within manageable levels of uncertainty—where firms can still leverage collaboration as a dynamic mechanism for exploration and adaptation.

Based on the Contingency Theory perspective, it is proposed that technological uncertainty strengthens the positive relationship between collaborative innovation and innovation performance, as firms under uncertain technological conditions derive greater value from external collaborations.

H2: Technological uncertainty positively moderates the relationship between collaborative innovation and innovation performance, such that the relationship is stronger under high levels of technological uncertainty.

Based on above hypothesis development and research gap, following research framework is proposed as shown in figure 1.



Sampling and Data Collection

The study targeted manufacturing Small and Medium-sized Enterprises (SMEs) listed on the Shanghai and Shenzhen stock exchanges, representing a total population of 2,817 firms. A purposive sampling technique was employed to ensure that participating firms possessed relevant innovation activities and technological engagement necessary for the study's focus.

Data were collected through an online questionnaire survey, which was distributed via email to 250 SME representatives occupying managerial or R&D-related positions.

The data collection process was conducted over a three-month period, beginning in January 2025. To improve participation, professional and academic networks were utilized to facilitate survey dissemination, a method demonstrated to enhance response rates in organizational research (Iqbal et al., 2020). A total of 163 valid responses were received, corresponding to a response rate of 65.2%, which is considered highly acceptable for survey-based studies involving managerial respondents.

Furthermore, the final sample size of 163 exceeded the minimum threshold of 98 required for adequate statistical power, as established through an a priori power analysis using G*Power software. This ensured the robustness and reliability of the data for subsequent Partial Least Squares Structural Equation Modeling (PLS-SEM) analysis..

Measures

All constructs were measured using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

Technological Uncertainty was measured using a five-item scale adapted from Song and Montoya-Weiss (2001). This instrument captures the degree of technological volatility and

the unpredictability of technological change within a firm's external environment. Collaborative Innovation was conceptualized as a second-order formative construct, reflected by two first-order dimensions: (1) partnership networks and (2) relational collaboration. The measurement items were adapted from Pundziene and Geryba (2023), whose original scales demonstrated high reliability (Cronbach's $\alpha = 0.846$ for partnership networks; $\alpha = 0.816$ for relational collaboration). Innovation Performance was measured using a five-item scale adapted from Wang et al. (2024), which has shown strong internal consistency in the context of Chinese firms (Cronbach's $\alpha = 0.941$).

Measurement Analysis

In Partial Least Squares Structural Equation Modeling (PLS-SEM), the measurement model (also known as the outer model) specifies the relationships between latent constructs and their observed indicators (Hair & Lukas, 2014). In this study, the measurement analysis aimed to ensure the reliability and validity of the constructs representing Collaborative Innovation, Innovation Performance, and Technological Uncertainty, as grounded in the Dynamic Capabilities and Contingency Theory frameworks.

Construct reliability was evaluated using Composite Reliability (CR), which provides a more accurate assessment of internal consistency than Cronbach's Alpha by accounting for varying indicator loadings (Hair & Lukas, 2014). All constructs in this study demonstrated CR values exceeding the 0.70 threshold, indicating acceptable internal reliability.

Construct validity was assessed through convergent and discriminant validity (Sekaran & Bougie, 2016). Convergent validity was confirmed through factor loadings, Average Variance Extracted (AVE), and CR (Hair, Ringle, & Sarstedt, 2013). Indicator loadings ranged from 0.634 to 0.882, with AVE values above 0.50 and CR values surpassing 0.70, demonstrating satisfactory convergence.

Discriminant validity was established using cross-loadings, the Fornell-Larcker criterion, and the Heterotrait-Monotrait (HTMT) ratio (Henseler, Ringle, & Sarstedt, 2015). The square root of each construct's AVE exceeded its inter-construct correlations, and all HTMT values remained below 0.85, confirming that each construct, particularly Collaborative Innovation, Innovation Performance, and Technological Uncertainty was empirically distinct.

This measurement validation provides a robust foundation for testing the study's hypotheses: H1, which posits that Collaborative Innovation positively influences Innovation Performance, and H2, which proposes that Technological Uncertainty positively moderates this relationship.

Structural Model Analysis

After confirming the reliability and validity of the measurement model, the structural model was evaluated to test the hypothesized relationships among constructs. Following the guidelines of Hair et al. (2019), the assessment included examining path coefficients, coefficient of determination (R^2), and effect size (f^2) to determine the strength and

significance of the proposed relationships. Bootstrapping with 5,000 resamples was employed to assess the statistical significance of each path.

The results supported H1, indicating that Collaborative Innovation has a significant and positive effect on Innovation Performance ($\beta = 0.487$, $p < 0.001$). This finding aligns with the Dynamic Capabilities framework, suggesting that firms that engage in effective collaborative practices are better able to transform and integrate resources to enhance innovation outcomes.

Furthermore, H2 was also supported. Technological Uncertainty positively moderated the relationship between Collaborative Innovation and Innovation Performance ($\beta = 0.213$, $p < 0.01$). This result is consistent with Contingency Theory, implying that when technological environments are more volatile, the benefits of collaboration become more pronounced, helping firms adapt and innovate more effectively. Collectively, these findings highlight the importance of dynamic and context-sensitive innovation strategies in Chinese manufacturing SMEs.

Table 4-1 Hypotheses Testing

Hypothesized Relationship	**β (Path Coefficient)**	**S.E.**	**T-value**	**P-value**	**LLCI**	**ULCI**	**Decision**
H1: Collaborative Innovation → Innovation Performance	0.314	0.046	6.826	0.000	0.224	0.404	Supported
H2: Technological Uncertainty × Collaborative Innovation → Innovation Performance	0.086	0.029	2.966	0.003	0.029	0.143	Supported

Discussion

The findings of this study provide compelling empirical evidence supporting both proposed hypotheses. First, the results confirm that collaborative innovation significantly and positively influences innovation performance ($\beta = 0.314$, $t = 6.826$, $p < 0.001$), indicating that manufacturing SMEs that engage more actively in collaborative activities achieve higher levels of innovation. This result aligns with the Dynamic Capabilities Theory, which emphasizes that firms enhance their competitiveness by reconfiguring internal and external resources to adapt to environmental changes (Teece, 2007). Collaborative innovation acts as a dynamic capability that enables firms to leverage external knowledge, share R&D risks, and co-create novel solutions with partners such as suppliers, customers, and research institutions. By fostering mutual learning and resource sharing, these collaborations strengthen the firm's ability to generate, absorb, and apply new knowledge effectively, leading to improved innovation outcomes.

Second, the study finds that technological uncertainty positively moderates the relationship between collaborative innovation and innovation performance ($\beta = 0.086$, $t = 2.966$, $p = 0.003$). This finding supports Contingency Theory, suggesting that the effectiveness of collaborative strategies depends on external environmental conditions. Under high technological uncertainty characterized by rapid technological changes and unpredictable market shifts collaboration becomes a crucial adaptive mechanism. It allows firms to access external expertise, share technological insights, and respond flexibly to emerging opportunities. Conversely, in more stable technological environments, the marginal benefits of collaboration may diminish, as firms rely more on internal processes and incremental innovations.

Taken together, these results highlight the complementary roles of internal and external capabilities. Collaborative innovation serves as a strategic capability that enhances performance outcomes, while technological uncertainty shapes the strength of this relationship. The findings underscore the importance for manufacturing SMEs to not only invest in building collaborative networks but also to adapt these partnerships dynamically in response to technological volatility. By aligning collaboration strategies with environmental contingencies, firms can better sustain innovation performance in an increasingly uncertain and competitive landscape.

Limitations and Future Research

Although this study provides valuable insights into the relationships among collaborative innovation, technological uncertainty, and innovation performance, several limitations should be acknowledged. First, the research employed a cross-sectional design, which limits the ability to infer causality between variables. Future studies could adopt longitudinal or panel data approaches to capture how these relationships evolve over time. Second, the study's data were collected from Chinese manufacturing SMEs, which may restrict the generalizability of findings to other industries or countries with different institutional and cultural contexts. Future research could extend the model to service sectors or international samples to enhance external validity.

Third, while the study focused on technological uncertainty as a moderating factor, other contextual variables, such as market turbulence, competitive intensity, or organizational culture may also influence the strength of the collaboration–performance link. Incorporating these factors would offer a more comprehensive understanding of environmental contingencies. Lastly, future research could employ mixed-method designs, integrating quantitative analysis with qualitative interviews, to explore how firms strategically manage collaboration under technological uncertainty.

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Institutional–Cultural Complementarities and Market Behaviour in China: A Literature Review from an Organisational Economics Perspective

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Abstract

This literature review examines how informal cultural institutions in China—particularly guanxi, Confucian values, and regional cultural tightness–looseness—shape market behaviour by influencing incentives, information flows, trust, and enforcement alongside formal market rules. Drawing on an organisational and institutional economics perspective, the paper synthesizes English-language peer-reviewed studies published between 2015 and 2025 across economics, management, and political economy. Using explicit inclusion criteria, the review evaluates evidence on Chinese firms and households and maps key mechanisms linking cultural norms to measurable outcomes in corporate governance, financial participation, innovation investment, and policy compliance. The synthesis shows that informal institutions can both complement and substitute for formal institutions: relational governance may reduce transaction costs while weakening arm's-length monitoring; Confucian legacies may support long-term orientation and human-capital investment while moderating risk-taking; and tighter cultural environments may strengthen compliance and regulatory effectiveness. The review also identifies persistent methodological challenges, especially causal identification, measurement validity, and regional heterogeneity. It argues that culture should be modeled as part of the institutional matrix rather than treated as residual context. The paper contributes a research agenda that integrates econometrics, quasi-experimental designs, field experiments, and text-as-data to improve theory building and empirical inference.

Keywords: China; Confucian values; corporate governance; cultural tightness–looseness; financial participation; guanxi; institutiona economics; market culture

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Executive Summary

Objective. To synthesize how informal cultural institutions in China shape market outcomes and clarify implications for economic analysis (North, 1990; Williamson, 2000; Fang et al., 2023).

Approach. Systematic review of studies (2015–2025), prioritizing peer-reviewed evidence that measures cultural variables and links them to outcomes (risk-taking, innovation, compliance), integrating findings through an institutional–cultural lens where informal rules complement or substitute formal institutions (Chua et al., 2019; Leng et al., 2023).

Findings. (i) Guanxi reduces transaction costs but weakens arm's-length monitoring (Bian, 2019; Li et al., 2021); (ii) Confucian legacies raise human-capital investment yet often temper firm-level risk-taking (Fan, 2020; Zhu & Zhang, 2024; Jiang & Li, 2025); (iii) cultural tightness increases compliance and shapes regulatory effectiveness (Gelfand et al., 2011; Chua et al., 2019; Ma & Xie, 2019); (iv) digital transformation interacts with local norms to influence participation and entrepreneurship (Lu et al., 2024; Cui, 2021); (v) peer networks diffuse norms and expectations, modulating regional market behavior (Lin & Wang, 2024).

Implications. Economic analysis benefits from explicit cultural parameters in models of governance, disclosure, and participation; policy design should account for cultural heterogeneity across provinces and sectors (North, 1990; Williamson, 2000).

Future Directions. Develop granular, validated cultural indices; use quasi-experimental designs; and bridge institutional economics with computational social science and organizational theory (Fang et al., 2023; Leng et al., 2023)

Introduction

Institutional economics defines institutions as the rules—formal and informal—that structure incentives and exchange (North, 1990; Williamson, 2000). In China, the informal layer is unusually salient: Confucian ethics, relational governance through guanxi, and strong community norms operate alongside evolving formal markets and regulatory frameworks (Bian, 2019; Fan, 2020; Chua et al., 2019; Gelfand et al., 2011). Analysts who ignore these features risk misattributing equilibrium outcomes to frictions that are, in fact, culturally rational responses. This review consolidates recent evidence on how market culture shapes firm strategies, investor behavior, and policy compliance, and outlines implications for theory and empirics (Nee & Opper, 2012; Fang et al., 2023).

Theoretical Framework: Institutional–Cultural Complementarities

Following North and Williamson, institutions minimize uncertainty and transaction costs. Cultural economics extends this by treating values and norms as endogenous institutions. In Chinese markets, guanxi offers relationship-based enforcement where courts or contracts are costly; Confucian hierarchies legitimate authority and shape organizational design; cultural tightness–looseness determines the strength of norm enforcement and tolerance for deviation. These channels enter economic models through preference parameters (social conformity), belief formation (trust), and constraint sets (enforcement technologies).

Methodology of the Review

We searched Scopus, Web of Science, JSTOR, SSRN, and publisher portals (Elsevier, Wiley, Taylor & Francis) for 2015–2025 English-language articles. Inclusion criteria: (1) explicit cultural or institutional variables, (2) Chinese context or Chinese firms/households, (3) measurable economic outcomes. Out of ~300 initial hits, 78 met criteria; we highlight ~30 studies on the basis of identification rigor, data richness, and theoretical contribution. Throughout, we privilege peer-reviewed sources and established scales for cultural constructs (e.g., tightness–looseness).

Literature Review and Thematic Analysis

We organize the synthesis into seven themes: guanxi and governance; Confucian legacies and organizational hierarchies; cultural tightness–looseness; institutional trust and financial participation; digital transformation and cultural adaptation; peer effects and regional norms; and state–market embeddedness. Table 1 summarizes representative empirical studies in China; Table 2 compares institutional–cultural features across China, Japan, and South Korea.

Table 1. Selected Empirical Studies on Cultural–Institutional Influences in China

Author(s) & Year	Topic	Method/Data	Main Result	Cultural Mechanism
Li et al. (2021)	Guanxi & independent directors	Firm panel; voting data	Relational norms reduce director independence	Relational obligation
Chua et al. (2019)	Tightness–looseness across provinces	Province-level scale; PNAS	Robust variation in norm enforcement	Tightness index
Leng et al. (2023)	Validate TL scales	Survey; psychometrics	Reliable measurement of TL in China	Norm strength
Lu et al. (2024)	Digital finance & participation	Household microdata	Digital products increase market entry	Lower fixed costs, social salience
Lin & Wang (2024)	Peer effects in participation	Micro + experiments	Peers amplify participation via norms	Social learning
Zhu & Zhang (2024)	Confucianism & education spend	Panel; gov. budgets	Confucian intensity → higher education outlays	Human capital emphasis
Jiang & Li (2025)	Confucianism & innovation	Firm patents/inputs	More conservative innovation profiles	Harmony/order values
Cui (2021)	Trust & participation	Household surveys	Trust ↑ risky asset holdings	Belief formation
Liang et al. (2020)	Local networks & credit	Bank–firm data	Networks ease credit constraints	Relational enforcement
Ma & Xie (2019)	Anti-corruption & culture	Policy shock	Stronger effects in tight cultures	Compliance norms

Note. TL = cultural tightness–looseness.

Guanxi and Relational Governance

Guanxi substitutes formal enforcement by embedding transactions in reciprocal ties. Evidence shows benefits—faster resource access and reduced search costs—and costs—reduced board independence and opacity. This duality aligns with institutional substitution, whereby informal governance fills gaps left by weak legal infrastructures.

Confucian Values and Organizational Hierarchies

Confucian ethics emphasize role obligations, respect for authority, and harmony. Firms with stronger Confucian imprinting exhibit longer horizons and stability, but sometimes lower radical innovation. Education-focused public investment is a macrochannel linking Confucianism to growth.

Cultural Tightness–Looseness and Compliance

Tighter provinces enforce norms more stringently, raising baseline compliance. Policy campaigns (e.g., anti-corruption, environmental enforcement) are more effective where tightness is high, while looser regions display more experimentation and entrepreneurial variance.

Institutional Trust and Financial Participation

Trust reduces perceived ambiguity in financial decisions, increasing stock market participation and the use of market-based savings vehicles. Peer networks transmit trust and know-how, magnifying regional disparities.

Digital Transformation and Cultural Adaptation

Digital platforms lower entry costs and reframe investing as a social activity. Adoption interacts with local norms: tight regions can coordinate adoption quickly; looser regions may exhibit frontier experimentation.

Peer Effects and Regional Norms

Geographic and social proximity shape expectations about risk, bubbles, and prudence. Dense networks accelerate diffusion of investment narratives and behaviors.

State–Market Embeddedness

The state remains a key institutional actor shaping norms via signaling (e.g., emphasis on dividends, disclosure). Cultural expectations about appropriate corporate behavior mediate how firms respond to these signals, producing heterogeneous outcomes across regions and sectors.

Table 2. Comparative Institutional–Cultural Features: China, Japan, South Korea

Dimension	China	Japan	South Korea	Implication for Economic Analysis
Cultural Tightness	Moderate–High; provincial variance	High; strong norm uniformity	High; strong conformity	Compliance, disclosure practices
Relational Governance	Guanxi salient in business	Keiretsu/long-term ties	Chaebol family ties	Monitoring vs. flexibility trade-offs
Hierarchy & Authority	Confucian hierarchy prominent	Seniority-based systems	Hierarchy with rapid change pressures	Innovation horizon, HR policies
Financial Participation	Rising via digital finance	Conservative household portfolios	Conservative with real estate focus	Risk appetite, policy levers
Corporate Governance	Mixed: SOEs/private, evolving	Stable boards, cross-shareholding	Family-led conglomerates	Minority protection, agency issues

Case Studies: Technology, Finance, and Local Governance

Technology: Platform ecosystems show how cultural norms of trust and community shape user acquisition and investment participation. Finance: Regional bank–firm ties reflect relational enforcement that coexists with formal prudential rules. Local Governance: Provincial tightness correlates with the intensity and durability of compliance responses to regulatory campaigns.

Critical Evaluation and Methodological Challenges

Identification remains the central challenge. Instruments based on historical exposure (temple density, examination legacy), border discontinuities, and staggered policy shocks help, but risks of measurement error and spillovers persist. Advances in text-as-data (cultural lexicons in filings), network inference from administrative data, and pre-registered field experiments can strengthen causal claims.

Research Gaps and Future Directions

Promising directions include: (i) firm-level cultural indices validated across languages; (ii) randomized information and incentive experiments in tight vs. loose regions; (iii) models integrating cultural parameters into contracting and disclosure; (iv) longitudinal studies on cultural adaptation to digitalization; and (v) comparative East Asian analyses connecting institutional paths to market behavior.

Conclusion

China's market culture acts as an institutional force that shapes incentives, beliefs, and enforcement. Recognizing culture as part of the institutional matrix improves explanatory power and policy relevance. Future work should integrate cultural parameters into mainstream economic models and measurement frameworks.

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Artificial Intelligence Integration in Accounting Curriculum: Mapping Global Trends, Competency Frameworks, Assessment, Pedagogy with Integrity and Educational Readiness

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Abstract

Systematically synthesize 2020–2025 evidence on how AI being integrated into accounting education, addressing four questions on global uptake, competencies framework, pedagogy with integrity, and readiness. Adopted PRISMA SLR across Scopus. Of 138 unique records, 40 peer-reviewed studies met inclusion criteria. Integration is accelerating yet uneven; efforts have expanded from analytics/RPA to GenAI, infrastructure, faculty development as key enablers; industry/professional partnerships help. Convergence on data analysis, ML literacy, AI-supported decision making, and ethical reasoning; assessment shifts toward authentic projects/cases; align with IFAC/AACSB expectations. Pedagogy : Blended/PBL with AI for materials, feedback, and personalization; integrity-by-design (process logs, reflections, oral defenses) mitigates misuse; scaffolding particularly benefits lower-performing students. Student PU/PEOU, faculty capability, clear policies, privacy/bias management, equitable access shape successful adoption; balanced, responsible-use policies are preferred over bans. Embed AI across curricula; upskill faculty; redesign assessment human reasoning; set fair, flexible AI policies.

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Keywords: accounting education, artificial intelligence, generative AI, data analytics, curriculum innovation, competency framework, technology adoption, academic integrity, AI literacy, higher education

Introduction

Accounting education is undergoing a paradigm shift as artificial intelligence (AI) and related technologies become pervasive in professional practice. Since 2020, AI's rapid diffusion from machine learning (ML) and robotic process automation (RPA) to generative AI (GenAI) like large language models has reshaped industry expectations of accounting graduates. No longer is it sufficient for graduates to excel only in traditional bookkeeping and financial reporting; they must also be adept in data analytics, automation, and AI applications (Ng, 2023); (Holmes & Douglass, 2022). Professional bodies and accreditation agencies have responded by updating competency frameworks to emphasize AI literacy, data handling, and ethical governance of technology. For example, the International Federation of Accountants (IFAC) and Association to Advance Collegiate Schools of Business (AACSB) now explicitly call for integration of data analytics and AI-related skills into accounting curricula (Holmes & Douglass, 2022). These changes reflect a broad consensus that the accounting profession is evolving toward a technology-centric model, and educational programs must adapt to prepare "future-ready" accountants.

In this context AI is defined as computational methods (e.g., ML, NLP, expert systems) performing human-like tasks; GenAI as models that generate novel content. AI literacy is the ability to understand, use, critically evaluate, and ethically manage AI; educational readiness is stakeholder preparedness (policies, skills, infrastructure) to integrate AI effectively; and competency frameworks are standards-aligned technical, analytical, ethical, and socio-technical learning outcomes that guide curriculum design.

This SLR (2020–2025) synthesizes empirical, conceptual, case, and review studies on AI integration in higher-education and professional accounting worldwide, focusing on curricula, pedagogy, competency development, readiness, and governance. Its aims are to (1) map global adoption trends; (2) synthesize competency frameworks and learning outcomes; (3) evaluate pedagogical and assessment approaches—including GenAI tools—for effectiveness and academic integrity; and (4) assess student, faculty, and institutional readiness and the governance mechanisms enabling sustainable adoption. By addressing these objectives, the review seeks to answer four Research Questions (RQs):

- RQ1: What global trends characterize AI integration in accounting curricula (2020–2025) across regions and institution types?
- RQ2: Which competency frameworks and learning outcomes underpin AI-integrated accounting education?
- RQ3: Which pedagogical and assessment strategies – including GenAI – are most effective in accounting education, and how is academic integrity safeguarded?
- RQ4**:** What factors shape educational readiness (among students, faculty, institutions), and what governance mechanisms enable sustainable AI integration?

By comparing cross-regional patterns and synthesizing lessons across theories and methods, the review provides an evidence-based foundation for curriculum and policy decisions that keep pace with innovation while upholding academic rigor and integrity.

Methods

This review followed a systematic approach guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Ndanu, 2025). A review protocol was defined a priori, including search strategy, inclusion criteria, and quality appraisal methods, to enhance transparency and reproducibility. We focused on literature published between 2020 and 2025 to capture the most recent developments, especially the integration of GenAI tools in education, which largely postdates 2020. Figure 1 illustrates the selection process in a PRISMA flow diagram.

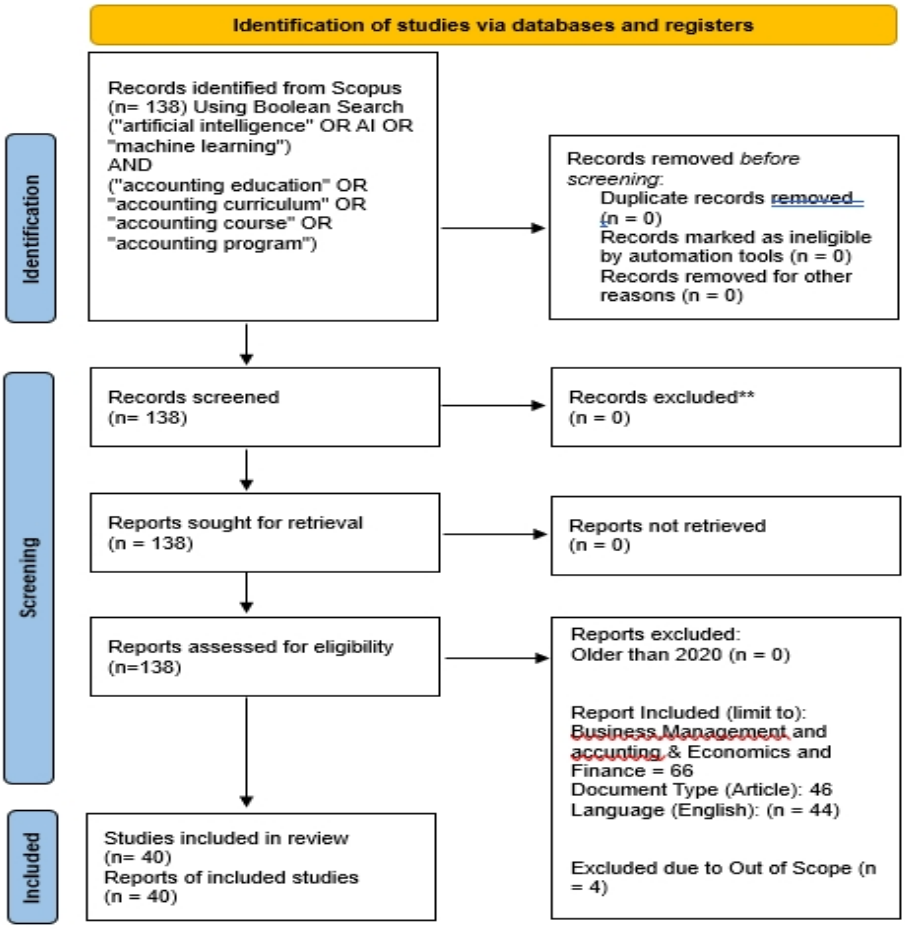

Figure 1. PRISMA 2020 flow diagram

Comprehensive searches were conducted in major scholarly databases, primarily Scopus. The search was executed using Boolean keyword strings designed to capture AI in the context of accounting education. An illustrative search string in Scopus targeted the Title/Abstract/Keywords fields:

("artificial intelligence" OR AI OR "machine learning" OR "generative AI" OR "large language model" OR RPA) AND ("accounting education" OR "accounting curriculum" OR "accounting course" OR "accounting program")*

This query, limited to 2020–2025 and English language, yielded an initial 138 records from Scopus. Duplicates were removed (no significant duplicates were found in this case), yielding 138 unique records for screening. We also applied subject-area filters (business, accounting, and education fields) during database searches to focus on relevant literature.

Screening and Selection: The selection process was conducted in four stages, following PRISMA's flow: Identification, Screening, Eligibility, and Inclusion. In the screening stage, two reviewers independently assessed titles and abstracts of the 138 records to remove obviously irrelevant items. Studies that did not explicitly connect AI or data analytics to accounting education or training were excluded at this stage. After screening, a subset of potentially relevant studies remained (in our case, 138 records passed the title/abstract screen). In the eligibility stage, full texts of these remaining studies were retrieved and reviewed against inclusion/exclusion criteria. Inclusion criteria were: (a) studies examining the use of AI (including ML, GenAI, RPA, or data analytics) in accounting curricula, courses, pedagogy, assessment, or training, (b) studies addressing development of AI-related competencies or literacy among accounting students or professionals, (c) research on readiness of educators or institutions for AI integration, or on governance issues (e.g., academic integrity policies, ethical considerations of AI in education). Both empirical research (quantitative, qualitative, or mixed-methods) and rigorous conceptual or review papers were included. We excluded papers focused purely on technical aspects of AI with no educational component, studies in K-12 or non-accounting domains, and non-systematic opinion pieces lacking evidence. After full-text review, studies that did not meet the criteria (e.g., off-topic or older than 2020) were excluded 4 records. We also applied quality filters: limiting to peer-reviewed journal articles, conference proceedings, and recognized scholarly publications. For example, of the records screened, 66 fell within relevant business or accounting education subject categories, and 46 of those were journal articles; two non-English papers were excluded, leaving 40 studies that fully met the criteria for inclusion.

Theoretical Background

Relevant Theories and Models

The intersection of AI and accounting education is often examined through the lens of technology adoption and learning theories. Prominently, the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) provide a basis for understanding how students and educators come to adopt AI tools. TAM posits that two beliefs – perceived usefulness (PU) and perceived ease of use (PEOU) – largely determine an individual's intention to use a technology. In the context of accounting education, recent studies have found these constructs to be highly relevant. For instance, surveys of accounting students show that their perception of AI's usefulness and its relevance to future jobs significantly influences their intention to learn and use AI tools (Nouraldeen, 2023); (Krishnanraw & Ismail, 2025). When students recognize that AI skills are valued in

the job market and that AI tools can enhance their learning or productivity, their behavioral intent to engage with such tools increases (Holmes & Douglass, 2022). UTAUT expands on TAM by adding factors like social influence and facilitating conditions. A study of accounting faculty in Kuwait (Alahmed, 2025) used a UTAUT-based model and found that while awareness of AI was high, actual usage in teaching was low, attributable to limited facilitating conditions and cultural factors in institutions. This suggests that beyond individual attitudes, organizational support and normative pressures (e.g. peer usage, student expectations) play a role in AI adoption in academia. Both TAM and UTAUT have thus been instrumental in framing empirical research on AI integration, helping to identify which factors (ease of use, usefulness, social norms, etc.) need to be addressed to encourage acceptance of new tools by students and educators.

From a learning theory perspective, Bloom's Revised Taxonomy and constructivist theories offer guidance on integrating AI in pedagogy. Bloom's Taxonomy categorizes cognitive skills from lower-order (remember, understand) to higher-order (analyze, evaluate, create). AI tools, especially GenAI like ChatGPT, have shown potential to assist with lower- and mid-level cognitive tasks – for example, generating explanations or examples (understanding) and aiding in problem-solving steps (application/analysis). (Tharapos et al., 2025) map GenAI capabilities to Bloom's taxonomy and find that AI is highly effective at supporting learning outcomes in the *remember-understand-apply* range, but less so for *evaluate-create* without additional scaffolding. This aligns with the idea that AI can handle procedural and knowledge-intensive tasks, freeing up educators to focus on developing students' higher-order critical thinking and judgment

Historical Development, Debates and Controversies

Integration of technology in accounting curricula has unfolded over decades, but AI's post-2020 impact marks a step-change. The 1990s–2000s introduced automation tools and enterprise software; the 2010s pivoted to data analytics/BI, with projects, statistics, and visualization to build analytical capability (Ng, 2023); (Aldredge et al., 2021). Late 2010s courses added RPA in AIS. 2020–2025 saw acceleration: reforms embedding AI/ML (sometimes blockchain) and regional "data analytics in accounting" initiatives; Middle Eastern programs partnered with industry to add analytics/AI content (Qasim et al., 2022). With ChatGPT (2022–2023), discourse expanded to GenAI, prompting assessment redesign (open-book, oral defenses) and studies benchmarking AI on accounting exams (e.g., (Wood et al., 2023)) and using AI for materials/feedback (Cheng et al., 2024). In parallel, accreditation tightened as IFAC and AACSB explicitly referenced analytics and emerging technologies curricula (Holmes & Douglass, 2022), spurring courses like "Accounting Analytics and AI" and AI infusions into auditing/financial accounting (Nusa et al., 2024), while professional exams (e.g., CPA) increased technology content.

The rapid introduction of AI, especially generative AI, into education has sparked vigorous debates and some polarization among educators and researchers. the debates around AI in

accounting education oscillate between seeing AI as a *threat* (to integrity and independent learning) and as an *ally* (for enhancing engagement and providing personalized support). One major controversy centers on academic integrity and authorship. Generative AI tools can produce human-like responses to accounting problems and even write essays, raising concerns that students might use these tools to complete assignments dishonestly. (Tharapos et al., 2025) warn that uncritical use of GenAI by students could result in superficial learning, as students might bypass the cognitive effort required to truly understand accounting concepts. There is apprehension that if students rely on AI-generated answers, they may not develop essential skills in critical thinking and problem-solving. (Moore & Felo, 2022) found that stakeholders valued analytics skills but cautioned against over-emphasizing tech at the cost of accounting fundamentals..This has led some commentators to label AI as a potential *detractor* of deep learning – an enabler of academic misconduct that could erode the quality of accounting education if left unchecked. On the other hand, proponents argue that AI can be an enhancer of learning when used appropriately: for example, AI can provide instant feedback or alternative explanations to students, functioning as a personal tutor and thereby deepening understanding (Cheng et al., 2024); (Taylor et al., 2025). (Zhou & Luo, 2025) found that accounting students are less likely to use AI for creativity tasks or to accept AI-generated outputs without questioning their accuracy, bias, or currency, especially when it comes to decision making. This duality underlies the debate: whether AI will *augment* human learning or simply *shortcut* it.

Perspectives hinge on implementation and rules: used well, AI can individualize learning—scaffolding weaker students and letting advanced learners go beyond the syllabus via AI-driven tools.. Some studies (e.g., (Cheng et al., 2024) have shown improved student engagement when AI is used to create interactive case studies or to simulate real-world scenarios, suggesting that judicious use of GenAI can indeed foster deeper engagement rather than cheating. Skeptics, however, raise the issue of dependency: if students always have AI assistance, will they develop a false sense of mastery or lose the ability to perform without it? (Alahmed, 2025) reported that faculty are concerned about a "calculator effect," where students might trust AI outputs blindly without understanding underlying principles. There are also ethical concerns: Who owns the work produced by AI? How do we attribute ideas in an essay partly written by a machine? Academic honesty policies are scrambling to catch up, with some institutions requiring disclosure of AI use, while others banning AI-generated content altogether – an indication of the unsettled nature of this debate.

Review of Findings

The findings of this study are organized into four themes. Below is a brief overview of each theme; a more detailed discussion is presented in the subsequent sections.

Table 1. Summary of Findings

Theme		Author	Key Finding	Comment
Global Trends	America	(Holmes & Douglass, 2022) USA; (Ng, 2023) USA; (Huang & Wang, 2023) USA; (Cheng et al., 2024) USA; (Blondeel et al., 2025) USA; (Carmelo Castellanos Polo et al., 2025) Colombia	AI is widely welcomed, but curricula still lag behind industry data-skill demands. Integrating RPA and AI enhances learning outcomes and automation literacy, while no-code machine learning improves students' predictive and audit understanding. Although AI excels at providing explanations, it remains weak in producing structured outputs. Notably, proficiency in tools like ChatGPT correlates with higher grades, with the most significant gains seen among lower-GPA students	Evidence is practice-based with measurable designs, accessible no-code ML, and broad instructor input, but remains perception-heavy, context-limited, and lacking long-term or policy transfer validation.
	Eropa	(Sundkvist & Kulset, 2024) Nordic; (Dosumu et al., 2025) UK;	**Adoption:** Enthusiasm, ease, and social influence drive ChatGPT use; accounting majors lag peers; trust is not decisive. **Assessment:** Even with low visible use, ChatGPT's mere availability compels redesign—shift to application/explanation tasks and tighter rubrics to protect integrity.	Strengths: Timely insights into early GenAI adoption, combining practitioner and student perspectives. Limitations: Anecdotal, small-sample data with limited generalizability; self-reported intentions may not reflect actual behavior.
	Asia	(Imjai et al., 2025) Thailand; (Ismail & Krishnanraw, 2025) Malaysia; (Tran, 2025) Vietnam;	**Synthesis:** AI literacy boosts higher-order skills; job relevance drives intention (via perceived usefulness); tech readiness helps while discomfort hinders; a strong digital culture amplifies impact. **Actions:** Link assignments to employability; teach AI literacy (prompting, evaluation, limits); provide low-stakes sandbox practice; invest in infrastructure and model tool use across courses.	Strengths: Insightful emerging-economy context, theory-based focus on AI literacy and readiness, and practical employability links. Limitations: Small, single-country samples; perception-based data with limited generalizability.
	Afrika	(Abdo-Salloum & Al-Mousawi, 2025) Lebanon; (Alahmed, 2025) kuwait; (Al-Maaitah et al., 2025) Jordan	Synthesis: Adoption hinges on tech readiness via PU/PEOU; information literacy (not generic digital literacy) best predicts uptake. Faculty awareness is high but use is low due to weak support, low confidence, and thin peer norms. Policies guard integrity yet constrain practice—seek a balanced, enabling stance. Actions: Teach information literacy & prompt evaluation; showcase concrete use-cases to lift PU/PEOU; build faculty capacity and peer communities; adopt policies that permit guided, accountable AI use.	Strengths: Clear mediators (usefulness/ease) with large student sample; rare faculty lens on barriers; strong policy–pedagogy link from big instructor sample. Limitations: Cross-sectional perceptions (not outcomes); single-country faculty context; domain-specific (sustainability) limits generalization.

Theme		Author	Key Finding	Comment
	Australia	(Tharapos et al., 2025),	Effectiveness: GenAI supports remember/understand/basic apply; it adds little to analyze/evaluate/create without strong scaffolds. Use pattern: Let GenAI draft/ideate first; students must critique, refine, and extend to reach higher-order outcomes. Design: Stage prompts, set explicit criteria, require reflection/rationale; assess both process (AI use) and product.	Strength: Offers program-level perspective—demonstrates systematic AI integration and evaluation across course levels. Limitation: Tool/version-specific (e.g., ChatGPT 2023); findings may shift as models evolve, so periodic revalidation is needed.
	Multi-Country Study/ Global	(Qasim & Kharbat, 2020); Wood et al. (2023); (Handoyo, 2024); (Brabete et al., 2024); (Indrayani et al., 2024);	Curriculum: Program-level integration of accounting + AI/blockchain/analytics aligned with industry. Research: Post-2016 pivot to tech-centric pedagogy (AIS, analytics, e-learning clusters). Implementation: Universities drive change—faculty development, staged updates, measurable outcomes. Theory: "Education transformation" with TAM central; adoption factors key; classroom/career impact evidence still thin.	Strengths: Practical curriculum model, cross-country AI–student comparison, and long-term research insights. Limitations: No empirical test; version-specific results; limited course-level and regional relevance.
Competency Framework		(Qasim & Kharbat, 2020) Global ; (Dos Santos et al., 2025) Brazil ; (Castellanos Polo et al., 2025) ; Colombia (Brabete et al., 2024) Global	Universities need to redesign accounting curricula to integrate AI, analytics, and related tech. Proposed frameworks and audits outline specific course additions and skill requirements to balance core accounting knowledge with IT/data competencies.	Curriculum reform is vital. Gradual implementation through faculty training and stakeholder input industry and regulators helps ensure programs remain aligned with technological change.
		(Holmes & Douglass, 2022) USA ; (Moore & Felo, 2022) USA; (Ballantine et al., 2024) Global; (Ardichvili, 2022) Global	Gap vs. overload: Industry needs more data/AI skills than current curricula provide, but experts caution not to over-tech at the cost of fundamentals. Critical perspectives warn of *"technical reductionism"* – focusing on tools over human judgment. All stress integrating analytics/AI while preserving ethics and core accounting skills.	Balance tech and fundamentals by updating outcomes with tech skills, ethics, and critical thinking, supported by accreditation and faculty development to bridge the industry–academia gap.
		(Imjai et al., 2024; 2025) Thailand; (Blondeel et al., 2025) USA; (Voshaar et al., 2025) Germany	Across contexts, higher AI literacy/proficiency improves outcomes: in Thailand, AI literacy boosts adaptability and critical thinking, strengthening analytical performance; in the US, ChatGPT proficiency raises grades—especially for lower-GPA students; in Germany, AI-simplified exam texts increase comprehension and modestly improve scores for lower performers.	Make AI proficiency a core competency: embed AI literacy and effective tool use (querying, verification) across the curriculum; provide extra support and practice for less tech-proficient students; and use AI to improve accessibility (e.g., simplify assignment wording) while preserving academic rigor.

Theme	Author	Key Finding	Comment
Pedagogy	(Ng, 2023) USA; (Huang & Wang, 2023) USA; (Wiseman & Foster, 2025) USA; (Marcy et al., 2025) USA	Integrating AI tools into coursework enhances learning: students gain practical automation and analytics skills, build confidence, and—through manual-vs-AI comparisons—strengthen critical thinking and error detection. Overall, hands-on GenAI/RPA activities raise learning outcomes and foster professional skepticism.	Use AI to drive higher-order thinking: let tools draft, then have students critique, verify, and refine. With clear scaffolds, AI becomes an instructional amplifier—so embed prompt engineering, result verification, and AI-output critique as explicit learning outcomes.
	(Wood et al., 2023/2025) Global; (Cheng et al., 2024) USA; (Tharapos et al., 2025) Australia; (Tenakwah et al., 2025) Global. (Dosumu et al., 2025) UK	AI handles lower-order questions well (~56–75% correct) but struggles on complex, judgment-heavy tasks; students still outperform overall. In open-book settings, unchecked AI inflates scores, signaling a need for redesigned assessments and human oversight. Use GenAI for foundational learning, with advanced work done under scaffolding and verification.	Redesign assessments for the GenAI era: shift from recall to applied, case-based, and oral tasks emphasizing reasoning and originality; require process logs and unique data; set clear AI-use policies and gradually limit AI in advanced courses to maintain rigor.
Readines	(Damerji & Salimi, 2021); (Sundkvist & Kulset, 2024) (Ismail & Krishnanraw, 2025) (Krishnanraw & Ismail, 2025) ; (Abdo-Salloum & Al-Mousawi, 2025); (Tran, 2025)	Adoption rises with perceived usefulness/ease and job relevance; tech readiness/optimism lift PU/PEOU, while anxiety suppresses use. Information literacy (search/evaluate) predicts uptake better than generic digital skills. Accounting students are more cautious unless instructor/peer encouragement normalizes AI use	Boost adoption by making AI visibly career-relevant (real cases, alumni), normalizing practice in coursework, and training tech readiness + information literacy (e.g., fact-checking). Use low-stakes sandbox activities to build confidence, and foster a supportive culture via peer learning and instructor modeling.
	(Al-Maaitah et al., 2025) Jordan; (Alahmed, 2025) Kuwait	Faculty recognize AI's teaching benefits but adoption is constrained by strict integrity policies, weak institutional support, unclear guidelines/training, unsupportive culture, and low peer usage—so even tech-aware instructors hesitate to use AI in class.	Adopt flexible AI policies, invest in faculty training and support, and foster communities of practice to encourage safe, innovative AI integration in teaching.

Global Trends & Adoption Patterns

AI adoption in accounting education has been rapid in recent years but remains uneven across different regions and institutions. Developed regions with robust technological infrastructure – such as North America, Western Europe, and parts of Asia-Pacific – have generally led the way in integrating AI and data analytics into accounting curricula. These areas benefit from greater funding, access to technology, and industry-academic collaboration, resulting in earlier curriculum reforms (e.g., adding analytics courses or AI case studies). For instance, universities in the United States and Australia report incorporating tools like AI-based auditing software or RPA exercises into coursework by the early 2020s. In contrast, many

developing countries face challenges such as limited resources, fewer trained faculty in AI, and inadequate infrastructure, which slow adoption (Qasim et al., 2022); (Holmes & Douglass, 2022). (Carmelo Castellanos Polo et al., 2025) analyzed current accounting programs in Colombia and noted a lack of dedicated technology content. In regions like parts of the Middle East, Africa, or Southeast Asia, there is often strong interest in AI but practical constraints – e.g., lack of reliable internet in some areas, or outdated computer labs – hinder implementation. Nevertheless, some emerging economies have shown significant initiative: (Tran, 2025) notes that in Vietnam, a national push for digital transformation spurred some universities to include AI and digital workplace skills in accounting programs, albeit starting from a lower base compared to Western counterparts. A common thread is that where policy mandates and industry demand align, institutions move faster. Governments and professional bodies that issue directives or incentives for tech integration create momentum that individual universities often follow.

The focus of technology content in curricula has evolved, expanding from earlier topics like data analytics and RPA to today's emphasis on GenAI and advanced AI applications. Universities are central to technology-driven curriculum redesign and notes common solutions like faculty training and incremental curriculum updates (Brabete et al., 2024). Many programs initially started by embedding data analytics modules (covering data extraction, visualization, statistical analysis) into accounting courses around 2020–2021. As shown in Table 1 (e.g., (Qasim & Kharbat, 2020); (Ng, 2023)), these efforts marked the first wave of modern curriculum redesign – ensuring students could handle big data and use tools like Tableau or Python for accounting analytics. Following this, RPA and basic AI (like predictive algorithms) found their way into coursework, especially in auditing and accounting information systems courses (Huang & Wang, 2023). By 2023, with the advent of generative AI, educators began experimenting with tools like ChatGPT for various purposes: answering student queries, generating practice questions, or even as content in case studies (Cheng et al., 2024). Thus, the trend is one of broadening scope – from focusing on *data and automation* to including *intelligent systems and machine-assisted decision-making*. This expansion raises curricular questions: Should AI be a standalone course or integrated throughout the curriculum? How to update syllabi continuously given the fast pace of tech changes? Bibliometric analyses (Handoyo, 2024); (Indrayani et al., 2024) confirm a spike in education research on AI/analytics in accounting post-2020, indicating that the academic community's attention is clustering around these innovations. Interestingly, some gaps are also noted: for example, ethics-by-design (how to embed ethics into tech training) appears less frequently in the early wave of publications, suggesting an area that might need more focus as integration deepens.

Collaboration between academia and industry/professional bodies is a key driver of global adoption patterns**.** We see numerous instances of universities partnering with accounting firms, software companies, or accounting associations to facilitate AI integration. Professional bodies in various countries have provided resources or frameworks – such as the

AICPA's initiative on data analytics in the USA, or IFAC's guidance on accounting education and technology globally. These collaborations often ensure that curricula stay relevant to practice. For example, (Qasim & Kharbat, 2020) documented a partnership where an international firm helped design a module on AI in auditing for a university, ensuring students learned tools actually used in practice. Likewise, professional certifications (like CPA, CA, or ACCA) increasingly include technology components, indirectly pressuring university programs worldwide to include similar content to prepare their students (Krishnanraw & Ismail, 2025) (Nusa et al., 2024)). This convergence of academic and professional standards is especially evident in regions where regulatory bodies mandate curricular content (some countries require accredited programs to demonstrate coverage of certain emerging topics). The review finds that where such external drivers exist, AI adoption in curriculum is more systematic and widespread. Conversely, in environments lacking these drivers, adoption can be ad-hoc – perhaps initiated by a few enthusiastic faculty members rather than as an institution-wide strategy.

Infrastructure and faculty development emerge as critical bottlenecks in adoption. Having modern computer labs, software licenses, and reliable internet is a prerequisite for integrating AI tools into teaching. Not all institutions have these readily available, especially under budget constraints. Several studies (Al-Maaitah et al., 2025); (Alahmed, 2025) emphasize that even where the will to adopt exists, inadequate infrastructure or institutional support can stall progress. More nuanced is the issue of faculty readiness: many accounting professors were trained years ago with little exposure to AI or programming. Expecting them to teach AI-related content requires significant upskilling. (Holmes & Douglass, 2022) note a gap between professional needs and what educators emphasize, partly because educators themselves may not be comfortable with AI technologies. In the global context, some regions have addressed this by hiring adjunct instructors or "professors of practice" with industry tech experience, or by running faculty development workshops (as suggested by (Holmes & Douglass, 2022). Others, unfortunately, lag due to faculty resistance or lack of training opportunities. The importance of faculty buy-in is evident: (Sundkvist & Kulset, 2024) found that even student interest in using tools like ChatGPT can be dampened if their instructors discourage or do not support such tools, pointing to the social influence factor in technology uptake in education.

Competency Frameworks & Learning Outcomes

With AI technologies making inroads into accounting tasks, educators and professional bodies have been actively redefining the competencies and learning outcomes expected of accounting graduates. A clear consensus in the literature is that programs must move beyond teaching narrow procedural skills towards cultivating integrated competencies that combine accounting knowledge with data-savvy and AI-related skills.

Core AI-related competencies for accounting graduates identified in recent studies include: data analytics proficiency, ML basics, RPA skills, and AI-assisted decision-making

abilities**.** For instance, multiple sources ((Qasim et al., 2022); (Nusa et al., 2024)) highlight skills such as data management and cleansing, statistical analysis, and interpreting outputs from AI systems as essential. Accounting students are now expected not just to use Excel but to handle large datasets, possibly using Python/R or specialized audit analytics software, to uncover insights. Machine learning competencies can range from understanding how predictive models work (conceptually, without heavy math) to actually training a simple model on financial data. (Huang & Wang, 2023) showed that even without coding, auditing students can learn to use ML tools for tasks like risk assessment, thereby boosting their *predictive reasoning literacy*. Robotic process automation (RPA) is another practical skill students learn to automate routine processes (e.g. invoice processing, reconciliations) which fosters an understanding of how bots can increase efficiency and where human judgment is still needed. Underlying all these is AI literacy, which encompasses not just technical know-how but the ability to critically question AI outputs and consider their implications (bias, errors, etc.). The integration of these technical skills with traditional accounting is often framed as producing a "hybrid professional" who is both accountant and analyst. Competency frameworks documented in various countries (e.g., the UK's ACA syllabus updates, or Australia's CAANZ revisions) reflect this hybridization, mandating evidence of data and tech competencies.

Learning outcomes related to AI and data literacy are increasingly being embedded and assessed through innovative methods. Educators are designing project-based assessments and capstone projects where students must apply AI tools to real-world accounting problems. For example, a course might require students to use a data analytics tool on an audit case and present findings, thereby assessing their ability to derive insights from AI (analysis and evaluation outcomes). In academic studies, (Tharapos et al., 2025) utilized Bloom's Revised Taxonomy (RBT) to categorize learning outcomes and found that many AI-related assignments hit the middle layers of cognition (apply/analyze) but can be extended to higher layers if combined with reflection or explanation components. One approach to assessing higher-order outcomes is to have students interpret or critique AI outputs – for instance, if an AI model makes an accounting prediction, students might be asked to verify it and discuss its reasonableness. Such tasks enforce understanding, not just tool operation. (Wood et al., 2023)and others also suggest that generative AI can be used to generate multiple solution approaches or viewpoints, which students then compare and evaluate, thus testing their critical thinking and understanding of underlying principles. Additionally, instructors are aligning assessments with industry standards. (Krishnanraw & Ismail, 2025) note that assignments which students perceive as closely related to job skills (like using an AI-based audit software similar to what firms use) tend to have better engagement and learning outcomes because students see the relevance (this ties to the "job relevance" mediating effect discussed earlier). Overall, assessment of AI literacy is moving towards *authentic assessments* – tasks that mirror real-world tasks – and often includes components of

reflection to ensure students aren't just pushing buttons but actually comprehending and internalizing the knowledge.

Several frameworks have been proposed to link AI integration with broader educational goals like employability, ethics, and critical thinking. One example is the PSAIS framework (Professional Skills in Accounting Information Systems**)** proposed by (Dos Santos et al., 2025) for Brazilian accounting education. This framework delineates skills categories (like technical, analytical, ethical, etc.) and explicitly includes AI, big data, and statistical skills as part of the professional skillset. It underscores that to be considered competent, a graduating accountant should have not only domain knowledge but also data analysis, IT control, and ethical reasoning in tech use. Many authors stress ethical competency as equally important – knowing how to use AI responsibly. This includes understanding issues of data privacy, algorithmic bias, and the social impact of AI on decision-making. (Ballantine et al., 2024), adopting a critical perspective, argue that accounting education should *transcend technical reductionism* – meaning it's not enough to teach the tools; programs must also instill the ability to question and contextualize AI outcomes ethically and strategically. They advocate centering human judgment and ethics even as we teach tech, so that graduates can serve as conscientious "gatekeepers" of AI in practice (ensuring AI outputs are fair, accurate, and used appropriately). This viewpoint is reflected in calls to incorporate AI ethics modules or discussions in class whenever AI tools are taught, essentially integrating ethics across the curriculum rather than as an isolated topic.

Another common framework element is critical thinking and problem-solving. Many sources link AI integration with the need to bolster these higher-order skills. The rationale is twofold: (1) AI can automate routine tasks, so human accountants will increasingly focus on complex problem-solving; (2) AI provides information, but humans must interpret and act on it, which requires critical thinking. Some studies ((Imjai et al., 2025); (Meesook et al., 2025) present models where AI literacy improves students' diagnostic and prognostic abilities, which are facets of critical thinking in accounting contexts (like analyzing why a variance occurred or forecasting financial risks). They empirically show that teaching AI can, perhaps counterintuitively, improve non-technical skills by forcing students to engage in interpretation and reasoning about AI outputs. This evidence supports curricular approaches that treat AI tools as means to an end: the end being sharper analytical and evaluative skills in students.

Alignment with accreditation standards and curriculum guidelines is a driving force for competency development. Bodies such as IFAC and AACSB, as mentioned, emphasize technology competence and have begun to expect evidence of it in program assessments (assurance of learning). For example, AACSB's standards might require business schools to demonstrate that students "can analyze data and leverage technology in decision-making." Accounting programs respond by defining specific learning outcomes like "students will be able to use data analysis software to identify trends in financial data" or "students will evaluate the outputs of an AI tool for a given accounting scenario, considering accuracy and

ethics." These outcomes are then measured via course-embedded assignments or exit exams. (Al-Maaitah et al., 2025)) note that ethical reasoning in use of AI is now considered a competency – accreditation reviews increasingly ask how programs cover ethics related to emerging tech. For instance, an outcome might be "apply ethical frameworks to scenarios involving AI in accounting" and could be assessed by case studies on dilemmas like AI-generated financial reports. This reflects a holistic view of competencies: not just technical proficiency but the ability to integrate technical skills with professional values and judgment.

Pedagogy & Assessment with GenAI

The advent of GenAI tools (like ChatGPT and similar large language models) in the last few years has catalyzed both innovative teaching practices and urgent rethinking of assessment strategies in accounting education. This theme examines how educators are leveraging AI to enhance learning, and conversely, how they are adapting assessments to maintain academic standards in the presence of AI.

Innovative instructional strategies incorporating AI have emerged, emphasizing experiential, blended, and problem-based learning approaches. Educators are finding that AI tools can enrich *experiential learning* by simulating real-world accounting scenarios. For example, in cost accounting courses, instructors have introduced assignments where students interact with an AI as if it were a client or colleague – the AI provides data or analysis and the student must interpret or correct it (Wiseman & Foster, 2025). (Marcy et al., 2025) Students used an LLM to analyze an audit inspection report and draft a memo, then they had to critique the AI's memo and relate findings to auditing standards This mimics workplace situations and engages students actively in diagnosing and solving problems. Blended learning models, which combine traditional face-to-face instruction with digital tools, naturally extend to using AI: outside of class, students might use an AI tutor for practice problems or concept review at their own pace, then in class, discuss or deepen those learnings. (Nouraldeen, 2023) notes that such hybrid models can increase student autonomy and cater to different learning speeds. Problem-based learning (PBL) is another strategy well-suited to AI integration. In a PBL setting, students are given complex, open-ended problems (e.g., "Recommend an internal control improvement using an AI tool in an accounting information system") and must work through them, often in teams. AI can assist by providing hints, offering data sets, or generating multiple solution paths that students can evaluate. (Tharapos et al., 2025) implemented GenAI in case studies and found that it can help generate scenario variations or role-play different stakeholders, adding depth to problem-based exercises. These approaches all require the instructor to shift from being the sole source of knowledge to being a facilitator and guide, as AI takes on a supportive role in delivering content or feedback.

Generative AI is being used creatively in designing and grading assessments, though its presence mandates new measures to uphold integrity. On one hand, GenAI enables dynamic assessment design: instructors can quickly generate new variations of accounting problems, case facts, or data sets by prompting AI, thus reducing repetition and potential for cheating

via question banks. It also allows for more frequent low-stakes quizzes or practice exercises, since marking can be assisted by AI (especially for objective questions or draft evaluations). For example, (Voshaar et al., 2025) explored using ChatGPT to simplify complex exam text or to provide hints, which in turn improved student comprehension of questions. On the grading side, tools have been tested where AI provides preliminary grading or feedback on written assignments, highlighting areas for instructor review (Wood et al., 2023)) even suggests AI could flag likely AI-generated content by analyzing style, although this is an evolving area. The immediate benefit seen is that AI can offer instant feedback to students – something highly valued for learning. Instead of waiting for an instructor, a student can get a quick appraisal from an AI on whether their solution approach is on track (Cheng et al., 2024) used ChatGPT in this way to give students feedback on case analysis structure). However, this same capability raises the question: if AI can give answers or feedback, how do we ensure the work is the student's own and that learning is genuine?

This leads to the challenge of ensuring academic integrity and proper authorship in AI-assisted assessments. Traditional take-home assignments or unsupervised exams are now problematic because a student could potentially generate entire solutions via AI. Educators are implementing several strategies to counter this: one is assessment redesign towards more authentic tasks that are harder for AI to handle, such as oral exams, presentations, or vivas where students must explain their reasoning. Another is requiring process artifacts – for example, students might need to submit outlines, drafts, or even their interactions (prompts and responses) with AI as part of the assignment. By inspecting these, instructors can gauge the student's thought process and detect if they simply accepted an AI answer without understanding. Some courses now have a rule that if AI is used, it must be disclosed and the student should reflect on how they used it – turning potential misconduct into a learning opportunity and normalizing transparency (similar to citing sources). (Tharapos et al., 2025) advocate for "integrity-by-design" in assessments, which includes measures like these as well as using plagiarism or AI-output detectors, setting individualized tasks, or doing in-class components that an AI can't assist with. A study by (Tenakwah et al., 2025) (an interdisciplinary analysis including accounting tasks) noted that while AI could answer many questions, it often lacked the ability to show reasoning steps or context-specific nuances. Therefore, assessments that require showing work, justification, or application to a specific context (e.g., a case unique to the class) remain more robust against AI "cheating."

The impact of AI tools on student engagement, learning outcomes, and academic honesty is a mixed but emerging picture. On the positive side, several studies report increased engagement when AI is incorporated. (Al-Maaitah et al., 2025) found that students were more motivated and participated more when AI tools were used to personalize learning materials or provide diverse examples. ChatGPT's ability to rephrase or clarify complex accounting topics in simpler terms, for instance, can reduce student frustration and improve confidence (Voshaar et al., 2025) observed reduced student frustration when difficult exam texts were simplified by AI, leading to better perceived comprehension). Moreover, AI can serve as

a sparring partner for students, making practice more game-like – some students enjoy trying to "beat" the AI or find where it's wrong, which in turn deepens their own learning.

In terms of learning outcomes, early evidence suggests AI is a double-edged sword. It can improve outcomes for some domains and skills, while possibly hindering others if misused. For instance, Ardichvili (2022) raises the concern that over-reliance on automation might impede the development of experiential knowledge – you learn less by doing if the AI does it for you. However, when used in moderation, AI can strengthen understanding: (Wood et al., 2023)showed that students who had access to AI (with proper guidance) did not have worse exam performance; in fact, in some cases they learned to approach questions more systematically by seeing AI's approach versus theirs. A crucial outcome that multiple studies emphasize is learning *how to learn* with AI – a meta-skill. This means students understanding when to consult AI, how to formulate effective queries, and how to critically evaluate the responses. Those who develop this meta-skill see improved outcomes (e.g., (Blondeel et al., 2025) noted better course performance among students who mastered effective AI use).

Regarding academic honesty, the presence of AI undeniably introduces temptation for easy answers(Khan & Gupta, 2025) caution that without a strong ethical culture, AI tools can foster shortcuts (for example, copy-pasting answers). Instances of students submitting AI-generated work have been reported anecdotally, although systematic study is just beginning. Some institutions responded with outright bans on AI use, but this is increasingly seen as impractical and perhaps even undesirable educationally. Instead, cultivating an academic integrity culture is key: explaining to students the value of doing their own thinking and the risks of blindly trusting AI (which can produce incorrect or nonsensical answers) – essentially treating misuse of AI like any other form of cheating with some distinct nuances. Many syllabi now include specific AI usage policies. Early data (Dosumu et al., 2025) suggests that when openly discussed, most students actually used AI less than feared, and those who did often used it for minor assistance rather than wholesale cheating. This might imply that transparency and dialogue about AI's role can mitigate academic dishonesty, combined with the assessment strategies mentioned earlier.

Educational Readiness, Governance & Ethics

The successful integration of AI into accounting education hinges not only on technology and pedagogy, but also on the readiness of stakeholders (students, faculty, institutions) and the governance frameworks that guide ethical and effective use. This theme explores these human and institutional factors, highlighting what enables or hinders sustainable adoption of AI in the curriculum. (Damerji & Salimi, 2021) Found that students' technology readiness influences AI adoption via perceived usefulness and ease of use. Tech-savvy students felt AI tools were useful and easy, leading to higher intent to use them in learning.

Student and faculty readiness are pivotal factors that mediate AI adoption in education. Student readiness refers to students' aptitude and willingness to engage with new

technologies in their learning. Studies often operationalize this via the concept of technology readiness – encompassing traits like optimism (positive view of tech), innovativeness (tendency to try new tech), and discomfort or insecurity with tech. Research in multiple contexts (e.g., (Abdo-Salloum & Al-Mousawi, 2025) in Lebanon; (Krishnanraw & Ismail, 2025) in Malaysia) consistently finds that students scoring high on optimism and innovativeness are more likely to embrace AI tools, especially when they perceive them as useful and easy to use. A key insight is that perceived usefulness and ease of use (the TAM factors) often mediate the effect of raw tech readiness on actual adoption. So even a tech-confident student won't use an AI study tool if they think it doesn't help their learning or is too cumbersome, whereas even a less tech-savvy student might try it if convinced it's beneficial and straightforward. (Ismail & Krishnanraw, 2025) Confirmed that when students perceive AI skills as relevant to their future jobs, they find AI tools more useful and are more inclined to engage with them. Job relevance had a strong indirect effect on intention via perceived usefulness. This suggests that part of readiness is also about mindset and understanding the value of AI in learning. Importantly, studies indicate that information literacy – the ability to find, evaluate, and use information – is a more significant predictor of productive AI use than general digital gadget skills. This makes sense: a student who knows how to research and cross-verify information can better leverage AI (for example, by using AI to gather initial info then validating it), whereas someone who only knows how to operate devices might not automatically know how to use AI critically.

Faculty readiness is equally, if not more, critical. Many faculty members in accounting were trained in eras before AI was prevalent, and thus integrating AI requires them to step outside their comfort zone. (Alahmed, 2025) showed that in a context with high awareness (faculty knew about AI and even its potential), actual usage in teaching remained low due to lack of experience and institutional support. Faculty need not only technical training but also pedagogical training on how to effectively incorporate AI – for instance, designing assignments that involve AI or developing new assessment rubrics. Some faculty members may be resistant, fearing that AI undermines their expertise or threatens academic integrity. Others might be willing but unsure how to start. The literature suggests that faculty development programs, workshops, and incentives can significantly improve instructor readiness. For example, at universities where centers for teaching offered AI-in-education workshops, early adopter faculty emerged and piloted changes (Nusa et al., 2024) document such initiatives in Indonesia, where train-the-trainer models helped spread AI teaching competencies). Additionally, a supportive community – faculty sharing experiences, administration recognizing innovative teaching – can boost confidence and uptake.

Institutional readiness involves having the necessary infrastructure, policies, and culture to support AI integration. Infrastructure is the backbone: without adequate computer labs, software licenses, or internet bandwidth, AI integration stalls. Many developing institutions struggle here – something as basic as not all students having laptops can derail plans to use certain AI tools. Some studies ((Tran, 2025); (Mohammed & Wahhab, 2024) indirectly

highlight that schools with modern IT infrastructure and access to latest software have students with more positive outcomes or adoption rates. Moreover, technical support – having IT staff or learning technologists who can assist with new tools – is a part of readiness. If a professor wants to use a new AI platform but there's no one to manage accounts or troubleshoot, they might give up.

Institutional policy and culture shape responsible AI use. Clear governance—through explicit AI policies, disclosure rules, and ethical guidelines—builds confidence and prevents misuse. Updated honor codes now treat uncredited AI use as misconduct, while supportive measures like vetted AI tools and ethical-use resources encourage safe, constructive adoption.

A notable finding is that overly strict or unclear policies can constrain adoption (Al-Maaitah et al., 2025). Instructors might avoid using AI at all if they fear any student use could be cheating under a zero-tolerance stance. Conversely, a laissez-faire approach might lead to abuse and subsequent backlash. Thus, a balance is needed – a governance framework that stresses transparency, responsible use, and integrity, rather than outright prohibition or total freedom. One concept gaining traction is "adaptive integrity frameworks", which could include measures like requiring students to do an oral defense for any assignment with AI usage above a threshold, or using AI output detectors as part of (but not the sole) evidence in academic honesty investigations.

Resource equity and accessibility are ethical and readiness issues as well. Not all students have equal access to AI tools – some may not own powerful devices, or paid tools may be out of reach. If AI becomes integral to learning, institutions have a duty to ensure equitable access (e.g., providing lab access or licenses). Otherwise, we risk creating a divide where only those who can afford personal AI subscriptions or devices fully benefit. Some papers (Handoyo, 2024) noted mental wellbeing; (Khan & Gupta, 2025)in a different context noted educational quality moderating outcomes) hint at these disparities and their consequences. Institutions should monitor whether AI integration is benefiting all or only a subset of students, and adjust support accordingly.

Governance also covers mitigating bias and ensuring fairness in AI usage. If AI tools are used to grade or to provide content, we must ensure they don't inadvertently introduce bias (e.g., an AI translating a case might add a bias, or an AI tutoring system might favor certain learning styles). Accountability mechanisms – like teachers reviewing AI-provided grades or content – are recommended. Additionally, if AI is used to generate content for students (cases, questions), ensuring that content is accurate and does not violate any copyrights or privacy is an institutional responsibility.

Cultural and contextual factors influence perceptions of AI ethics in education**.** For example, in more collectivist cultures, there might be a strong emphasis on not gaining unfair advantage, so students might be more cautious or guilt-ridden about using AI unless it's clearly allowed ((Tharapos et al., 2025)discuss how cultural values can shape attitudes). In contrast, in more individualistic or tech-positive cultures, students might adopt new tools

readily and consider restrictions as stifling innovation. Local regulations also play a role: data protection laws (like GDPR in Europe) may restrict what tools can be used if they send student data to third-party servers, etc. Thus, governance frameworks need to be culturally sensitive and legally compliant, not just technologically sound.

Discussion

AI integration in accounting education follows maturity stages: institutions move from basic awareness, to exploratory pilots in isolated courses, and then to deeper program-level transformation. Early stages center on defining essential AI competencies and overcoming foundational constraints—especially limited faculty expertise and resources.Research from around 2020–2021 indicates a widespread *recognition* among educators of the importance of AI and big data concepts, evidenced by pilot courses and workshops being introduced (Nusa et al., 2024). An initial, often piecemeal commitment to curriculum updates evolves into a mid-stage where institutions build more robust instructional strategies and diffuse AI content across the program. (Ng, 2023) Mid-stage integration brings coordinated curriculum changes (e.g., required analytics, program-wide tech competencies) and AI-enhanced assessment/learning. At the advanced stage, GenAI is embedded across courses with system-level policies; assessments incorporate GenAI in controlled ways to emphasize reasoning/process and strengthen academic integrity. (Tharapos et al., 2025)) At maturity, GenAI is creatively embedded in assignments while integrity is safeguarded through redesigned, scaffolded assessments. Overall, AI integration is a continuous evolution—from adoption to transformation—across pedagogy, curriculum, and policy, not a one-off tweak..

In examining the methodologies of studies in this domain, common strengths and limitations emerge. Many studies employ mixed-methods approaches, combining surveys, case studies, and experiments, which is a strength as it provides both quantitative scale and qualitative depth (Khan & Gupta, 2025) is one such mixed analysis). The mixed evidence base adds value by spanning diverse contexts and outcomes: quantitative studies link AI use to performance, while qualitative work explains mechanisms (e.g., engagement or confusion). A further strength is its pragmatic focus—many studies propose implementable interventions (curricula, assignments), enhancing relevance for practitioners..

However, limitations are notable. Generalizability is a challenge due to varied sample sizes and specific contexts. For instance, several studies are single-institution case studies or conducted in one country's education system, making it risky to generalize findings globally (Krishnanraw & Ismail, 2025) examined four universities in one country; Awwad et al., 2024 might focus on a specific region). What works in a U.S. graduate class might not directly translate to an undergraduate class in Asia or Africa with different student backgrounds and resources. Also, many studies rely on self-reported data (student or faculty surveys about perceptions), which can introduce biases – optimism bias, social desirability, etc., potentially inflating positive perceptions of AI or glossing over problems.

A consistent limitation across the field is dealing with the ethical implications of AI use. While most studies acknowledge integrity issues, not all delve deeply into them, and those that do sometimes provide limited evidence on effectiveness of solutions. For example, some studies propose using honor codes or AI detectors, but few have robust data on how well these mitigate cheating or misuse (Cheng et al., 2024) discuss concerns but don't measure actual cheating incidents; (Voshaar et al., 2025) provide insights on comprehension but not integrity directly). Additionally, potential bias in AI outputs (e.g., if an AI model has inaccuracies or cultural biases) is often mentioned as a concern but rarely systematically evaluated in accounting education research – representing a gap in methodological thoroughness.

As the field evolves, refining methodologies will be crucial. Future research should strive for more longitudinal designs (tracking cohorts over time) and multi-site studies to enhance generalizability. Including direct measures of learning (like performance on standardized tests, or analysis of student work quality) rather than just self-perception would strengthen conclusions about AI's impact. Also, given AI's dynamic nature, researchers must continuously adapt – a study done with 2022's AI tools might need replication with 2024's more advanced tools for the results to remain valid.

Findings across the four themes show both alignment and contrast. Most studies agree that AI is reshaping essential competencies and that accounting education must adapt. There is strong consensus on prioritizing ethics and integrity, as well as on TAM/UTAUT factors—highlighting that technology adoption depends as much on human perceptions of usefulness and ease as on the technology itself.

Divergences arise in how to implement integration and the pace or degree of optimism. Some works paint a very optimistic picture – suggesting AI can greatly enhance learning outcomes and engagement (e.g., authors demonstrating improved grades or excitement in classes that used AI). Others are more cautious or even critical – pointing out potential downsides, such as superficial learning or the de-skilling risk (Ardichvili, 2022); (Ballantine et al., 2024). Differences in findings reflect time and context. Optimistic studies focus on short-term classroom gains, while critical ones highlight long-term risks to independent thinking. Regional gaps also matter—tech-advanced universities downplay challenges that less-resourced institutions still face.

Outcome divergences largely reflect implementation and context. When AI is scaffolded and integrated to complement teaching, gains appear; when it's merely available without guidance, use skews—high achievers extend learning while lower achievers shortcut work—yielding neutral or negative effects. Subject matter also matters: AI is more effective for writing/explanation tasks and less reliable for precise quantitative problem-solving, mirroring its strength in theory and weakness in complex calculations. Differences in assessment design, student agency, and course norms further modulate results..

Reaffirm TAM/UTAUT with edu-specific extensions (job relevance, anxiety, AI literacy, expectancy–value, self-efficacy). Cognitively, AI lifts lower/mid levels; higher-order needs scaffolding (ZPD). Ethics: extend Kohlberg/Rest for machine-mediated agency. Steps: audit staged AI curriculum, upskill faculty, bring practitioners, and co-teach with IS/data science..

For instructors, a practical takeaway is to start small but start somewhere: for example, incorporate a single AI-based assignment or demonstration in a course, monitor how it goes, and iterate. The review provides many ideas (like using ChatGPT to illustrate internal control weaknesses, or to generate multiple choice distractors) that can be tried with relatively low risk. Another implication is to communicate with students about AI – set norms, encourage questions about usage, perhaps involve students in co-creating guidelines (which could improve buy-in and ethical understanding).

nstitutions should revise academic integrity, IT use, and privacy policies to reflect AI realities. They can offer vetted AI tools—such as internal chatbots trained on accounting materials or privacy-compliant AI services—to promote safe, guided use. Accrediting bodies should reinforce requirements for AI and tech competencies, ensuring learning outcomes show students are taught to use AI ethically and effectively..

Future research should prioritize longitudinal cohort studies that track AI-integrated curricula's effects on workplace performance and professional exams, and cross-cultural comparisons to separate universal drivers from context-specific factors (e.g., governance, exam stakes, integrity norms). Comparative, mixed-methods designs (e.g., U.S. vs. China) can reveal how policy environments and cultural attitudes shape student/faculty adoption and learning. Standardized outcome measures and quasi-experimental evaluations will strengthen causal claims and scalability.

Future research should also explore emerging AI technologies beyond text-based GenAI. For instance, AI-driven simulation environments or AI that can analyze students' problem-solving process (learning analytics) – these weren't a focus in the current review but are on the horizon and could profoundly impact learning. Investigating their efficacy and any new ethical issues they bring (like learner surveillance concerns) will be important.

Furthermore, research can delve into faculty-focused studies: what interventions truly help accounting educators learn and adopt AI? Are there personality or background factors (like age, prior industry experience) that predict which faculty will champion AI integration? Understanding this can help target faculty development efforts.

Finally, a broad area for future inquiry is the evaluation of AI-integrated pedagogy's efficacy on higher-order learning outcomes. It remains somewhat contested whether AI usage improves critical thinking or if it might hamper it by making things too easy. Controlled experiments where one group of students uses AI under structured conditions and another does not, with measurement of critical thinking growth over a semester, could provide stronger causal evidence to guide pedagogy.

Conclusion

This review underscores that the integration of Artificial Intelligence (AI) into accounting education is both inevitable and globally accelerating. Across regions, curricula are being reshaped to embed AI, data analytics, and automation skills in response to evolving industry expectations. The evidence reveals that tools such as RPA, no-code machine learning, and Generative AI can enhance automation literacy and analytical capability when appropriately scaffolded, while also raising new challenges for assessment integrity and independent thinking. Adoption is primarily driven by perceived usefulness, ease of use, and job relevance, confirming that human attitudes remain central within the TAM and UTAUT frameworks. Institutions must therefore advance beyond restrictive policies toward flexible, enabling governance that encourages ethical, transparent, and innovative AI use. Future research should empirically validate proposed models across diverse cultural and economic contexts, track longitudinal impacts, and examine how global trends in AI adoption shape both learning and employability outcomes. Ultimately, sustainable integration of AI in accounting education will depend on balancing technological competence with ethics, critical reasoning, and the enduring principles of professional judgment.

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Linking Digital Employee Experience to Performance: The Mediating Role of User Engagement in e-HRM Systems

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Abstract

This study analyzes the influence of Digital Employee Experience (DEX) on Employee Performance (PRF) through User Engagement (UE) as a mediator. This study was conducted on ASN of the West Java Provincial Government and obtained 420 respondents in data collection which were then analyzed using a quantitative approach and PLS-SEM analysis. The results show that DEX has a significant effect on UE ($\beta = 0.857$, $p < 0.001$) and PRF ($\beta = 0.886$, $p < 0.001$). UE partially mediates the relationship between DEX and PRF, indicating that employe engagement strengthens the influence of digital experience on performance. This model explains 78.4% of the performance variance, indicating high predictive power. This study emphasizes the importance of a human-centered digitalization approach to improve public sector performance.

Keywords: Digital Employee Experience, e-HRM, Employee Performance, Public Sector, User Engagement.

Introduction

The digital transformation trend has a positive impact on administrative governance in government agencies. Human resource management exemplifies this trend, digitizing previously manual business processes through digital applications, with the purpose of increasing efficiency and effectiveness. In Indonesia, the West Java Provincial Government developed the SIAP Jabar program for the purpose of HRM digitalization. The government develops various information systems to change manual administration into a digital system. There are some information systems that are used by all civil servants (ASN), including KMOB for attendance recording, TRK for performance evaluation, and Peer Review for performance appraisal by colleagues. This initiative significantly improves bureaucratic efficiency, accountability, and transparency. How the system works and how it engages with users will affect digital transformation to achieve its purpose. User engagement with the technology itself can determine the success of digital transformation.

This study utilizes a Digital Employee Experience (DEX) perspective, which encompasses employee perceptions of ease of use, digital collaboration, learning, technology support, and the organization's digital work culture. Studies have demonstrated that a positive DEX can boost motivation, alleviate techno-distress, and improve work efficiency (Tarafdar et al., 2019; Moganadas & Goh, 2022). However, few empirical studies have examined the effect of DEX on employee performance, particularly in government institutions. Civil servants in government institutions have quite diverse backgrounds and have varying levels of technology acceptance. These factors impact user interaction and engagement with the system itself.

Furthermore, the mechanisms explaining the relationship between DEX and employee performance remain poorly understood. This study proposes User Engagement (UE) as a mediating variable that bridges the relationship between employee digital experience and employee performance. This study aims to (1) analyze the direct effect of DEX on UE and employee performance, and (2) examine the mediating role of UE in the relationship between DEX and civil servant performance in the West Java Provincial Government.

By analyzing ASN users of the KMOB, TRK, and Peer Review apps, this research seeks to offer solutions to the following questions:

- Does Digital Employee Experience have a direct and positive impact on User Engagement?
- Does User Engagement have a direct and positive impact on Employee Performance?
- What is the contribution of User Engagement as mediators between DEX and Employee Performance?

The findings of this study will provide both theoretical contributions through integration of key concepts in the digital and organizational behaviour literatures, and practical recommendations for the West Java Provincial Government to develop digital transformation strategies emphasizing human factors for sustainable public services performance improvement.

Literature Review

Digital Employee Experience

Employee experience (EX) is associated with higher levels of employee satisfaction and engagement, which in turn support organizational performance and long-term sustainability. EX can be defined as employees' holistic perception of their relationship with the employing organization, formed across touchpoints throughout the employee journey (Plaskoff, 2017). It encompasses the full range of interactions, perceptions, and emotions employees encounter while working within the organization.

Within this context, the ongoing digitalization of human resource management (HRM) has become a major driver of EX. The adoption of technologies such as Human Resource Information Systems (HRIS), Artificial Intelligence (AI) in recruitment, and digital learning platforms enables companies to provide a more flexible and efficient work experience for employees (Munde, 2023). Consequently, attention must shift from deploying tools to understanding the cumulative employee perceptions that shape the Digital Employee Experience (DEX)

The DEX is the result of a comprehensive and holistic employee's perceptions in the digital workplace, resulting from the sum of the employee's direct and indirect interactions with his/her career, other employees, managers, customers, strategy, systems, culture, brand, organization, competitors, and is also influenced by his/her personal characteristics. (Moganadas & Goh, 2022). Organizations should rethink their digital employee experience (DEX) to meet the needs of younger workers, boost employee engagement and productivity, deliver a successful digital transformation and customer experience, and attract and retain the best talent (to drive innovation and deliver better customer experience).

Moganadas and Goh (2022) describe Digital Employee Experience (DEX) as the ways that employees use workplace technology that have a big impact on their motivation, engagement, and productivity. In creating a good change, we need to create supported technology that is easy to use, make sure that information is easy to find, and make sure that digital platforms that help people work together and adapt to new situations function well. Organizations need to develop digitalization plans that focus on improving operational efficiency and enhancing the quality of the experience. This will create an innovative, adaptive, and growth-oriented work environment.

User Engagement

User engagement represents a multidimensional construct reflecting users' cognitive, emotional, and behavioral involvement when interacting with digital systems. It goes beyond mere system use to capture the depth of attention, enjoyment, and value that users derive from their digital experience. O'Brien and Toms (2010) define user engagement as a process characterized by perceived usability, aesthetics, novelty, felt involvement, focused attention, and endurability dimensions that jointly explain how users experience immersion, motivation, and sustained interaction within digital platforms.

In subsequent studies, Barker et al. (2015) emphasized the evaluative and outcome-oriented dimensions of engagement, framing it as a combination of satisfaction, incidental knowledge gain, focused knowledge gain, and affirmation. This perspective links engagement not only to the user's affective state but also to learning outcomes and cognitive enrichment derived from interaction. Consequently, user engagement serves as both a psychological state and a predictor of continued system use, loyalty, and knowledge retention. More recent perspectives extend engagement into digital ecosystems. Oh et al. (2018) identify physical interaction, interface assessment, absorption, and digital outreach as the core mechanisms that shape engagement in interactive and social environments. These elements highlight how users' engagement is influenced by design interactivity, system responsiveness, and the social dimension of digital participation factors increasingly relevant in human–technology interaction research.

Integrating these perspectives, the current research conceptualizes user engagement as a combination of perceptual, affective, and behavioral factors that determine the intensity and quality of users' relationship with digital HRM systems. The adopted measurement dimensions perceived usability, novelty, felt involvement, endurability, satisfaction, affirmation, and use (adapted from O'Brien & Toms, 2010; Barker et al., 2015), capture engagement as a sustained state of positive involvement and intrinsic motivation toward technology-mediated work processes. Within digital public-sector environments, high user engagement indicates that employees perceive the HRM system not merely as a compliance tool but as an enabler of meaningful participation, self-efficacy, and continuous performance development.

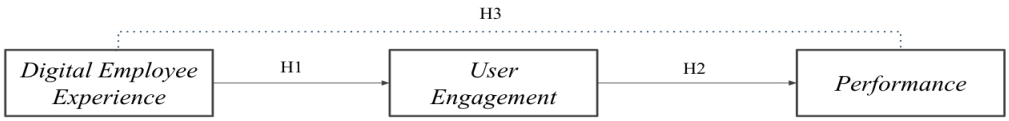
Performance

Employee performance refers to employees' efforts to meet job expectations, achieve unit targets, and help the organization grow through both task-related and contextual behaviors. Research findings indicate that performance is evaluated using objective parameters (e.g., target attainment, problem solving, and collaboration) as well as contributions to broader organizational outcomes. In general, engagement and leadership are key factors influencing these results. Open communication, recognition, and professional development facilitated by HRM digitalization systems are correlated with increased job satisfaction, commitment, and performance (Mohammad et al., 2025).

HRM digitalization can improve performance by expanding the availability of resources, increasing social involvement, and enabling leaders to make data-driven decisions. Empirical models show that transformational leadership fosters organizational citizenship behavior (OCB), thereby strengthening individual performance patterns aligned with social bond and social exchange theories. In digital environments, these effects are amplified because platforms provide clear objectives, real-time guidance, explicit recognition, which enhance proactivity, discretionary contributions, and continuous performance improvement (Qalati et al., 2022).

There is a set of indicators that governs how well the public sector in Indonesia works. Government Regulation No. 30/2019 delineates a performance management system that includes planning, execution, monitoring and coaching, appraisal, follow-up, and an integrated performance information system, with evaluation based on Employee Performance Targets / Sasaran Kinerja Pegawai (SKP) and the principles of objectivity, measurability, accountability, participation, and transparency. The digitalization of HRM is strongly aligned with these objectives; for instance, e-SKP modules, dashboards, and continuous feedback systems implement the regulatory standards at scale, enhancing timeliness, traceability, and developmental value in ASN performance monitoring. Thus, investigations into digital transformation and employee experience within government should construct mediated pathways (leadership → engagement/OCB → performance) and ensure that outcome metrics correspond with the SKP-based framework (Republic of Indonesia, 2019). The proposed model, illustrating the aforementioned hypotheses, is depicted in Figure 1.

Figure 1. The proposed model.



Source: Elaborated by the authors.

Methods

Research design

This study uses a quantitative approach with an explanatory design to analyze the effect of Digital Employee Experience (DEX) on Performance (PRF), with User Engagement (UE) as mediating variables. The analysis method used is Structural Equation Modeling–Partial Least Squares (SEM-PLS) using SmartPLS software, which is suitable for predictive models with multiple latent constructs and does not require normally distributed data (Hair et al., 2021). This research model consists of five hypotheses:

- H1: Digital Employee Experience → User Engagement
- H2: User Engagement → Performance
- H3: Digital Employee Experience → User Engagement → Performance

Table 1 presents the four variables and the constructs of the proposed model, all satisfying the 'multiple indicators' assumption (Marôco, 2014).

Table 1. Description of constructs and variables proposed in the study.

Construct	Dimension	Code	Indicator Item	Source
Digital Employee Experience (DEX)	Digital tools usability	DEX1	The KMOB, TRK, and Peer Review systems are easy to use and help me accomplish tasks effectively.	Morgan (2017); Gartner (2020)
	Digital collaboration	DEX2	The organization's digital platforms make it easier for me to collaborate with colleagues.	
	Digital learning and growth	DEX3	I can improve my knowledge and skills through the digital tools provided by the organization.	
	Digital support	DEX4	IT support and digital infrastructure in the organization function reliably and responsively.	
	Digital environment and culture	DEX5	My organization promotes a positive and innovative digital work environment.	Adapted from Schein (2010)
User Engagement (UE)	Novelty	UE1	I am interested in the features provided by the KMOB, TRK, and Peer Review application.	Brien & Toms (2010) and Barker er.al (2015)
	Felt Involvement	UE2	By using KMOB, TRK, and Peer Review, I feel involved in monitoring my daily attendance and performance evaluation.	
	Endurability	UE3	I feel it is important to use the KMOB, TRK, and Peer Review applications every day.	
	Satisfaction	UE4	I'm satisfied with KMOB, TRK and Peer Review System. It streamlines my work, runs reliably, and makes reporting and performance reviews more professional.	
	Affirmation	UE5	By using KMOB, TRK, and Peer Review, I feel my daily activity and peer evaluation is well documented.	
	Use	UE6	I will use the KMOB, TRK, and Peer Review applications consistently.	
Performance (PERF)	Task efficiency	PRF1	I can complete my tasks faster using the KMOB, TRK, and Peer Review platforms.	Koopmans et al. (2014); Borman & Motowidlo (1997)
	Quality of output	PRF2	My work results meet the expected quality standards due to digital support.	
	Adaptive performance	PRF3	I easily adapt to new digital tools and working environments.	
	Productivity	PRF4	Digital applications have helped me improve my overall productivity.	

Note. Elaborated by the authors.

Population

The subjects of this study were civil servants (ASN) employed by the West Java Provincial Government who utilized digital applications in their daily responsibilities.

Sampling Technique & Criteria

The sampling method employed was purposive sampling, adhering to established criteria.

1. ASN that has used the KMOB, TRK, and Peer Review digital apps for at least six months.
2. ASN is involved in administrative or managerial work supported by digital systems.
3. Willing to be respondents and complete the questionnaire voluntarily.

Sample Size

The sample size was determined using the 10-times rule in SEM-PLS (Hair et al., 2019), which is a minimum of ten times the number of structural paths leading to a construct. Because the Performance construct has two predictors (Digital User Satisfaction and Work Engagement), the minimum number of respondents was 20. However, to increase statistical power and model representativeness, this study targeted a minimum of 400 valid respondents. After data collection, 420 respondents completed the research questionnaire.

After data cleaning. including removing data with a standard deviation of 0 (respondents who answered the same for all items), incomplete data, too fast response times (<90 seconds), and outliers based on a z-score of ±3.0—404 valid data points were obtained, which were processed using SEM-PLS. This stage adheres to the guidance of Hair et al. (2021), Meade & Craig (2012), and Podsakoff et al. (2012) to guarantee data integrity and prevent straight-lining responses that may compromise model reliability. This figure also satisfied the power analysis requirements and was beyond the minimal goal sample size. Consequently, the research model was considered to possess sufficient statistical power.

Data collection

From May to August 2025, data were collected using questionnaires distributed both online and offline at government agencies in the West Java provincial administration. Participants received questionnaires that contained a summary of the research goals, guarantees of data privacy, and an expected completion time of about 10 minutes.

The data cleansing process was done very carefully to make sure that the results of the analysis were real and reliable. Each participant's standard deviation (std. dev) number was used to examine the data. Respondents exhibiting a standard deviation of 0 were omitted due to their consistent responses across all items (straight-lining responses), hence lacking the requisite data variation for correlation analysis between variables (Hair et al., 2021; Meade & Craig, 2012; Podsakoff et al., 2012).

Data Analysis

SmartPLS version 4.0 was used to analyze the data. There were two key steps: (1) checking the measurement model (outer model) and (2) checking the structural model (inner model).

The outer model was assessed for reliability and validity using the following criteria: Indicator reliability: Outer loadings ≥ 0.70. Internal consistency: Cronbach's α and Composite Reliability (CR) ≥ 0.70. - Convergent validity: Average Variance Extracted (AVE) ≥ 0.50. Discriminant validity: Fornell–Larcker criterion and HTMT ratio less than 0.90. Indicators with loadings just below 0.70 were kept if CR was above 0.70 and there was a theoretical reason to do so. The inner model was evaluated via bootstrapping with 5,000 resamples to determine path coefficients, significance levels, and explanatory power. Evaluation criteria encompassed: Path coefficients (β) and their significance ($p < 0.05$, two-tailed).

- Coefficient of determination (R^2): 0.25 (weak), 0.50 (moderate), 0.75 (substantial).
- Effect size (f^2): 0.02 (small), 0.15 (medium), 0.35 (large).
- Predictive relevance (Q^2): Values > 0 indicate predictive accuracy.
- Model fit indices: SRMR < 0.08, NFI > 0.90.

Findings

Respondent Profile

Overall, 420 civil servants took part in this study, and these respondents' profiles are captured in Table 2.

Table 2. Respondent Profile

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	215	51.2
	Female	205	48.8
	Total	**420**	**100.0**
Age (years)	21–30	125	29.8
	31–40	109	26.0
	41–50	130	31.0
	51–60	56	13.2
	Total	**420**	**100.0**
Institutional Affiliation	Education Office	133	31.7
	Industry and Trade Office	54	12.9
	Food Security and Livestock Office	40	9.5
	Library and Archives Office	40	9.5
	Marine and Fisheries Office	29	6.9
	Regional Development Planning Agency	27	6.4
	Environment Office	25	6.0
	Health Office	24	5.7
	Tourism and Culture Office	13	3.1

	Human Resources Development Agency	13	3.1
	Regional Revenue Agency	7	1.7
	Manpower and Transmigration Office	8	1.9
	Regional Secretariat	4	1.0
	Financial and Asset Management Agency	1	0.2
	Food Crops and Horticulture Office	2	0.5
	Total	**420**	**100.0**

Measurement Model Evaluation

Table 3. Indicator Loading Elimination

Variable	Items	Outer Loading	
		Consideration	**Revised Model**
Digital Employee Experience	DEX1	Valid	0.524
	DEX2	Valid	0.699
	DEX3	Valid	0.713
	DEX4	Valid	0.819
	DEX5	Valid	0.751
	DEX6	Valid	0.647
	DEX7	Valid	0.747
	DEX8	Valid	0.715
	DEX9	Valid	0.556
	DEX10	Valid	0.757
	DEX11	Valid	0.581
	DEX12	Valid	0.796
	DEX13	Valid	0.786
	DEX14	Valid	0.797
	DEX15	Valid	0.783
	DEX16	Valid	0.760
	DEX17	Valid	0.788
	DEX18	Valid	0.682
	DEX19	Valid	0.713
	DEX20	Valid	0.806
	DEX21	Valid	0.645
	DEX22	Valid	0.752
	DEX23	Valid	0.739
	DEX24	Valid	0.815
	DEX25	Valid	0.787
	DEX26	Valid	0.777
	DEX27	Valid	0.731
	DEX28	Valid	0.702
	DEX29	Valid	0.784
	DEX30	Valid	0.820
User Engagement	UE1	Valid	0.786
	UE2	Valid	0.814
	UE3	Valid	0.793
	UE4	Valid	0.795
	UE5	Valid	0.790

Variable	Items	Outer Loading	
		Consideration	**Revised Model**
	UE6	Valid	0.804
	UE7	Valid	0.856
	UE8	Valid	0.854
	UE9	Valid	0.813
	UE10	Valid	0.810
	UE11	Valid	0.808
	UE12	Valid	0.773
	UE13	Valid	0.820
	UE14	Valid	0.788
	UE15	Valid	0.802
Performance	KI1	Valid	0,824
	KI2	Valid	0.847
	KI3	Valid	0.856
	KI4	Valid	0.851
	KI5	Valid	0.844
	KI6	Valid	0.847
	KI7	Valid	0.831
	KI8	Valid	0.883
	KI9	Valid	0.882
	KI10	Valid	0,861

The quality of the research instruments was validated through comprehensive reliability and validity testing. As presented in Table 3, all indicators for the Digital Employee Experience (DEX), User Engagement (UE), and Performance constructs met the outer loading requirements, confirming their validity. Specifically, the outer loadings for DEX items ranged from 0.524 to 0.820, showing that all 30 indicators were retained after meeting the threshold for construct reliability. Similarly, the User Engagement indicators demonstrated consistently strong loadings, ranging from 0.773 to 0.856, confirming the robustness of this construct. The Performance construct also displayed excellent indicator reliability, with all items showing high outer loadings between 0.824 and 0.883, These results indicate that each indicator contributed meaningfully to its respective construct, and none required elimination during model refinement.

Table 4. Measurement of Validity and Reliability

Variable	Cronbach's alpha	Rho_A	Composite Reliability	Average Variance Extracted (AVE)
Digital Employee Experience	0.969	0.972	0.971	0.532
Performance	0.958	0.959	0.964	0.727
User Engagement	0.967	0.968	0.970	0.628

Source: Processed Data (2025)

Before testing the structural relationships, the reliability and convergent validity of the constructs were evaluated. As shown in Table 4, all constructs demonstrated excellent internal consistency and validity. Cronbach's alpha values ranged from 0.958 to 0.969, while Composite Reliability values exceeded 0.96, far above the minimum threshold of 0.70, indicating strong internal consistency. The Average Variance Extracted (AVE) values were also satisfactory Digital Employee Experience (0.532), Performance (0.727), and User Engagement (0.628) each surpassing the minimum criterion of 0.50, confirming good convergent validity.

Structural Model Evaluation

Table 5. R Square

Variable	R Square
Performance	0,784
User engagement	0,735

Source: Processed Data (2025)

After confirming measurement quality, the structural model was tested to validate the hypothesized causal relationships. Table 5 shows the Coefficient of Determination (R Square), which measures the prediction power of the structural model. The R^2 values of 0.735 for User Engagement and 0.784 for Performance indicate that DEX and UE jointly explain more than 70% of variance in user engagement and employee performance. This represents a substantial level of explanatory power (Hair et al., 2021).

Table 6. Direct and Mediated Relationships

Relationship	Total effect	Interpretation
DEX → UE	0.857	Positive digital experience strongly increases user engagement.
DEX → PRF	0.886	DEX directly improves performance
DEX → UE → PRF	0.759	Engagement partially mediates this relationship, showing that emotionally and cognitively engaged employees translate positive digital experiences into measurable performance gains.

Table 6 illustrates the relationships between Digital Employee Experience (DEX), User Engagement (UE), and Employee Performance (PRF). All proposed path hypotheses were statistically significant. The strongest relationship was observed between DEX → UE (β = 0.857, $p < 0.001$), indicating a very strong positive influence of Digital Employee Experience on User Engagement. DEX also showed a significant direct effect on Performance (β = 0.886,

$p < 0.001$). Furthermore, the indirect effect of DEX on Performance through User Engagement was 0.759, confirming that User Engagement partially mediates this relationship. This implies that emotionally and cognitively engaged employees translate positive digital experiences into measurable performance gains.

Discussion

The findings of this study provide strong empirical evidence that Digital Employee Experience (DEX) significantly influences both User Engagement (UE) and Employee Performance (PRF) among civil servants in the West Java Provincial Government. The substantial R^2 value of 0.784 for Performance confirms that the quality of the digital work environment and the level of employee engagement are key determinants of performance in public organizations, extending the application of the Job Demands–Resources (JD-R) model to the digital context.

The DEX → UE relationship ($\beta = 0.857$) demonstrates that Digital Employee Experience is a beneficial way to measure User Engagement. This means that a positive digital experience makes employees substantially more emotionally and mentally involved with the e-HRM system. When digital platforms are intuitive, responsive, and user-friendly, employees are more likely to develop psychological connection and active participation with the system.

The DEX → PRF relationship ($\beta = 0.886$) indicates that DEX directly enhances employee performance, implying that employees who perceive an improved digital environment are likely to exhibit greater efficiency and productivity. This direct effect underscores the importance of investing in digital infrastructure and user-centered design as strategic tools for improving organizational outcomes.

The mediating role of User Engagement (indirect effect = 0.759) reveals that engagement acts as a psychological mechanism linking digital experience to performance outcomes. This partial mediation suggests that while DEX directly improves performance, a substantial portion of its total effect is channeled indirectly through enhanced user engagement. Employees who are emotionally and cognitively engaged with digital systems are better positioned to leverage these tools for improved task execution and productivity.

The overall model fit indices (SRMR ≈ 0.063; NFI ≈ 0.722) indicate an acceptable model fit, supporting the robustness of the structural relationships among the constructs. These findings collectively confirm that the success of government digital transformation depends not only on technological infrastructure, but also on employee experience and engagement in supportive, intuitive, and participatory digital systems.

Conclusion

This study empirically demonstrates that Digital Employee Experience (DEX) significantly impacts User Engagement (UE) and Employee Performance (PRF) among civil servants in

the West Java Provincial Government. DEX is shown to have a strong direct effect on performance as well as an indirect effect through user engagement, indicating that a positive digital experience drives employee motivation, participation, and improved performance.

The research model demonstrates high explanatory power ($R^2 = 0.784$), indicating that the quality of the digital work environment and the level of employee engagement are key determinants of performance in public organizations. These findings extend the application of the Job Demands–Resources (JD-R) model to the digital context by positioning UE as a psychological mechanism linking digital experience and performance outcomes.

Overall, the results of this study confirm that the success of government digital transformation depends not only on technological infrastructure, but also on employee experience and engagement in supportive, intuitive, and participatory digital systems

Based on the results of this study, the following points are recommended:

- Human-centered Digital Design: Government institutions should develop digital platforms that prioritize user-friendliness, accessibility, and responsiveness to strengthen DEX and sustain engagement.
- Employee Engagement Programs: Introduce digital literacy workshops, gamified performance dashboards, and recognition systems to enhance continuous user participation and motivation.
- Leadership and Policy Alignment: Leaders should model digital engagement behaviors and ensure alignment between HRM policies, performance metrics, and digital transformation goals.
- Ongoing Evaluation: Implement continuous feedback loops and data-driven monitoring to assess user satisfaction, engagement, and performance improvements over time.

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The Digital Transformation of MSME Financing: A Review of Global Challenges and Pathways to Inclusion, with a Focus on Bangladesh

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Abstract

Micro, Small, and Medium Enterprises (MSMEs) are the foundation of the global economy, yet they persistently face a substantial finance gap estimated at US$5.2 trillion (Washington CORE, 2024). This gap is primarily driven by challenges such as high transaction costs, stringent collateral requirements, and high rates of informality, which are particularly acute in emerging economies like Bangladesh. This state-of-the-art review synthesizes recent literature to examine these long-standing barriers and the transformative role of Digital Financial Services (DFS), Financial Technology (FinTech), and Artificial Intelligence (AI) in addressing them. Evidence from Bangladesh shows that while MSMEs contribute 25-30% of GDP, they face a financing gap of approximately 20% of GDP, and women-led firms are disproportionately affected (Hossain, n.d.; Jahan & Miles, 2021). The rapid proliferation of Mobile Financial Services (MFS) in Bangladesh, with over 111 million clients, demonstrates the potential for DFS to leapfrog traditional banking infrastructure (Innovision Consulting, n.d.). Globally, digital lending models leverage alternative data for credit scoring, enhancing efficiency and financial inclusion (GPFI, 2023). However, widespread adoption is constrained by inadequate digital infrastructure, high implementation costs, low digital literacy, and the need for robust regulatory frameworks to address algorithmic bias and data privacy. This paper concludes by outlining strategic pathways for fostering an inclusive digital ecosystem to unlock the potential, resilience, and growth of MSMEs in Bangladesh and beyond.

Keywords: Artificial Intelligence, Bangladesh, Digital Finance, Financial Inclusion, MSME Performance, Risk Management

Introduction

The Critical Role of MSMEs and the Persistence of the Finance Gap

Micro, Small, and Medium Enterprises (MSMEs) are universally recognized as pivotal drivers of economic resilience, employment, and innovation in both developed and developing nations (Risman et al., 2024). Globally, MSMEs constitute over 97% of all businesses and employ more than half of the workforce, making them the lifeblood of nearly every economy (Washington CORE, 2024). Their economic contribution is profound; they are not merely small-scale operations but are collectively a dominant force in generating national income and fostering entrepreneurship (Bhuiyan, 2018).

The context of Bangladesh starkly illustrates this importance. MSMEs in Bangladesh represent over 99% of all private enterprises, contribute an estimated 25-30% to the Gross Domestic Product (GDP), and provide up to 87% of civilian employment (Alam & Ullah, 2006; Bhuiyan, 2018; Innovision Consulting, n.d.). They are integral to the country's industrial fabric, accounting for 80% of industrial jobs and playing a crucial role in poverty alleviation and rural development (SME Foundation, n.d.; Bhuiyan, 2018). The government's "Vision 2041" and its associated national policies identify MSME development as a strategic priority for achieving upper-middle-income status (Jahan & Miles, 2021).

Despite this foundational role, MSMEs face pervasive and systemic constraints that severely impede their potential. The foremost of these is a chronic lack of access to formal financial resources, which has culminated in a substantial and widening global MSME finance gap. For formal MSMEs in developing economies alone, this unmet financing need is estimated at a staggering US$5.2 trillion annually (Washington CORE, 2024). This challenge is particularly severe in Bangladesh, where the financing gap is estimated to be 20% of GDP, or approximately US$2 billion. Critically, this gap is not gender-neutral; women-owned enterprises face disproportionately greater unmet demand for credit (Jahan & Miles, 2021).

The vulnerability of this sector was acutely exposed during the COVID-19 pandemic. The crisis disrupted supply chains, decimated demand, and strained liquidity, pushing millions of MSMEs to the brink of collapse and accelerating the urgent need for more resilient, accessible, and inclusive financial mechanisms (IFC & SME Finance Forum, 2021). In response, digital technologies have emerged as a powerful force for transformation.

This state-of-the-art review synthesizes contemporary research to address three core areas defining the current MSME landscape, using Bangladesh as a key case study to ground global trends in a specific national context. The paper will explore: (1) the nature and persistence of traditional financing barriers that have historically excluded MSMEs; (2) the transformative role of Digital Financial Services (DFS), Financial Technology (FinTech), and Artificial Intelligence (AI) in bridging these access and efficiency gaps; and (3) the strategic, regulatory, and social challenges that must be overcome to ensure that this technological shift drives sustainable and truly inclusive growth for all MSME segments.

Literature Review

Traditional Constraints and the Digital Transformation Mandate

The academic and policy discourse on MSME development is fundamentally structured around two interconnected themes: first, diagnosing and overcoming the historic, systemic failures in traditional financial markets that exclude smaller enterprises; and second, harnessing new digital capabilities to foster competitive advantage, resilience, and sustainability.

Traditional Constraints to MSME Financing

For decades, MSMEs have been trapped in what is often termed the "missing middle"—a precarious position where they are too large or commercially oriented for microfinance institutions (MFIs) yet too small, informal, or opaque for traditional commercial banks (Hasan & Hasan, 2014). These challenges are rooted in both supply-side risk aversion from lenders and demand-side structural deficiencies within the MSME sector itself.

The Centrality of Collateral and Perceived Risk

The primary and most frequently cited obstacle to securing traditional bank loans is the requirement for tangible collateral, typically in the form of fixed assets like land or buildings (Shaikh et al., 2017). Banks and other formal financial institutions have historically relied on collateral-based lending as their primary mechanism for mitigating the information asymmetry and perceived high risk associated with smaller, less formalized borrowers (Alam & Ullah, 2006). This practice is deeply entrenched in the Bangladeshi banking sector, where lenders often view MSMEs as inherently high-risk due to low capitalization, insufficient assets, and a perceived inability to weather economic shocks (Alam, 2006; Nehereen, 2010).

This rigid insistence on fixed collateral effectively excludes a vast majority of MSMEs. In Bangladesh, where land ownership can be complex and many businesses operate from leased premises, this requirement is particularly prohibitive. It forces a significant number of entrepreneurs to depend on internal funds or informal, often predatory, financing from sources like friends, family, or local moneylenders, which stifles investment and long-term growth (Nehereen, 2010). The efficacy of this collateral-centric model is, however, contested. A rigorous empirical study conducted in Bangladesh found no statistically significant evidence that possessing collateral either increases an SME's access to credit or reduces its rate of default (Rahman et al., 2016). This suggests that banks' unwavering adherence to this requirement may be a legacy practice that is both inefficient and counterproductive to the goal of expanding financial inclusion.

Informality, Documentation, and Administrative Hurdles

A significant portion of MSMEs, particularly in developing economies, operate within the informal sector. This means they often lack official business registration, tax identification numbers, and, most critically, the audited financial statements required by institutional lenders (United Nations, 2021). In Bangladesh, this informality is widespread, making it exceedingly difficult for banks to assess creditworthiness using their conventional underwriting models (Herwiyanti & Rafinda, 2021).

Even for formal MSMEs, the loan application process itself presents a formidable barrier. It is frequently characterized as lengthy, complex, and bureaucratic, creating high transaction costs for borrowers in terms of both time and money (Alam & Ullah, 2006). One study in Bangladesh found that 22% of MSMEs operate without formal registration, and entrepreneurs frequently cite the cumbersome nature of the application process as a major deterrent (Innovision Consulting, n.d.; Chowdhury et al., 2013). This combination of stringent documentation requirements and administrative inefficiency discourages many otherwise viable MSMEs from seeking formal credit, further entrenching their reliance on less stable, informal financial channels.

The Digital Finance Imperative: DFS, FinTech, and New Lending Models

In the face of these persistent challenges, digital transformation is no longer an optional upgrade but a fundamental necessity for MSME survival and growth (Rahman & Putri, 2020). Digital Financial Services (DFS) and the broader FinTech ecosystem are uniquely positioned to address the core market failures of traditional lending by radically reducing transaction costs, overcoming information asymmetry, and expanding reach to previously unbanked populations (Gomber et al., 2017).

FinTech Lending and the MFS Revolution in Bangladesh

Bangladesh serves as a powerful example of the "leapfrogging" potential of DFS. Despite having one of the world's lowest levels of traditional banking penetration, with over 70% of its population historically unbanked, the country has witnessed an explosive growth in Mobile Financial Services (MFS) (Rahman et al., 2021). With over 111 million registered clients by 2021, MFS providers like bKash, Rocket, and Nagad have become the primary channel for financial transactions for millions of individuals and small businesses (Innovision Consulting, n.d.; Banna, 2020).

Initially, these platforms focused on basic services such as peer-to-peer payments and remittances. However, they are increasingly evolving into comprehensive digital financial ecosystems. A pivotal development is the integration of digital credit products, such as the nano-loan offered through a partnership between bKash and City Bank. This product provides small, instantaneous, collateral-free loans directly to a user's mobile wallet, with eligibility determined by an automated analysis of their MFS transaction history (Innovision Consulting,

n.d.). This model bypasses the need for physical bank branches and traditional documentation, significantly expanding credit access for previously excluded populations. While awareness of such digital lending solutions among Bangladeshi MSMEs remains low, the infrastructure represents a monumental step toward closing the finance gap (Innovision Consulting, n.d.).

Globally, this trend is mirrored by the rise of Peer-to-Peer (P2P) and marketplace lending platforms. A study of the Latin American market found that these FinTechs are essential for bridging the MSME finance gap, with alternative finance originations reaching US$5.27 billion in 2020. For MSMEs using these platforms, the speed of receiving funds was cited as the most critical decision-making factor, a direct response to the lengthy delays of traditional banking (Ziegler et al., 2022).

Alternative Credit Scoring and the Power of Data-Driven Decisions

Perhaps the most significant innovation driven by FinTech and AI is the development of alternative credit scoring models. By applying Machine Learning (ML) algorithms to vast amounts of non-traditional or "alternative" data, lenders can construct reliable and predictive credit profiles for "thin-file" individuals and businesses that lack a formal credit history (GPFI, 2023; Puschmann & In, 2025).

These alternative data sources are diverse and include MFS transaction histories, mobile phone usage patterns (e.g., top-ups and call data records), e-commerce sales data, utility payment records, and even social media footprints. This methodology allows lenders to assess an applicant's capacity and willingness to repay without relying on traditional financial statements or collateral. A landmark study demonstrated that ML models based on mobile phone metadata could significantly outperform traditional credit bureau scores for individuals with limited financial histories, effectively creating a pathway to credit for the previously unbankable (Björkegren & Grissen, 2018).

This technology fundamentally alters the economics of small-scale lending by drastically reducing the information collection and verification costs that made serving MSMEs unattractive for traditional banks (World Bank Group, n.d.). For a country like Bangladesh, where MSME informality is high, alternative credit scoring offers a viable path to formal financial inclusion that aligns with the realities of the local economy (IFC & SME Finance Forum, 2021). The development of Digital Public Infrastructure (DPI)—such as digital identity systems and data-sharing frameworks—further accelerates this trend by enabling secure, consent-based access to the data needed for these models to function effectively (GPFI, 2023).

The Role of Digitalization in MSME Performance, Innovation, and Sustainability

The impact of digital transformation extends far beyond just improving access to finance. Technology is now inextricably linked to enhancing core business functions, driving innovation, and ensuring the long-term sustainability and competitiveness of MSMEs.

Enhancing Performance and Fostering Innovation

A growing body of research consistently finds that the adoption of digital finance and a broader commitment to business innovation are strong positive predictors of MSME performance (Risman et al., 2024). The key areas of impact can be broken down as follows:

1. **Operational Efficiency and Productivity:** The integration of AI and other digital tools enables the automation of routine administrative and operational processes, which reduces manual workloads, minimizes human error, and frees up entrepreneurs to focus on strategic activities. Studies indicate that MSMEs adopting AI technology can achieve significant increases in efficiency, with some reporting improvements of up to 30% (Usman & Harto, 2024). In an Indonesian survey, 65% of MSMEs confirmed that AI adoption had directly enhanced their operational efficiency (Khaq et al., 2024). This includes everything from digital bookkeeping and inventory management to more complex supply chain optimizations.
2. **Market Access, Sales, and Customer Experience:** Digital platforms and AI-driven strategies have democratized marketing and sales, allowing MSMEs to reach a much broader customer base than was previously possible. E-commerce platforms, social media marketing, and AI-powered tools like personalized recommendation engines and 24/7 customer service chatbots have a direct, positive effect on sales and customer satisfaction. An Indonesian case study found that 70% of respondents reported a tangible increase in sales after implementing AI-based tools (Khaq et al., 2024). In Bangladesh, where e-commerce is booming, FinTech-enabled digital payments are a critical enabler of this growth (Rahman et al., 2021).
3. **Knowledge Management and Dynamic Capabilities:** Information Technology (IT) plays a crucial role as a moderator, enhancing the relationship between a firm's internal and external knowledge management practices and its overall dynamic capabilities—that is, its ability to adapt and innovate in a changing market. Effective knowledge management, facilitated by IT, can shorten product development lead times, reduce operational costs, and enable greater product differentiation and customization (Azyabi, 2017).

Driving Sustainability and Improving Risk Management

In the contemporary business environment, true long-term sustainability requires the integration of economic, environmental, and social considerations (Rahman & Putri, 2020). Digitalization and AI can support this holistic approach in several ways. AI-powered analytics can help MSMEs optimize resource usage, reduce waste in production processes, and make data-driven decisions that minimize their environmental footprint (Usman & Harto, 2024).

Furthermore, studies have shown that digital financial inclusion can indirectly enhance the environmental performance of MSMEs by providing them with the necessary capital to invest in greener technologies and more sustainable practices (Sudrajat et al., 2024).

Finally, the implementation of robust risk management strategies is a cornerstone of business sustainability. The adoption of digital finance has been shown to positively influence a firm's ability to manage risk. Digital tools provide real-time visibility into cash flow, allow for more accurate financial forecasting, and enable easier access to products like digital insurance. This enhanced capacity for risk identification, measurement, and mitigation is crucial for protecting business assets and ensuring long-term viability (Risman et al., 2024).

Barriers and Risks to Digital Adoption and Scale

Despite the evident and transformative potential of digital technologies, their widespread adoption and the realization of their benefits for MSMEs are severely hindered by a range of significant technical, social, and regulatory barriers. These challenges threaten to create a new form of exclusion, where the opportunities of the digital economy are only accessible to a privileged few.

The Pervasive Digital and Financial Literacy Divide

The digital divide—a multifaceted issue encompassing gaps in access, usage, and skills—remains the most formidable structural barrier to inclusive digital transformation (Khaq et al., 2024).

- **Inadequate Digital Infrastructure:** In many developing countries, including large parts of Bangladesh, the foundational infrastructure required for a digital economy is either underdeveloped or unevenly distributed. Limited access to affordable, high-speed internet and unreliable electricity supply effectively curtails the reach of digital finance, creating a deep chasm between urban centers and rural or remote areas (Banna, 2020). Without reliable connectivity, the promise of digital inclusion remains unfulfilled for a significant portion of the MSME population.
- **Low Digital and Financial Literacy:** The effective use of digital financial tools requires a baseline level of both digital and financial literacy. Many MSME owners, particularly those from older generations or with lower levels of formal education, lack the technical skills and knowledge needed to navigate digital platforms securely and efficiently (Usman & Harto, 2024; Khaq et al., 2024). This is compounded by low financial literacy, which prevents entrepreneurs from understanding the terms, risks, and benefits of digital credit and investment products, making them vulnerable to predatory practices (Herwiyanti & Rafinda, 2021). A study in Bangladesh revealed that a significant number of MSME owners are unaware of the digital lending services available to them, indicating a critical gap in awareness and education (Innovision Consulting, n.d.).
- **Prohibitive Costs and Lack of Trust:** For many micro and small enterprises operating on thin margins, the high initial costs of investing in digital hardware, software, and training can be a major deterrent (Usman & Harto, 2024). This is often coupled with a lack of trust in digital systems, driven by concerns about fraud, data

security, and the perceived impersonality of digital channels compared to face-to-face interactions with traditional financial agents.

- **The Exacerbated Gender Gap:** The digital divide is not gender-neutral. In many societies, women face greater barriers to digital and financial inclusion due to social norms, lower educational attainment, and less control over household resources. This is starkly evident in Bangladesh, where a study found that only 42% of female MSME owners had their own smartphone, compared to 60% of their male counterparts. This disparity severely limits their ability to engage with the MFS ecosystem, which is the primary gateway to digital finance in the country (Innovision Consulting, n.d.).

Inherent Risks of Technological Transformation

The very technologies that drive efficiency and inclusion also introduce new and amplified categories of risk that threaten the stability of MSMEs, the integrity of the financial system, and the trust of consumers.

- **Cybersecurity Threats and Data Privacy Concerns:** As financial services become increasingly digitized and interconnected, the risk of cybersecurity breaches, financial fraud, and data theft grows exponentially. Information security and data privacy are consistently cited as primary concerns for the continued growth of the FinTech sector in Bangladesh and globally (Rahman et al., 2021). The collection and use of vast amounts of sensitive personal and transactional data for credit scoring and other financial services necessitate the implementation of robust, well-enforced consumer data protection frameworks to prevent unauthorized access and misuse (IFC & SME Finance Forum, 2021). Without adequate security measures, a single major breach could irrevocably damage consumer trust in the entire digital financial ecosystem.
- **The Danger of Algorithmic Bias:** Automated credit scoring systems, while powerful, are not inherently neutral. If the AI and ML models that power them are trained on historical data that reflects existing societal biases, they can inadvertently perpetuate and even amplify discriminatory lending practices against certain demographic groups, such as women, ethnic minorities, or residents of specific geographic areas. Without careful design, continuous auditing, and the proactive use of bias mitigation techniques, these AI models risk reinforcing the very patterns of financial exclusion they are intended to overcome (Mariscala et al., 2024).
- **The Risk of Digital Over-indebtedness:** The rapid, remote, and often frictionless accessibility of digital credit—particularly short-term, high-interest products offered via mobile platforms—raises serious concerns about the potential for over-indebtedness among vulnerable and financially unsophisticated borrowers. The ease of access can lead to impulsive borrowing without a full understanding of the costs and repayment terms. Studies from markets like Kenya and Tanzania have documented cases where digital credit has led to debt traps for low-income individuals and small business owners (Kaffenberger & Totolo, 2018). This highlights the critical need for responsible lending principles and effective consumer protection regulations in the digital credit space.

Policy, Regulatory Frameworks, and Strategic Recommendations

To effectively and responsibly harness the power of technology for MSME growth, policy and regulatory frameworks must evolve. They need to move beyond traditional, static models to create and support a resilient, innovative, and fundamentally inclusive digital ecosystem. This requires a delicate balance between fostering innovation and managing the inherent risks, a goal that is central to national strategies like the "Digital Bangladesh Vision 2021" (Rahman et al., 2021).

The Imperative of Regulatory Modernization and Experimentation

Regulatory bodies, such as Bangladesh Bank (BB), are at the heart of this transformation. Their oversight must be agile enough to manage emerging risks like cybersecurity and consumer protection without stifling the innovation that drives financial inclusion (Arner et al., 2017). A one-size-fits-all approach is no longer viable. Instead, a dynamic regulatory toolkit is needed.

APEC economies offer valuable models, with some establishing comprehensive, forward-looking FinTech legislation, while others utilize **regulatory sandboxes**. These sandboxes provide a controlled environment where startups and financial institutions can test new technologies, products, and business models under the supervision of regulators. This "test and learn" approach allows for evidence-based policymaking and helps regulators develop a deeper understanding of new technologies before crafting permanent rules (Washington CORE, 2024).

Furthermore, the relationship between disruptive FinTechs, dominant BigTech firms, and incumbent banks requires careful regulatory management. The rise of "TechFins" and Banking-as-a-Service (BaaS) models presents both opportunities for greater efficiency and risks of market concentration. Policymakers must ensure a level playing field that promotes healthy competition and prioritizes the interests of MSME consumers (Anagnostopoulos et al., 2024).

In Bangladesh, Bangladesh Bank has already implemented several supportive measures, including setting annual MSME lending targets for banks, establishing a dedicated SME & Special Programmes Department, and launching various refinancing schemes to lower the cost of funds for lenders (Jahan & Miles, 2021). Building on this foundation, embracing more agile regulatory approaches like sandboxes could further accelerate responsible innovation in the country's burgeoning FinTech sector.

Essential Policy Directives on Collateral and Credit Access

Direct and decisive policy intervention remains necessary to dismantle the persistent collateral barrier, which continues to be a primary bottleneck for MSME financing. Based on findings from Bangladesh and other emerging economies, key policy recommendations include:

- **Expanding and Promoting Collateral-Free Lending:** Governments and central banks should expand and actively promote collateral-free loan products. In Bangladesh, this could involve increasing the limit for loans offered against a personal guarantee (currently BDT 2.5 million) and launching awareness campaigns to ensure MSMEs know these options exist (Jahan & Miles, 2021).
- **Developing Cluster-Based Financing Approaches:** MSMEs often concentrate geographically in specific industry clusters (e.g., the light engineering cluster in Bogura or the handloom cluster in Tangail, Bangladesh). Policies should be designed to support these clusters with coordinated financing, shared infrastructure, and dedicated credit guarantee schemes. This approach allows lenders to develop sector-specific expertise and reduce monitoring costs (Hossain, n.d.).
- **Strengthening the Framework for Alternative Collateral:** To truly move beyond fixed-asset lending, the legal and regulatory framework must be updated to formally recognize and facilitate the use of alternative forms of collateral. This includes digital transaction histories, accounts receivable, and other movable assets. Supporting the development of robust Digital Public Infrastructure (DPI), especially digital identity systems and secure data-sharing platforms, is a prerequisite for making this a reality on a national scale (GPFI, 2023).

Strategic Recommendations for an Inclusive Digital Ecosystem

Based on the synthesis of global challenges and successes, four interdependent strategic pathways are essential for developing a sustainable and inclusive MSME digital ecosystem, particularly in a context like Bangladesh.

1. **Prioritize and Scale Financial and Digital Literacy Initiatives:**

   Financial and digital knowledge is not a peripheral issue; it is a prerequisite for the safe and effective adoption of FinTech. Policymakers, in partnership with the private sector and civil society organizations, must invest in widespread, tailored training programs. These initiatives should be designed to reach the most excluded segments, including women entrepreneurs, rural business owners, and those in the informal sector. The curriculum should go beyond basic digital skills to cover core financial principles (e.g., cash flow management, debt management), digital risk awareness (e.g., identifying scams, protecting personal data), and the practical application of digital financial tools for business growth (Herwiyanti & Rafinda, 2021; Innovision Consulting, n.d.).

2. **Commit to Investing in Inclusive and Interoperable Digital Infrastructure:**

   The vision of a "Digital Bangladesh" can only be realized if its foundations are inclusive. This requires a concerted national effort, involving both public and private investment, to ensure universal access to affordable, reliable, high-speed internet. Infrastructure development must prioritize underserved rural and remote areas to avoid deepening the urban-rural digital divide. Furthermore, promoting

interoperability between different MFS providers and banking systems is critical for creating a seamless and competitive digital payments ecosystem that lowers costs and enhances convenience for all users (Relifra et al., 2024; GPFI, 2023).

3. **Establish and Enforce a Framework for Responsible and Fair AI:**

   As AI becomes increasingly central to credit underwriting, the risk of automated discrimination becomes a major policy concern. Regulators like Bangladesh Bank must proactively establish and enforce clear, robust frameworks for governing how AI models are developed, validated, audited, and deployed in the financial sector. This framework should mandate transparency in decision-making processes and require the use of state-of-the-art bias mitigation techniques to ensure that automated credit scoring is fair, equitable, and does not systematically disadvantage protected or vulnerable groups (Mariscala et al., 2024).

4. **Foster the Development of Localized and Adapted Financial Products:**

   Financial products and services are most effective when they are designed to meet the specific, context-driven needs of their target users. A one-size-fits-all approach is destined to fail. For example, digital credit products for agricultural MSMEs in Bangladesh must be structured with flexible repayment schedules that align with seasonal cash flows, rather than rigid monthly installments. Fostering this kind of user-centric innovation requires strong public-private partnerships. Governments can play a role by providing incentives and platforms for collaboration that support local entrepreneurs and FinTech innovators in developing financial products that are culturally relevant, affordable, and truly adapted to the operational realities of local MSMEs (United Nations, 2021).

Conclusion

The transformation of Micro, Small, and Medium Enterprises, particularly in emerging economies like Bangladesh, is at a critical juncture. The sector's ability to drive economic growth, create employment, and reduce poverty is undeniable, yet it remains shackled by the limitations of a traditional financial system that has historically failed to meet its needs. The rise of a data-driven digital ecosystem, powered by Digital Financial Services, FinTech, and Artificial Intelligence, offers a clear and powerful pathway to break these constraints.

This review has demonstrated that digital innovations are not merely incremental improvements; they represent a fundamental paradigm shift. The proliferation of Mobile Financial Services in Bangladesh exemplifies how technology can leapfrog legacy infrastructure to bring millions into the formal financial fold. Globally, the use of alternative data and AI for credit scoring holds the promise of finally solving the information asymmetry problem that has long plagued MSME lending. Beyond finance, digitalization enhances operational efficiency, expands market access, and provides the tools for greater resilience and sustainability.

However, this technological promise is not a panacea. The digital revolution carries its own inherent risks and can create new forms of exclusion if not managed with foresight and intention. The path to an inclusive digital economy is fraught with challenges, including the deep-seated digital and financial literacy divide, inadequate infrastructure in rural areas, and the significant risks posed by cybersecurity threats and algorithmic bias.

For Bangladesh and other nations at a similar stage of development, the way forward requires a concerted and coordinated effort from all stakeholders. Policymakers and regulators must act as both enablers of innovation and guardians of stability and fairness. This means creating agile regulatory environments that encourage experimentation while robustly protecting consumers. It means dismantling archaic barriers like the over-reliance on fixed collateral and actively promoting cluster-based and data-driven financing models.

Ultimately, the success of this transformation will not be measured by the number of FinTech startups or the volume of digital transactions alone. The true measure of success will be the extent to which these innovations empower the most vulnerable entrepreneurs, close the persistent gender gap in financial access, and foster a dynamic MSME sector that is resilient, competitive, and inclusive. By prioritizing digital literacy, investing in equitable infrastructure, enforcing responsible AI, and fostering localized innovation, Bangladesh can harness the full potential of the digital revolution to achieve its long-term development aspirations and build a more prosperous future for all its citizens.

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Talent Cultivation of China's Supply Chain in the Digital Era: A Concept Study

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Abstract

The upgrading of supply chains has become an essential prerequisite for the high-quality development of China's economy. This necessitates establishing a talent pool capable of navigating digital transformation. The paper aims to evaluate the existing research on the current status of supply chain management talent cultivation and to provide guidance on a pathway for Chinese enterprise practitioners to advance talent cultivation reforms systematically. Chinese enterprises have a “skills gap” in supply chain management talent cultivation. Thereby, this study develops a systematic reconstruction framework with three dimensions: "strategic planning leadership, cultivation content restructuring, and cultivation model innovation". It emphasizes that a new supply chain management talent cultivation system adaptable to future competition in the digital era can only be built by establishing talent cultivation to the level of corporate strategy, integrating digital and intelligent knowledge systems, and adopting hybrid and practical empowerment models.

Key Words: Digital Transformation; System Reconstruction; Supply Chain Management; Talent Cultivation

Introduction

Global artificial intelligence (AI), big data, and the Internet of Things (IoT) have penetrated various industries, driving a profound restructuring of China's industrial forms and business models. The stability, agility, and resilience of supply chains serve as the cornerstone for national economic security and the core competitiveness of enterprises (Christopher & Holweg, 2017; Teng et al., 2024; Yin & Sun, 2025). In this context, advancing the modernization and digital transformation of supply chains serves not only as a guarantee for enterprises to reduce costs, enhance efficiency, and address uncertain risks, but also as an essential prerequisite for them to expand markets, innovate services, and foster differentiated competitive advantages (Fan et al., 2025; Nawaiseh et al, 2025).

The execution of any strategy ultimately relies on talent. The modernization transformation of supply chains is a profound revolution driven by professional talents who possess digital literacy, a global perspective, and outstanding management competence. However, enterprises currently face a prevalent dilemma: a critical shortage of compound and innovative supply chain talents with expertise in both business and technology, as well as proficiency in both analysis and management. This challenge is not unique to China but a global phenomenon, commonly termed the "Supply Chain Skills Gap" (Myerson, 2025).

According to Shonubi (2025), the existing talent cultivation models of enterprises need to be more in line with the requirements of digital transformation. Despite more discussions, most studies focus on either phenomenological description or specific segments (e.g., training course design), lacking a systematic perspective to analyze problems and develop a comprehensive solution framework. To fill this research gap, this paper systematically reviews existing literature and focuses on two core questions: (1) What key issues exist in Chinese enterprises' supply chain management talent cultivation? (2) How to restructure the talent system to address digital challenges? By answering the questions, this paper constructs a conceptual framework to enhance the comprehensive capabilities of talents and have a positive impact on the digital performance of enterprises by reconfiguring the talent cultivation system. Finally, it intends to provide a clear and actionable framework for future theoretical research and corporate practice.

Literature Review

By synthesizing relevant literature, this study finds that scholars have critically analyzed the current status and dilemmas of supply chain management talent cultivation in Chinese enterprises, primarily from three dimensions: strategy, content, and model.

Strategic Level: Lack of Top-Level Design and Strategic Short-Sightedness

Talent cultivation is not effectively aligned with corporate strategy. Some Chinese enterprises generally have insufficient understanding of the strategic role of supply chain talent cultivation, leading to a lack of systematic top-level design (Chang & Sangkhiew, 2023; Li et

al, 2019). Behind this phenomenon is the issue of the evolving strategic position of supply chain functions within enterprises. As early as Ellram & Cooper (1990) argued that for supply chain management to become a strategic function, it must secure recognition and support from senior management. However, many enterprise managers still cling to the traditional mindset of regarding the supply chain as a cost center (Christopher, 2016), which directly leads to the neglect of investment in talent's soft skills and the emergence of strategic short-sightedness.

The systems for talent assessment and talent pipeline construction are underdeveloped. According to Kang et al (2025), numerous enterprises lack a scientific competency model for supply chain talents and cannot clearly specify the capability requirements for talents in different positions and ranks. Thereby results in a lack of clear goals for talent cultivation. Meanwhile, the absence of succession planning exposes key supply chain positions to significant succession risks, as losing core talents will severely impact supply chain operations (Liu & Wei, 2022). This kind of strategic short-sightedness shows that enterprises' vulnerabilities in human capital management and risk governance.

Hypothesis 1 (H1): Top-level digital strategy positively influences talent cultivation.

Content Level: Outdated Knowledge Systems and Imbalanced Competency Structures

Traditional training content overemphasizes operational knowledge such as logistics management, inventory control, and procurement processes, while traditional curriculum systems have obvious shortcomings in digital and intelligent competencies as big data analytics, artificial intelligence algorithms, Internet of Things (IoT) applications and etc (Fang et al, 2023; Nawaiseh et al, 2025; Shonubi, 2025). As a result, the talents trained this way cannot well understand or apply advanced practices such as smart supply chains, digital twins, and predictive analysis, forming a huge "Digital Divide" (Agnieszka et al., 2023). This gap has been characterized by global scholars as a core challenge in the transition from "Supply Chain Management (SCM)" to "Digital Supply Chain Management (DSCM)". Dubey & Gunasekaran (2015) emphasized that future supply chain managers must function as a hybrid of data scientists, technologists, and business strategists.

The existing system focuses excessively on execution, alongside a neglect of strategic planning. Training content needs pay more attention to strategic topics such as end-to-end (E2E) supply chain integration, supply chain finance, global supply chain governance, Environmental, Social, and Governance (ESG) and green supply chains, as well as supply chain risk governance and business continuity planning (Fernández-Migue et al, 2024; Li et al, 2019; Liu & Wei, 2022). This leads to a limited perspective among supply chain managers, and it becomes difficult for them to make forward-looking decisions in a complex international environment. The complexity of global supply chains necessitates that talents possess superior analytical, planning, and risk management competencies (Gammelgaard & Larson, 2001). Particularly in the "Volatile, Uncertain, Complex, Ambiguous" era,

competencies related to supply chain resilience and risk management have become crucial (Pettit et al, 2013). But these are exactly the deficiencies in current training content.

Additionally, soft skills including communication and coordination, cross-cultural team leadership, conflict resolution, change management, and complex negotiation are of critical importance to talents within a context of high uncertainty (Gammelgaard & Larson, 2001; Mangan & Christopher, 2005; Myerson, 2025). However, the number of existing training system remains focused on rote teaching of knowledge instruction and allocates minimal resources to the development of these soft skills that determine management effectiveness

Hypothesis 2 (H2): Content restructure positively influences talent cultivation..

Model Level: Disconnection Between Traditional Methodologies and Practical Contexts

Some enterprises continue to rely heavily on a traditional training modality that is dominated by one-way knowledge transfer approaches, such as classroom teaching and external expert lectures. This modality is characterized by low learner engagement, suboptimal knowledge retention, and an inability to foster learners' innovative thinking and competence in addressing complex problems (Vallée et al, 2020). This goes against the active learning and constructivist principles advocated by contemporary educational theory. Moreover, highly practical talent cultivation approaches, including job rotation, action learning, and project-based learning are either insufficiently applied in enterprises or implemented in a perfunctory manner. Wu & Pagell (2011) emphasized that balancing academic theories with practical experience and learning by doing is of critical importance for nurturing competent supply chain managers. As a powerful development tool, action learning has been extensively adopted in leadership development within Western enterprises, yet its in-depth integration into the supply chain domain remains inadequate.

Closed internal talent cultivation constitutes another significant deficiency. A closed-loop training system cannot adapt to the open and interconnected digital economy environment. The establishment of "University-Industry Collaboration (UIC)" with institutions of higher education and research organizations represents a key approach to bridge the gap between theory and practice, and expediting knowledge transfer (Liu, 2025; Rossoni et al, 2024; Zheng et al, 2021). Therefore, enterprises need to proactively build an open talent cultivation ecosystem, including UIC and cooperation with industry associations and leading enterprises to get higher performance (Liu, 2025; Rossoni et al, 2024). But in reality, this kind of in-depth industry-academia-research cooperation mechanism has not been widely established, and internal enabling platforms such as internal mentorship programs and knowledge communities often suffer from ineffective operation, leading to a paucity of learning resources and sluggish knowledge renewal.

Hypothesis 3 (H3): Training model innovation positively influences talent cultivation.

Methods

This paper is a conceptual review, it contributes a foundational framework that can guide future empirical research on talent cultivation within supply chains. To examine the hypothesized relationships, a cross-sectional survey design employing standardized instruments is suggested for testing the theoretical model. Future research may adopt a survey-based methodology to collect a minimum of 350 valid responses through online questionnaires administered to employees across various hierarchical levels within supply chain enterprises. These participants are expected to provide meaningful input on training content, modes of delivery, and resulting digital impacts. The representative sample should include enterprises from diverse geographic regions—including eastern, central, and western China—as well as companies of varying sizes. This approach can capture heterogeneity in regional contexts and organizational characteristics, thereby enhancing the contextual richness and external validity of the findings.

Findings & Discussions

Drawing on an in-depth understanding of issues from reviews, this paper establishes a systematic reconstruction framework for higher enterprises' performance, which is shown in the figure below.

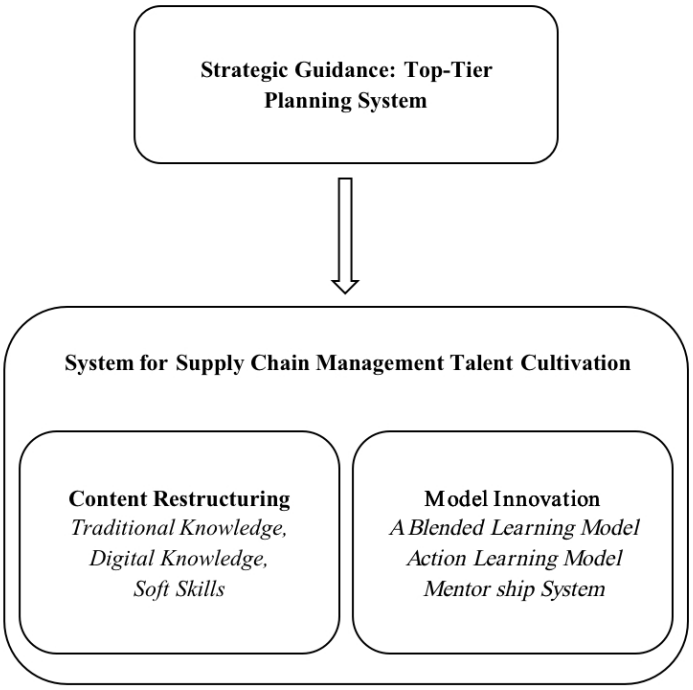

Figure 1: Reconstruction Framework for Supply Chain Management Talent Cultivation System

The primary prerequisite for system reconstruction lies inideological transformation and strategic dimension elevation. Enterprises are required to elevate the development of supply chain talent from a tactical support dimension to a strategic investment dimension. This transformation aligns with the core idea of Strategic Human Resource Management (SHRM), which holds that human resource practices need to be closely integrated with organizational strategic objectives to generate competitive advantages (Wright & McMahan, 1992). This implies that investment in systematic and modernized supply chain management talent training is not an operational cost, but a strategic priority bearing on the long-term survival and development of enterprises (Nawaiseh et al, 2025). Enterprises need to develop a hierarchical, discipline-specific dynamic competency model for supply chain talents in accordance with the demands of digital transformation (Li & Xiong, 2025). This model should comprehensively cover three pillars, traditional business knowledge, digital technology application and strategic and management soft skills. It serves to provide a clear benchmark for talent selection, development, and evaluation (Jiang et al, 2023). Regularly implementing supply chain talent inventory to identify high-potential talents, formulate personalized career development paths and talent succession plans can ensure the continuity and stability of talent supply for key positions, minimizing human resource risks.

After determining the top-level strategy and planning framework, it is necessary to fill the powerful content and adopt diversified, practical, and ecological empowerment models for implementation. Establish a "Business + Digital + Strategy" integrated knowledge content that needs to keep consolidating traditional core business knowledge, which is the foundation of supply chain management. Also, systematically incorporate advanced digital technologies into training design, and combine supply chain education with SDGs and business ethics to improve strategic management capabilities for value creation and strategic security (Setó-Pamies & Papaoikonomou, 2020). To optimize talent training, a blended learning model needs to be promoted by integrating flexible online learning platforms with in-depth interactive offline workshops and seminars, thus catering to talents' personalized and fragmented learning demands (Siripongdee & Tuntıwongwanıch, 2020). Then, enhance practice-oriented training including job rotation and cross-border practice, and focus on action learning projects addressing real business problems (Revans, 2011). Meanwhile, to establish mentorship systems, foster a coaching culture, and build sharing platforms internally, and proactively cooperate with universities or other organisations through the application of Open Innovation externally (Kankam & Dza, 2025; Liu, 2025; Zheng et al, 2021).

Conclusion

By conducting a systematic literature review, this paper indicates that the quality of supply chain talent management has a significant impact on enterprises' competitiveness and the modernization-driven upgrading of supply chains. However, Chinese enterprises currently still face multiple challenges in talent training planning, content, models, and other aspects. To build a new talent cultivation system for supply chain management that meets the needs of the digital era, Chinese enterprises can develop an integrated reconstruction framework covering three dimensions: strategy, content, and model. This framework provides an

approach for understanding and addressing these issues. A new talent cultivation system should be constructed through three major pathways: first, reshape a strategically oriented and dynamically adaptive training plan to ensure that talent cultivation keeps pace with enterprise development and industry trends; second, optimize digital, practical, and international training content to enhance talents' core competitiveness; third, innovate a blended, and full-cycle training model to strengthen talents' practical capabilities and job adaptability. It provides a systematic solution to address the shortage of supply chain talent.

Furthermore, the paper outlines directions for future research. Firstly, the integrated framework put forward in this study still needs to be verified and revised via rigorous case studies or large-sample empirical research. Especially, the differentiated challenges and adaptive strategies that enterprises of different industries and sizes may face in implementing the framework are worth further exploring. Secondly, existing literature's discussions on the quantitative evaluation mechanism of training effectiveness are relatively ambiguous. Future research can focus on developing a scientific and quantifiable indicator system to measure the ROI of supply chain talent cultivation, which may involve learning from cutting-edge methods in human resource management like Human Resource Accounting and People Analytics. Finally, regarding the specific construction of digital content, how to effectively transform rapidly updated technical knowledge into standardized internal courses and competency certifications for enterprises is also a research topic with important practical value.

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Navigating Turbulence: An Integrated Framework of Strategic Resources, Knowledge Dynamics, and Digital Readiness for Sustainable SME Performance in Emerging Markets

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Abstract

Purpose: This study develops an integrated conceptual framework examining how intangible strategic resources, specifically entrepreneurial orientation (EO), intellectual capital (IC), organizational learning (OL), and digital transformation readiness (DTR), shape small and medium-sized enterprise (SME) performance in Pakistan's manufacturing sector through knowledge sharing (KS) as the central mediating mechanism. Design/Methodology/Approach: Grounded in the Resource-Based View (RBV), Knowledge-Based View (KBV), and Dynamic Capabilities Theory (DCT), the study constructs a theoretically informed framework. Empirical validation will employ a quantitative cross-sectional survey targeting SME owners and managers in Sindh and Punjab, with data analyzed using Partial Least Squares Structural Equation Modelling (PLS-SEM). Findings: The framework proposes that EO, IC, OL, and DTR positively influence SME performance, with KS as the primary transmission mechanism. Organizational resilience is proposed as a moderator that strengthens the KS-performance link under environmental turbulence. Research Limitations/Implications: As a conceptual paper, empirical validation is needed. Cross-sectional data and geographic focus on two provinces may limit generalizability. Practical Implications: SME managers should priorities knowledge-sharing practices and digital readiness as strategic levers for performance. Policymakers can use this framework to design capability-based support programs. Originality/Value: This study offers a novel integration of RBV, KBV, and DCT tailored to Pakistani manufacturing SMEs, incorporating DTR as an emergent resource alongside established strategic constructs.

Keywords: Digital transformation readiness, Emerging markets, Entrepreneurial orientation, Environmental turbulence, Innovation performance, Intellectual capital, Knowledge sharing, Organizational learning, Organizational resilience, SME performance

Introduction

Small and medium-sized enterprises (SMEs) are widely recognised as crucial catalysts for economic development, innovation, and employment creation (Nguyen et al., 2022). In Pakistan, SMEs constitute approximately 90 percent of all business establishments, contribute nearly 40 percent to gross domestic product (GDP), and employ a substantial share of the non-agricultural workforce (Economic Survey of Pakistan, 2024). Despite this structural importance, Pakistan's manufacturing SMEs continue to face persistent challenges, including economic volatility, institutional inefficiencies, limited access to finance, and weak technological infrastructure (Ahmad et al., 2022; Bakhtiari et al., 2020). These conditions create a turbulent operating environment that undermines performance and threatens survival.

Contemporary strategic management research increasingly recognises that competitive advantage in volatile environments stems not merely from resource possession, but from superior capabilities in orchestrating, reconfiguring, and converting these resources into performance outcomes (Kusa et al., 2024; Al Koliby et al., 2024). While extensive research examines individual strategic resources such as entrepreneurial orientation (EO), intellectual capital (IC), and organizational learning (OL), scholarly understanding remains fragmented regarding how these resources interact synergistically and through what mechanisms they translate into performance (Taghizadeh et al., 2024). Moreover, the post-pandemic digital acceleration has introduced digital transformation readiness (DTR) as an emergent strategic imperative, yet its integration within established resource-performance frameworks remains theoretically underdeveloped.

Knowledge sharing (KS) has emerged as a critical mediating mechanism through which organisations convert tacit and explicit knowledge into actionable capabilities and innovative solutions (Harsono et al., 2025). Existing studies have examined KS in isolation or in partial combinations with other resources; however, a unified framework that situates KS at the intersection of multiple strategic resources and performance in a developing economy context remains absent from the literature.

This study addresses that gap by developing an integrated conceptual framework that examines how EO, IC, OL, and DTR influence SME performance through the mediating role of KS, with organisational resilience (OR) serving as a boundary condition. The study is anchored in the Resource-Based View (RBV) (Barney, 1991), the Knowledge-Based View (KBV) (Grant, 1996), and Dynamic Capabilities Theory (DCT) (Teece, 2007), thereby offering a theoretically pluralistic and contextually grounded contribution.

SME Sector of Pakistan

Pakistan's SME sector faces a distinct set of structural and environmental challenges that differentiate it from SMEs in developed economies. Information opacity, weak governance, and limited policy support hinder effective targeting and performance measurement of SME-directed interventions (Mushtaq et al., 2022). Studies show that Pakistani SMEs consistently lag behind their regional counterparts in China, India, and Bangladesh in terms of growth rate and technology adoption (Ullah et al., 2022). A significant barrier to performance improvement is the instability of the business environment, which discourages investment, constrains exports, and erodes entrepreneurial motivation (Nazir & Khan, 2022). Against this backdrop, understanding which strategic resources and capabilities can build resilience and drive performance is both theoretically important and practically urgent.

Theoretical Foundation

The Resource-Based View (RBV) posits that sustainable competitive advantage derives from valuable, rare, inimitable, and non-substitutable (VRIN) resources (Barney, 1991). In the proposed framework, EO, IC, and OL represent VRIN resources that, when effectively deployed, generate superior performance outcomes. The Knowledge-Based View (KBV) extends RBV by positioning knowledge as the most strategically significant organisational resource (Grant, 1996). KBV argues that organisations exist primarily to integrate and apply specialised knowledge, with KS serving as the fundamental integration mechanism. Dynamic Capabilities Theory (DCT) addresses how organisations sense opportunities, seize them through resource reconfiguration, and transform organisational structures to maintain competitiveness in changing environments (Teece, 2007). Together, these three theoretical perspectives provide a coherent multi-layered rationale for the proposed framework.

Research Objectives

The primary objectives of this research are: (1) to examine the influence of EO, IC, OL, DTR, and KS on SME performance; (2) to investigate the impact of EO, IC, DTR, and OL on KS; (3) to assess the mediating role of KS in the relationship between strategic resources and SME performance; and (4) to identify the moderating role of OR in the relationship between KS and SME performance.

Significance of the Study

This study makes several contributions. Theoretically, it integrates three prominent theoretical lenses (RBV, KBV, and DCT) into a unified framework customised for the Pakistani manufacturing SME context. Empirically, it introduces DTR as an explicit strategic construct within the resource-performance model, responding to calls for greater attention to digital readiness in emerging market research. Practically, the findings are expected to guide SME managers on resource allocation priorities and inform policymakers in designing capability-based support programmes.

Literature Review

SME Performance

Performance remains a central concern for all organizations, encompassing both financial and non-financial dimensions (Kusa et al., 2021). In this study, SME performance is understood through the framework suggested by Kusa et al. (2021), which integrates financial indicators such as revenue growth and market share with non-financial indicators such as customer satisfaction and innovation output. The measurement instrument is adapted from Hughes and Morgan (2007) and modified for the manufacturing SME context. In the Pakistani context, performance emerges from the integrated influence of entrepreneurial behavior, knowledge assets, and continuous learning processes, which collectively shape the firm's capacity to compete effectively and innovate under resource-constrained conditions (Matloob et al., 2023).

Entrepreneurial Orientation and SME Performance

Entrepreneurial orientation (EO) refers to a firm-level strategic posture characterized by innovativeness, proactiveness, and risk-taking (Lumpkin & Dess, 1996). EO has been widely recognized as a driver of firm performance across diverse economic contexts (Aftab et al., 2024; Kiyabo & Isaga, 2020). In Pakistan's manufacturing sector, EO-enabled firms exhibit greater ability to identify market opportunities and respond to institutional challenges, resulting in stronger financial and non-financial performance (Abbas et al., 2022; Iqbal & Malik, 2019). The present study proposes that EO positively influences both SME performance and KS.

H1: Entrepreneurial orientation has a positive and significant influence on SME performance.
H2: Entrepreneurial orientation has a positive and significant influence on knowledge sharing.

Intellectual Capital and SME Performance

Intellectual capital (IC) encompasses the sum of all knowledge resources that an organization can use to create competitive advantage, including human capital, structural capital, and relational capital (Bontis et al., 1999; Edvinsson & Sullivan, 1996). In SME contexts, IC has been shown to be a significant predictor of innovation capacity and financial performance (Bansal et al., 2023; Khalique et al., 2020). The integration of IC with KS facilitates the conversion of knowledge stocks into actionable routines and innovative outputs (Cabrilo & Dahms, 2018; Kumar et al., 2024). Firms with richer IC are better positioned to share knowledge across functional boundaries, thereby enhancing overall performance (Kim & Tran, 2024).

H3: Intellectual capital has a positive and significant influence on SME performance.
H4: Intellectual capital has a positive and significant influence on knowledge sharing.

Organizational Learning and SME Performance

Organizational learning (OL) refers to the process through which organizations acquire, interpret, distribute, and embed new knowledge into their routines and culture (Huber, 1991). As a dynamic capability, OL enables firms to continuously adapt their knowledge base in response to environmental change (Eisenhardt & Martin, 2000). In SME settings, OL is particularly important because it compensates for limited formal structures by building adaptive capacity and facilitating informal knowledge exchange (Kasim et al., 2018). Research confirms that OL positively affects performance through its role in building organizational resilience and sustaining innovation (Do et al., 2022; Kordab et al., 2020).

H5: Organizational learning has a positive and significant influence on SME performance.
H6: Organizational learning has a positive and significant influence on knowledge sharing.

Digital Transformation Readiness and SME Performance

Digital transformation readiness (DTR) refers to an organization's preparedness to adopt and integrate digital technologies into its core operations and strategic processes (Ahmed et al., 2022). The post-pandemic business environment has accelerated the necessity for digital readiness, particularly for SMEs operating in volatile emerging markets (Jaish et al., 2023). DTR enables firms to access new information channels, improve operational efficiency, and respond more rapidly to market shifts, all of which contribute to better performance outcomes (Cabrilo et al., 2024). Furthermore, digitally ready firms tend to exhibit higher levels of KS because digital platforms lower the barriers to knowledge exchange across organizational units (Jalil et al., 2025).

H7: Digital transformation readiness has a positive and significant influence on SME performance.
H8: Digital transformation readiness has a positive and significant influence on knowledge sharing.

Knowledge Sharing as a Mediator

Knowledge sharing (KS) refers to the deliberate exchange of information, experiences, and insights among organizational members to generate collective competence (Duan et al., 2021). Within the KBV framework, KS represents the primary mechanism through which specialized knowledge is integrated and applied to create value (Grant, 1996). Empirical studies confirm that KS mediates the relationship between strategic resources and performance outcomes by translating resource endowments into actionable capabilities (Hanifah et al., 2022; Ha et al., 2021). The proposed framework extends this logic by positioning KS as the central mediating mechanism linking EO, IC, OL, and DTR to SME performance.

H9: Knowledge sharing mediates the relationship between entrepreneurial orientation and SME performance.
H10: Knowledge sharing mediates the relationship between intellectual capital and SME performance.

H11: Knowledge sharing mediates the relationship between organizational learning and SME performance.

H12: Knowledge sharing mediates the relationship between digital transformation readiness and SME performance.

Organizational Resilience as a Moderator

Organizational resilience (OR) refers to a firm's capacity to absorb disturbances, recover from adverse events, and adapt successfully to new and shifting circumstances (Kantur & Iseri-Say, 2012). In turbulent environments, OR functions as a higher-order dynamic capability that amplifies the effectiveness of resource-driven behaviors (Damiano & Valenza, 2025; Evenseth et al., 2022). The present study proposes that OR moderates the relationship between KS and SME performance, such that the positive effect of KS on performance is stronger in firms with higher resilience. This moderating effect is particularly relevant in Pakistan's volatile manufacturing environment, where external shocks frequently disrupt established knowledge flows.

H13: Organizational resilience positively moderates the relationship between knowledge sharing and SME performance, such that the effect is stronger when resilience is higher.

Environmental Turbulence as a Moderator

Environmental turbulence refers to the rate and unpredictability of change in a firm's external environment, encompassing market volatility, technological shifts, and regulatory instability (McKee et al., 1989). High levels of turbulence can either stimulate or constrain the performance effects of strategic resources, depending on the firm's adaptive capacity (Taghizadeh et al., 2024; Imran et al., 2016). In the proposed framework, environmental turbulence serves as a boundary condition that influences the strength of the KS-performance relationship, particularly in contexts characterized by rapid institutional and market change, as experienced by Pakistani manufacturing SMEs.

Research Framework

The framework positions EO, IC, OL, and DTR as antecedent strategic resources that positively influence SME performance. Knowledge sharing occupies the central mediating role, transmitting the effects of these resources to performance outcomes. Organizational resilience and environmental turbulence are incorporated as moderating variables that condition the strength of the KS-performance relationship. This integrated design reflects the theoretical logic of RBV, KBV, and DCT working in concert.

Methodology

This study adopts a quantitative research design consistent with the positivist paradigm, which is appropriate for testing relationships among theoretically derived constructs (Bougie & Sekaran, 2019). A cross-sectional survey approach will be employed to collect primary data from SME owners, managers, and senior executives operating in the manufacturing sector of Pakistan, with a geographic focus on the provinces of Sindh and Punjab. The unit of analysis is the individual organization.

Data collection will combine online questionnaires administered via Google Forms with physical distribution of hard-copy questionnaires to respondents who may have limited internet access. The survey instrument will remain open for a minimum of three weeks, and the full data collection process is estimated to require at least two months. A purposive sampling strategy will target businesses registered as SMEs under the Small and Medium Enterprises Development Authority (SMEDA) definition.

All measurement items are adapted from validated scales in the existing literature. EO is measured using items adapted from Lumpkin and Dess (1996) and Covin and Lumpkin (2011). IC items are derived from Khalique et al. (2020) and Bansal et al. (2023). OL is measured using Bontis et al. (2002) and Huber (1991). DTR items are adapted from Ahmed et al. (2022). KS is measured using Hanifah et al. (2022). OR is measured using Kantur and Say (2015), and SME performance is measured using Kusa et al. (2021). Independent, mediator, and moderator variables are recorded on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), while SME performance is captured on a seven-point Likert scale to improve measurement precision (Taherdoost, 2019).

Data analysis will be conducted using Partial Least Squares Structural Equation Modelling (PLS-SEM) through SmartPLS 4. PLS-SEM is suitable for this study because it accommodates small-to-medium sample sizes, handles non-normal data distributions, and is well suited to predictive and exploratory frameworks (Hoe, 2008). The analysis will proceed in two stages: first, a measurement model assessment to evaluate reliability and validity, followed by a structural model assessment to test the hypothesized relationships.

Common Method Variance

Because the study relies on self-reported data from a single source, common method variance (CMV) poses a potential methodological concern. Several procedural remedies will be implemented to reduce this risk. These include the use of two different response scales (five-point for independent variables and seven-point for performance), assurances of respondent anonymity, clear and simple item wording, and temporal and psychological separation of constructs within the questionnaire (Kock et al., 2021). Statistical post hoc tests such as Harman's single-factor test will also be conducted to detect the presence of CMV.

Discussion

The integrated framework proposed in this study offers several theoretical contributions. First, by combining RBV, KBV, and DCT into a single coherent model, the study addresses the fragmented treatment of strategic resources in prior SME research. Most existing studies examine EO, IC, or OL in isolation or in bilateral combinations; the present framework considers all four resources simultaneously, thereby capturing the synergistic effects that may be lost when constructs are studied independently.

Second, the introduction of DTR as an explicit antecedent resource responds to growing calls in the literature for greater attention to digital capabilities in emerging market research (Jaish et al., 2023; Cabrilo et al., 2024). The post-pandemic environment has fundamentally altered the competitive landscape for manufacturing SMEs, and DTR is now as important a strategic resource as EO or IC in determining performance trajectories.

Third, the positioning of KS as a mediator connects the resource endowment literature with the knowledge management literature in a way that has practical significance for SME managers. Rather than treating KS as an outcome or an independent driver, this framework recognizes it as a transmission channel, a conceptualization that is more aligned with how knowledge actually flows in real organizations (Kusa et al., 2024).

Fourth, the inclusion of OR and environmental turbulence as boundary conditions acknowledges the context-dependent nature of resource-performance relationships. In Pakistan's volatile manufacturing environment, the strength of any resource-driven effect is unlikely to remain constant across different levels of external shock. This moderated-mediation design therefore offers greater explanatory precision than simple mediation models (Taghizadeh et al., 2024).

Conclusion

This paper develops an integrated conceptual framework that explains how strategic resources, specifically EO, IC, OL, and DTR, influence the performance of manufacturing SMEs in Pakistan through knowledge sharing mechanisms, with organizational resilience and environmental turbulence serving as critical boundary conditions. The framework is grounded in the Resource-Based View, the Knowledge-Based View, and Dynamic Capabilities Theory, providing a theoretically coherent and contextually relevant model.

The proposed framework provides both theoretical advancement and practical guidance for Pakistani manufacturing SMEs operating in post-pandemic turbulent environments. The study fills a recognized gap in the literature by treating multiple strategic resources in an integrated manner, positioning knowledge sharing as the central mediating mechanism, and incorporating digital transformation readiness as an emergent construct.

Future empirical research should test and validate this framework using primary survey data from manufacturing SMEs in Pakistan and other comparable emerging economies. Longitudinal designs would also strengthen causal inferences and capture the time-dependent nature of knowledge accumulation and resilience building. Additional research could extend the framework to service sector SMEs and examine whether the proposed relationships hold across different industry environments.

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