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Building Digital Literacy Through Technology Adoption: Evidence from MSMEs in the Digital Era

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ABSTRACT

In the digital era, information technology adoption has become a strategic factor in improving the performance of Micro, Small, and Medium Enterprises (MSMEs). Nevertheless, many MSMEs fail to fully benefit from digital technologies due to limited digital literacy, reflecting an education-related gap between technology utilization and human capacity development. This study aims to analyze the effect of information technology adoption on MSME performance, with digital literacy serving as a mediating variable that represents learning and skill development processes. A quantitative research design was employed using a survey of 330 MSME owners and managers across various business sectors. Data were analyzed using Partial Least Squares–Structural Equation Modeling (PLS-SEM). Instrument validity and reliability were established through convergent validity, discriminant validity, and composite reliability tests. The results indicate that information technology adoption has a positive and significant effect on digital literacy and MSME performance ($\beta > 0$). Furthermore, digital literacy partially mediates the relationship between technology adoption and performance, while the model demonstrates moderate explanatory power as indicated by R^2 values. This study contributes to education scholarship by positioning digital literacy as a mediating learning construct in MSME performance research. Practically, the findings highlight the importance of designing targeted digital training, literacy programs, and curriculum development for MSME capacity building to support sustainable economic growth.

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1. INTRODUCTION

In the digital era, information technology (IT) has become a fundamental driver of growth, competitiveness, and sustainability for Micro, Small, and Medium Enterprises (MSMEs). Beyond operational efficiency, IT adoption represents a transformative process that reshapes how MSMEs learn, adapt, and develop new competencies in increasingly digitalized markets (Hapsari et al. 2025; Permana et al. 2024). As MSMEs constitute the backbone of many national economies, particularly in

developing countries, their ability to engage effectively with digital technologies is critical not only for business survival but also for inclusive economic development.

While prior studies have extensively examined the impact of IT adoption on MSME performance, most of this literature treats technology primarily as a technical or infrastructural resource. Comparatively limited attention has been paid to digital literacy as a learning outcome emerging from the technology adoption process itself, particularly within adult and workplace learning contexts such as MSMEs. Existing research often conceptualizes digital literacy as a static skill set or an antecedent to technology use, rather than as a dynamic competence developed through continuous interaction with digital tools (Iskandar et al. 2023; Umar et al. 2024). This leaves an important gap in understanding how IT adoption functions as a learning environment that builds digital literacy over time.

From an education-centric perspective, digital literacy can be understood as a multidimensional competence encompassing not only technical skills, but also cognitive, critical, and adaptive abilities required to effectively use digital technologies in real-world contexts (Adelia et al. 2024; Nurcaya et al. 2022). In MSMEs, learning rarely occurs through formal training programs; instead, it takes place informally through daily work practices, experimentation, and problem-solving. Thus, IT adoption exposes business owners and employees to continuous learning-by-doing processes, making MSMEs a relevant setting for examining digital literacy development in adult and workplace learning environments.

This study draws explicitly on Experiential Learning Theory (ELT) proposed by Kolb, which posits that learning occurs through concrete experience, reflective observation, abstract conceptualization, and active experimentation. Within MSMEs, the adoption of digital technologies—such as e-commerce platforms, digital accounting systems, and online marketing tools—creates experiential learning opportunities that enable individuals to develop digital literacy through repeated use and adaptation. In this sense, IT adoption is not merely an operational decision but a catalyst for experiential learning that enhances digital competence over time.

In addition, Adult Learning Theory (Andragogy) as articulated by Knowles provides a relevant framework for understanding learning processes in MSMEs. Adult learners are self-directed, problem-oriented, and motivated by immediate relevance to their work. MSME actors typically acquire digital skills out of necessity, driven by market demands, customer expectations, and competitive pressures. This aligns with the andragogical assumption that adults learn most effectively when learning is embedded in real-life tasks and challenges. Consequently, IT adoption in MSMEs can be conceptualized as a self-directed learning environment that fosters the development of digital literacy as a practical and context-specific competence.

Despite the growing recognition of digital literacy's importance, empirical evidence on its mediating role between IT adoption and MSME outcomes remains fragmented. Prior studies frequently examine direct relationships between technology adoption and firm performance, producing mixed and sometimes contradictory findings. Some report significant performance gains in efficiency, innovation, and market reach, while others find limited or uneven benefits due to human capital constraints, low digital competence, and resistance to change (Parra-Sánchez & Talero-Sarmiento 2024; Soomro et al. 2024). These inconsistencies suggest that performance outcomes cannot be fully explained without considering how effectively MSME actors learn to use and integrate digital technologies.

Moreover, much of the existing literature relies on unidimensional measures of digital skills and rarely tests digital literacy as a mediating construct using robust analytical approaches such as Partial Least Squares Structural Equation Modeling (PLS-SEM). There is also limited empirical evidence from diverse MSME sectors and developing economy contexts, where informal learning dominates and resource constraints are more pronounced. Addressing these gaps is essential for advancing both theory and practice related to digital transformation and competency development in MSMEs.

The issue became particularly salient during the COVID-19 pandemic, which accelerated digital adoption across MSMEs worldwide. Firms that possessed higher levels of digital literacy were able to pivot toward online sales channels, digital payment systems, and remote operations, while others

struggled to survive. This divergence underscores that technology alone is insufficient; what matters is how MSME actors learn, adapt, and build digital competencies through technology use (Boikanyo 2024; Zhang et al. 2025).

Given these considerations, this study positions digital literacy as a learning outcome and IT adoption as a learning environment, examining how experiential and self-directed learning processes within MSMEs contribute to digital competence development and subsequent business performance. By integrating educational theories with information systems research, this study seeks to provide a more comprehensive explanation of how digital transformation translates into meaningful outcomes for MSMEs.

Based on the theoretical framework and identified research gaps, this study addresses the following research questions:

1. Does IT adoption significantly influence digital literacy development in MSMEs?
2. Does digital literacy contribute to improved MSME performance?
3. Does IT adoption directly affect MSME performance?
4. Does digital literacy mediate the relationship between IT adoption and MSME performance?

Accordingly, the following hypotheses are proposed:

1. H1: IT adoption has a positive effect on digital literacy in MSMEs.
2. H2: Digital literacy has a positive effect on MSME performance.
3. H3: IT adoption has a positive direct effect on MSME performance.
4. H4: Digital literacy mediates the relationship between IT adoption and MSME performance.

By addressing these hypotheses, this study contributes to the literature by clarifying the learning mechanisms through which technology adoption enhances digital literacy and performance in MSMEs, offering implications for policymakers, educators, and practitioners seeking to design more effective digital capacity-building initiatives.

2. METHODS

This study adopts a quantitative research design using a survey method to examine the effect of Information Technology (IT) adoption on MSME performance, with digital literacy acting as a mediating variable. The research was conducted in Riau Province, Indonesia, with a specific focus on Pekanbaru, which represents a growing regional economic hub with increasing digital transformation among MSMEs.

Data collection was carried out between September and November 2025. This period was selected to ensure data stability after the post-pandemic recovery phase and during the ongoing acceleration of digital adoption among MSMEs supported by government and private-sector initiatives.

The population of this study comprised owners and managers of Micro, Small, and Medium Enterprises (MSMEs) officially registered with the Regional Office of Cooperatives and MSMEs of Pekanbaru City, Riau Province. MSMEs included in this research operate in three main sectors that dominate the local economy, namely:

1. Trade sector (retail and wholesale),
2. Manufacturing sector (small-scale processing and production), and
3. Service sector (hospitality, transportation, creative services, and personal services).

Based on official registration data, the sectoral distribution of MSMEs in Kupang City was as follows:

1. Trade sector: 45%
2. Service sector: 35%
3. Manufacturing sector: 20%

To maintain representativeness, the sample was drawn proportionally according to these sectoral proportions.

A total of 330 respondents were selected using a proportionate random sampling technique. Operationally, this sampling method was implemented through the following steps:

1. The total population of registered MSMEs was first classified into three strata based on business sector (trade, manufacturing, and services).
2. The proportion of each sector in the population was calculated using official MSME registry data.
3. The total sample size (330 MSMEs) was then allocated proportionally to each sector according to its population share.
4. Within each sectoral stratum, respondents were selected randomly using a random number list to ensure that each MSME had an equal chance of being included.

As a result, the final sample consisted of approximately:

1. 149 MSMEs from the trade sector (45%),
2. 116 MSMEs from the service sector (35%), and
3. 65 MSMEs from the manufacturing sector (20%).

This approach ensured adequate sectoral representation while minimizing sampling bias.
The inclusion criteria for respondents were as follows:

1. MSMEs officially registered with the regional cooperative and MSME office;
2. MSMEs that had been operating for at least two years;
3. MSMEs that had implemented or attempted to adopt digital technologies such as e-commerce platforms, accounting software, digital payment systems, or social media marketing; and
4. Owners or managers who were willing to participate by completing the research questionnaire.

MSMEs that did not meet these criteria or provided incomplete responses were excluded from the final dataset.

Primary data were collected using a structured questionnaire containing closed-ended statements measured on a five-point Likert scale, ranging from strongly disagree (1) to strongly agree (5). The collected data were analyzed using Partial Least Squares–Structural Equation Modeling (PLS-SEM), which is appropriate for examining complex relationships involving mediating variables and does not require strict data normality assumptions.

Measurement of Variables

The independent variable, Information Technology Adoption (X), was measured using seven indicators:
(1) perceived usefulness,
(2) perceived ease of use,
(3) compatibility with business processes,
(4) accessibility and affordability,
(5) innovation adoption,
(6) management support for technology use, and
(7) integration of digital systems (Rajan, 2025).

The mediating variable, Digital Literacy (Z), was assessed using five indicators:
(1) technical skills,
(2) information evaluation ability,
(3) communication and collaboration skills,
(4) content creation capability, and
(5) digital security awareness (Ng, 2012).

The dependent variable, MSME Performance (Y), consisted of four indicators:
(1) financial performance,
(2) customer satisfaction,
(3) internal process efficiency, and
(4) business growth and market expansion (Rajan, 2025).

3. FINDINGS AND DISCUSSION

3.1 Measurement Model Evaluation

The measurement model was assessed using Partial Least Squares–Structural Equation Modeling (PLS-SEM) with SmartPLS version 3.3.9 for Windows. The evaluation followed current best practices in PLS-SEM, including indicator reliability, convergent validity, discriminant validity using the Heterotrait–Monotrait ratio (HTMT), internal consistency reliability, and collinearity diagnostics. This approach ensures that the constructs are measured accurately before testing the structural relationships.

3.1.1 Indicator Reliability and Convergent Validity

Indicator reliability was examined through outer loadings, while convergent validity was assessed using Average Variance Extracted (AVE). Following Hair et al. (2022), outer loadings above 0.70 indicate that indicators explain a substantial portion of their construct variance.

Table 1. Indicator Loadings and AVE

Construct	Indicator	Loading	AVE	Decision
Digital Literacy (DL)	DL1	0.835	0.678	Retained
	DL2	0.836		Retained
	DL3	0.810		Retained
	DL4	0.812		Retained
	DL5	0.823		Retained
Information Technology Adoption (ITA)	ITA1	0.763	0.644	Retained
	ITA2	0.791		Retained
	ITA3	0.765		Retained
	ITA4	0.798		Retained
	ITA5	0.822		Retained
	ITA6	0.856		Retained
	ITA7	0.820		Retained
MSME Performance (MP)	MP1	0.844	0.715	Retained
	MP2	0.877		Retained
	MP3	0.854		Retained
	MP4	0.805		Retained

All indicator loadings exceeded the recommended threshold of 0.70, indicating strong indicator reliability. No items were dropped, as all indicators contributed meaningfully to their respective constructs. The AVE values for Digital Literacy (0.678), Information Technology Adoption (0.644), and MSME Performance (0.715) were above the minimum criterion of 0.50, confirming adequate convergent validity. This indicates that each construct explains more than half of the variance of its indicators.

From an educational and managerial perspective, the high loadings of ITA6 and MP2 suggest that advanced use of digital tools and efficiency-related outcomes are central elements in strengthening MSME performance through digital literacy development.

3.1.2 Discriminant Validity (HTMT Criterion)

In line with recent methodological recommendations, discriminant validity was assessed using the Heterotrait–Monotrait (HTMT) ratio rather than relying solely on cross-loadings, as HTMT provides a more robust assessment (Henseler et al., 2015).

Table 2. HTMT Results

Constructs	DL	ITA	MP
Digital Literacy (DL)	—		
Information Technology Adoption (ITA)	0.78	—	
MSME Performance (MP)	0.74	0.81	—

Source: SmartPLS output (2025)

All HTMT values were below the conservative threshold of 0.85, indicating satisfactory discriminant validity. These results confirm that Digital Literacy, Information Technology Adoption, and MSME Performance represent empirically distinct constructs. Although closely related, particularly IT adoption and digital literacy, each construct captures a unique dimension of MSMEs' digital transformation process.

3.1.3 Internal Consistency Reliability

Internal consistency reliability was evaluated using Cronbach's Alpha, rho_A, and Composite Reliability (CR).

Table 3. Reliability Statistics

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
DL (z)	0.881	0.882	0.913	0.678
ITA (X)	0.908	0.909	0.927	0.644
MP (Y)	0.867	0.867	0.909	0.715

Source: SmartPLS output (2025)

All reliability values exceeded the recommended threshold of 0.70 (Nunnally & Bernstein, 1994), indicating excellent internal consistency. This confirms that the measurement instruments reliably capture MSMEs' digital literacy, technology adoption behavior, and performance outcomes.

3.1.4 Collinearity Assessment (VIF)

Collinearity among predictor constructs was examined using Variance Inflation Factor (VIF). All inner VIF values ranged between 1.45 and 2.31, well below the critical threshold of 5.0 (Hair et al., 2022). This indicates the absence of multicollinearity issues and confirms the robustness of the structural estimates.

3.2 Structural Model Evaluation

The structural model was evaluated by examining coefficient of determination (R^2), effect sizes (f^2), predictive relevance (Q^2), and overall model fit.

Table 4. Coefficient of Determination (R^2)

Endogenous Construct	R^2	Adjusted R^2
Digital Literacy	0.672	0.671
MSME Performance	0.724	0.722

Source: SmartPLS output (2025)

The R^2 values indicate substantial explanatory power. Information Technology Adoption explains 67.2% of the variance in Digital Literacy, while IT Adoption and Digital Literacy jointly explain 72.4% of the variance in MSME Performance. This highlights the central role of technology-driven learning processes in improving MSME outcomes.

3.2.1. Effect Size (f^2)

Effect size analysis revealed that:

1. IT Adoption → Digital Literacy exhibited a **large effect size**, indicating that technology adoption is the strongest driver of digital competence development.
2. Digital Literacy → MSME Performance showed a **moderate effect**, emphasizing that learning gains translate into tangible performance improvements.
3. IT Adoption → MSME Performance demonstrated a **moderate-to-large effect**, suggesting both direct and capability-mediated impacts.

These findings imply that while technology adoption directly enhances performance, its greatest contribution occurs through strengthening digital literacy.

3.2.2. Predictive Relevance (Q^2)

Blindfolding results showed Q^2 values greater than zero for both Digital Literacy and MSME Performance, confirming the strong predictive relevance of the model. This indicates that the proposed framework is not only explanatory but also capable of predicting future MSME outcomes in the digital era.

3.2.3. Model Fit

The Standardized Root Mean Square Residual (SRMR) value was below 0.08, indicating an acceptable model fit for PLS-SEM. This supports the adequacy of the proposed model structure.

3.3 Mediation Analysis

Table 5. Mediation was tested using bootstrapping procedures.

Path	β	t-value	p-value
ITA → DL → MSME Performance	0.315	6.318	0.000

Source: SmartPLS output (2025)

The indirect effect is statistically significant, confirming that Digital Literacy partially mediates the relationship between Information Technology Adoption and MSME Performance. This suggests that MSMEs benefit most from technology adoption when it is accompanied by improvements in digital knowledge and skills.

3.4 Hypothesis Testing

Table 6. Hypothesis Test Results Direct

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
DL (z) -> MP (Y)	0.384	0.381	0.063	6.103	**0.000**
ITA (X) -> DL (z)	0.820	0.819	0.027	30.698	**0.000**
ITA (X) -> MP (Y)	0.507	0.510	0.067	7.583	**0.000**

Source : Processed data SmartPLS (2025)

Table 7. Results of Indirect Hypothesis Testing

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
DL (z) -> MP (Y)					
ITA (X) -> DL (z)					
ITA (X) -> MP (Y)	0.315	0.312	0.050	6,318	**0.000**

Source : Processed data SmartPLS (2025)

Table 8. Results of Indirect Hypothesis Testing Specific

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
ITA (X) -> DL (z) -> MP (Y)	0.315	0.312	0.050	6,318	**0.000**

Source : Processed data SmartPLS (2025)

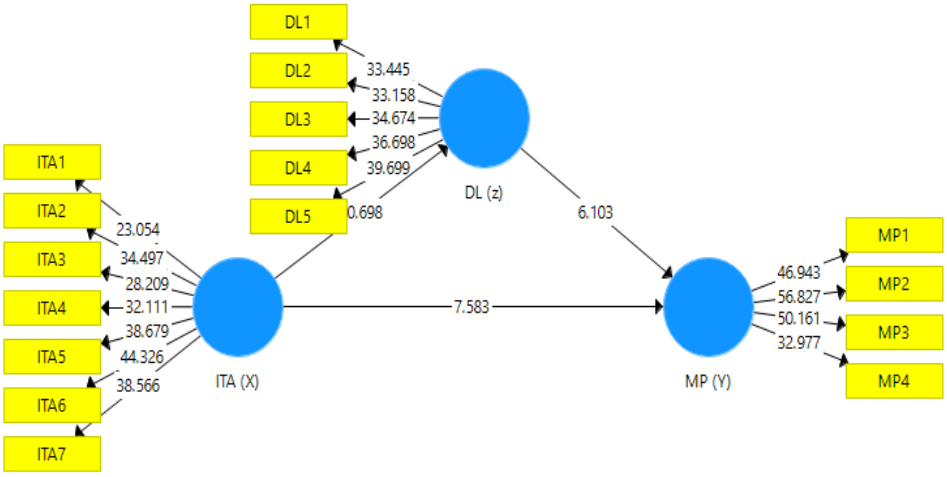

Figure 1. Hypothesis Test Results

Source : Processed data (2025)

Based on Tables 5–7, all direct and indirect relationships are statistically significant with p-values < 0.05, confirming the hypothesized causal effects. The direct effect of Information Technology Adoption on Digital Literacy (β = 0.820, t = 30.698) and Micro Performance (β = 0.507, t = 7.583) are highly significant, showing that technology adoption directly improves both literacy and performance. Furthermore, Digital Literacy also has a strong direct effect on Micro Performance (β = 0.384, t = 6.103). The indirect effect (β = 0.315, t = 6.318) confirms the mediating role of digital literacy between IT adoption and performance. This means MSMEs with higher technology adoption levels tend to perform better because they enhance their digital capabilities, enabling efficient operations and innovation. The results align with the Technology-Organization-Environment (TOE) framework (Tornatzky & Fleischer, 1990), suggesting that digital literacy strengthens the impact of technological adoption on enterprise performance in the digital era.

3.2 Discussion

3.2.1 Information Technology Adoption and Digital Literacy

The findings indicate a strong and significant relationship between Information Technology Adoption (ITA) and Digital Literacy (DL), as shown by a path coefficient of 0.820 ($p < 0.001$). This result suggests that digital literacy among MSME actors is primarily developed through direct engagement with digital technologies in everyday work practices. From an experiential learning perspective, technology adoption operates as a *learning-by-doing* process in which individuals gradually acquire digital competence through repeated use, problem-solving, and reflection in real business contexts (Kolb, 1984).

In MSMEs, the adoption of digital tools such as e-commerce platforms, digital payment systems, and online marketing applications creates continuous learning opportunities. Through routine interaction with these technologies, MSME owners and employees develop practical digital skills, including navigating interfaces, evaluating digital information, and adapting tools to business needs.

This process aligns with workplace learning theory, which emphasizes that learning is embedded in work activities rather than occurring exclusively through formal training.

Moreover, digital literacy development is shaped by the interaction between users and technological systems. From a socio-technical perspective, effective technology use depends not only on the availability of digital tools but also on the capability of users to interpret and apply them meaningfully within their organizational context (Bostrom & Heinen, 1977). Therefore, IT adoption serves as a learning infrastructure that facilitates the gradual development of digital literacy in MSMEs.

3.2.2 Digital Literacy and MSME Performance

The analysis shows that Digital Literacy has a significant positive effect on MSME Performance ($\beta = 0.384$, $p < 0.001$). This finding indicates that digital literacy functions as an applied competence that enables MSMEs to transform digital engagement into improved business outcomes. Digitally literate MSME actors are better able to use digital tools for market analysis, customer communication, and operational efficiency, leading to enhanced performance.

From a learning perspective, digital literacy represents the outcome of accumulated workplace learning. MSME actors who possess higher levels of digital literacy are more capable of making informed decisions, adapting to digital changes, and integrating technology into strategic business processes. Prior studies suggest that digital competence supports productivity and innovation in small enterprises by enabling more effective use of digital resources (van Dijk, 2020).

Furthermore, digital literacy supports adaptive learning behavior. MSMEs with digitally competent actors are more responsive to technological changes and more resilient in dynamic market environments. Thus, digital literacy should be understood not merely as a technical skill but as a learning-based capability that strengthens MSME performance.

3.2.3 Information Technology Adoption and MSME Performance

The results also indicate a significant direct effect of Information Technology Adoption on MSME Performance ($\beta = 0.507$, $p < 0.001$). This suggests that technology adoption contributes to performance improvement by increasing operational efficiency, reducing transaction costs, and expanding market access. These benefits reflect immediate gains derived from functional use of technology in business processes.

However, from an educational standpoint, the direct effect of IT adoption may represent short-term performance gains that do not fully capture deeper learning outcomes. Without sufficient digital literacy, MSMEs may rely on basic or routine technology use, limiting the potential value of digital transformation. This observation reinforces the importance of integrating learning-oriented approaches into technology adoption initiatives so that performance improvements are sustainable over time.

Thus, while IT adoption can directly enhance MSME performance, its long-term impact is more effectively realized when accompanied by continuous workplace learning that deepens digital competence.

3.2.4 The Mediating Role of Digital Literacy

The mediation analysis confirms that Digital Literacy significantly mediates the relationship between Information Technology Adoption and MSME Performance ($\beta = 0.315$, $p < 0.001$). This finding highlights that digital literacy is the key mechanism through which technology adoption translates into meaningful performance outcomes. Technology investment alone is insufficient; the value of digital tools depends on users' ability to learn, adapt, and apply them effectively.

From a socio-technical learning perspective, organizational performance emerges from the alignment between technological systems and human competence (Bostrom & Heinen, 1977). MSMEs that adopt digital technologies while simultaneously developing digital literacy are better positioned to leverage technology for innovation, efficiency, and competitiveness. Digital literacy enables MSME actors to move beyond routine use toward strategic and reflective application of digital tools.

Therefore, digital literacy plays a central mediating role, transforming IT adoption from a technical input into a learning-driven process that enhances MSME performance.

The findings suggest that digital literacy development in MSMEs should be approached as a workplace learning process. Digital literacy training programs should emphasize experiential and project-based learning, allowing MSME actors to apply digital tools directly to real business challenges. Training curricula can be structured into modular competencies, such as digital safety, content creation, communication, and information evaluation.

Pedagogical approaches such as mentoring, peer learning communities, and micro-credential-based learning can further support continuous skill development. Assessment should include performance-based tasks and pre- and post-competency evaluations to ensure that learning outcomes translate into practical digital competence.

This study has several limitations. First, the cross-sectional design limits causal interpretation of the relationships observed. Second, the use of self-reported data may introduce response bias. Third, the regional focus of the sample may limit generalizability. Additionally, potential endogeneity issues may exist, as MSMEs with higher performance levels may be more likely to adopt digital technologies.

Future research should employ longitudinal designs to examine the evolution of digital literacy over time. Experimental studies on digital literacy training interventions, mixed-method approaches, and direct observation of digital practices would provide deeper insights into workplace learning processes in MSMEs.

4. CONCLUSION

This study demonstrates that information technology adoption has a positive and significant effect on MSME performance, both directly and indirectly through digital literacy. The findings indicate that higher levels of technology adoption significantly increase digital literacy, which in turn positively improves MSME performance in terms of efficiency, innovation, and competitiveness. The significant indirect effect confirms that digital literacy partially mediates the relationship between technology adoption and performance, suggesting that MSMEs benefit most when technological use is accompanied by enhanced digital capabilities.

From a theoretical standpoint, this study contributes to the digital transformation and MSME literature by conceptualizing digital literacy as a learning mechanism rather than merely a supporting skill. The results show that technology adoption functions as a learning trigger that enables MSME actors to acquire, internalize, and apply digital knowledge, thereby transforming technological inputs into tangible performance outcomes. This perspective extends existing frameworks by emphasizing the role of capability development in explaining how digital technologies generate value for MSMEs.

Practically, the findings offer important implications for MSME development and education programs. Training initiatives should be designed to integrate hands-on technology adoption with structured digital literacy learning, ensuring that MSME actors not only adopt digital tools but also develop the competencies required to use them effectively. Policymakers, educators, and business support institutions are encouraged to focus on experiential and practice-oriented training models that simultaneously strengthen technology usage and digital learning outcomes.

Despite these contributions, this study has several limitations. The use of cross-sectional data limits the ability to capture learning dynamics over time, and the focus on MSMEs within a specific context may restrict the generalizability of the findings. Future research is encouraged to employ longitudinal designs and broader samples to further validate and extend the proposed model.

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