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The Impact of Robotics and Artificial Intelligence on Entrepreneurial Skills Development and Marketing Innovation

Efa Wakhidatus Solikhah¹, Riky Dwi Puriyanto²

¹²Universitas Ahmad Dahlan, Yogyakarta, Indonesia

Correspondence: efa.solikhah@mgm.uad.ac.id¹

Abstract

The rapid advancement of robotics and artificial intelligence (AI) has transformed business operations and accelerated digital innovation among technology startups. However, limited studies have simultaneously examined the roles of AI adoption, technological infrastructure, and digital entrepreneurship literacy in shaping digital entrepreneurial capability, marketing innovation, and entrepreneurial performance. This study investigates these relationships within technology startups in Yogyakarta, Indonesia. A quantitative approach was employed using survey data collected from startup founders, managers, and directors. The data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS. The findings reveal that robotics and AI adoption significantly enhances digital marketing innovation but does not have a significant effect on digital entrepreneurial capability. Technological infrastructure positively influences both digital marketing innovation and digital entrepreneurial capability, while digital entrepreneurship literacy significantly improves digital entrepreneurial capability but shows no significant impact on digital marketing innovation. Furthermore, digital marketing innovation and digital entrepreneurial capability positively contribute to entrepreneurial performance. These findings highlight that the benefits of robotics and AI adoption are primarily realized through innovation-oriented mechanisms rather than direct capability development. This study contributes to the digital entrepreneurship literature by providing empirical evidence from technology startups in an emerging digital ecosystem and emphasizing the importance of infrastructure readiness and entrepreneurial literacy in improving organizational performance.

KEYWORDS

artificial intelligence; digital marketing; entrepreneur; innovation; robotics adoption

Introduction

The evolution of robotics and artificial intelligence (AI) over the past decade has driven substantial changes in organizational operations and the dynamics of business competition (Stone et al., 2020). The digital transformation occurring across various sectors requires businesses to adopt intelligent technology to improve efficiency, accuracy, and adaptability to market dynamics (Solikhah et al., 2024). Within the technology startup sector, especially among emerging companies in Yogyakarta as one of Indonesia's rapidly expanding digital ecosystem hubs, the implementation of robotics and artificial intelligence has emerged as a crucial element in enhancing organizational competitiveness within the business environment. Beyond facilitating process automation, these technologies also create new possibilities for advanced data analytics, customer personalization, and the design of innovative business models (Muqtafi et al., 2023). This situation requires businesses to have more mature digital entrepreneurial skills to manage technology strategically and sustainably.

From the perspective of Resource-Based View (RBV), technological resources such as robotics and AI can serve as valuable organizational assets that create competitive

advantage when effectively combined with complementary capabilities and organizational resources (Barney et al., 2001). Furthermore, Dynamic Capabilities Theory suggests that firms must continuously integrate, develop, and reconfigure internal and external resources to respond effectively to rapidly changing digital environments (Teece et al., 1997). Consequently, the successful utilization of intelligent technologies depends not only on technology adoption itself but also on supporting factors such as technological infrastructure and digital entrepreneurship literacy.

The utilization of robotics and AI contributes to enhancing entrepreneurial skill development through various mechanisms. These intelligent technologies allow organizations to generate more accurate data-driven insights, thereby supporting faster and more accurate decision making activities. Implementation of robotics on operational processes helps startups achieve time and cost efficiencies, ultimately strengthening their innovation capacity (Solikhah et al., 2022). Access to various cloud-based AI platforms provides startup managers and leaders with the opportunity to explore digital creativity in product, service, and marketing strategy development. Thus, technology adoption not only increases productivity but also fosters a more adaptive and innovative entrepreneurial mindset.

AI technology has proven to be a key driver of innovation in digital marketing. AI enables personalized messages, real-time consumer behavior analysis, use of intelligent chatbots for customer service, and the strengthening of data-driven content strategies (Stone et al., 2020). For technology startups, the ability to leverage AI in marketing activities can help improve customer engagement, expand market reach, and strengthen competitive advantage. The integration of robotics and AI in marketing also enables entrepreneurs to design more relevant, rapid, and effective communication strategies, thereby impacting overall business performance (Solikhah et al., 2023). Nevertheless, the effectiveness of AI and robotics implementation is often influenced by the availability of technological infrastructure and the digital competencies possessed by entrepreneurs and managers. Inadequate infrastructure, limited technological readiness, and insufficient digital literacy may reduce the benefits generated from intelligent technology adoption.

Although previous studies have investigated the relationships among AI adoption, digital entrepreneurship, innovation, and business performance, most studies have examined these variables separately or within different industrial and geographical contexts. Limited empirical evidence is available regarding how robotics and AI adoption, technological infrastructure, and digital entrepreneurship literacy simultaneously influence digital entrepreneurial capability, marketing innovation, and entrepreneurial performance within technology startups operating in emerging digital ecosystems. Furthermore, existing findings regarding the effect of intelligent technology adoption on entrepreneurial capability remain inconclusive, suggesting the need for additional empirical investigation. Yogyakarta provides a relevant context for this study because it has emerged as one of Indonesia's growing digital startup ecosystems, supported by more than 140 technology startups, strong university-based innovation networks, and high internet penetration exceeding 89%. However, despite this favorable ecosystem, many technology startups continue to encounter challenges related to AI adoption, technological infrastructure readiness, digital entrepreneurial literacy, and the capability to translate digital technologies into sustainable marketing innovation and entrepreneurial performance. These practical challenges highlight the importance of examining how technological, infrastructural, and human capital factors interact to enhance startup competitiveness in

Yogyakarta.

Based on these considerations, this study aims to examine the influence of robotics and artificial intelligence adoption, technological infrastructure, and digital entrepreneurship literacy on digital entrepreneurial capability, digital marketing innovation, and entrepreneurial performance among technology startups in Yogyakarta. By integrating technological, organizational, and human-capital perspectives within a single framework, this study seeks to provide empirical evidence that contributes to the digital entrepreneurship literature and offers practical insights for technology startups seeking to improve innovation and business performance in an increasingly competitive digital environment.

Methods

A systematic methodological framework is applied to investigate the relationships between robotics and AI adoption, entrepreneurial capabilities, digital marketing innovation, and startup performance. Well structured research design is key to ensuring validity and dependability data analysis procedure. Therefore, quantitative research design is employed to objectively examine the interrelationships among variables through statistical techniques. This part explains the overall methodological structure of the study, including participant selection procedures, respondent sampling strategies, data acquisition processes, and applied to evaluate the conceptual framework formulated.

Research Type

Quantitative study:

A quantitative research design is applied to investigate the empirical relationships among robotics and artificial intelligence adoption, digital entrepreneurial capability, digital marketing innovation, and entrepreneurial performance. The quantitative approach was chosen because it provides objective measurements of the relationships between variables through statistical analysis based on structural models (Long & Nelson, 2013). Given that this study employs a cross-sectional survey design and Partial Least Squares Structural Equation Modeling (PLS-SEM), the findings should be interpreted as statistical associations rather than definitive evidence of causal relationships.

Literature review:

Various theoretical perspectives and empirical studies are reviewed to explore the contribution of intelligent technologies, especially robotics and AI, in strengthening entrepreneurial competencies and encouraging the emergence of innovative digital marketing practices within the rapidly evolving digital transformation landscape. The accelerated advancement of digital technology has fundamentally changed the manner in which businesses, especially startup enterprises, organize operational activities, generate innovation, and sustain their competitive position in the marketplace. Therefore, synthesizing existing literature on robotics and AI adoption, digital entrepreneurship skills, technology-oriented marketing innovation, entrepreneurial outcomes, and supporting elements such as digital literacy and infrastructure provides a fundamental basis for the formulation of the theoretical framework. By integrating diverse theoretical perspectives and empirical evidence from prior research, this literature review establishes a comprehensive conceptual foundation to clearly and thoroughly explain the relationships among the research variables within the context of technological advancement and the evolving digital entrepreneurship ecosystem.

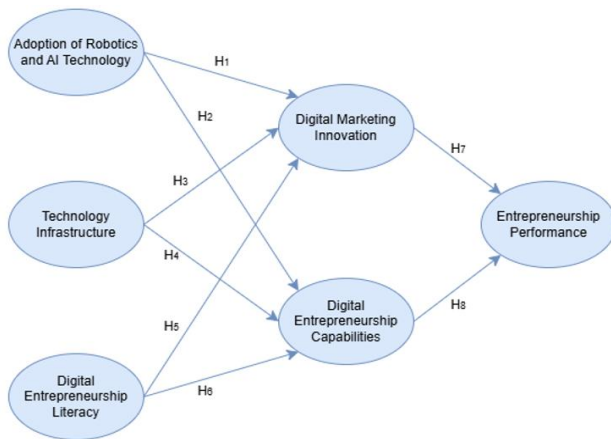


Figure 1. Research Model

Figure 1 presents the conceptual framework of the study. This model is used to analyze the relationship between technology adoption, digital resource readiness, and their impact on marketing innovation and entrepreneurial performance. The framework was developed to illustrate implementation robotics and artificial intelligence, supported by sufficient technological infrastructure and strong digital entrepreneurial literacy, can strengthen digital entrepreneurial competencies and stimulate marketing innovation, ultimately leading to improved entrepreneurial performance. This research framework also contains eight research hypotheses (H₁–H₈) formulated to explain the causal connections among the variables within the scope of digital transformation on entrepreneurial practices. Formulation of the research hypotheses (H₁–H₈) as illustrated in Figure 1 is as follows.

H₁: The adoption of robotics and artificial intelligence technology has a positive effect on digital marketing innovation.

H₂: The adoption of robotics and artificial intelligence technology has a positive effect on digital entrepreneurial capabilities.

H₃: Technological infrastructure has a positive effect on digital marketing innovation.

H₄: Technological infrastructure has a positive effect on digital entrepreneurial capabilities.

H₅: Digital entrepreneurial literacy has a positive effect on digital marketing innovation.

H₆: Digital entrepreneurial literacy has a positive effect on digital entrepreneurial capabilities.

H₇: Digital marketing innovation has a positive effect on entrepreneurial performance.

H₈: Digital entrepreneurial capabilities have a positive effect on entrepreneurial performance.

Robotics and Artificial Intelligence Technology in Business

Robotics and artificial intelligence (AI) have increasingly become critical components in shaping digital transformation within various sectors. Robotics refers to automated systems capable of performing physical tasks precisely and consistently, while AI focuses on the ability of machines to mimic human thought patterns through learning, pattern recognition, and data analysis (Omar et al., 2020). Both technologies have exerted a substantial influence on contemporary business operations, with a strong emphasis on improving efficiency, reducing errors, and accelerating production and service processes (Solikhah et al., 2024). Numerous literature confirms that the integration of robotics and AI can improve the quality of managerial decisions by processing large-scale data that humans cannot perform quickly and accurately. This technology is even beginning to

be considered a key competitive advantage for digital-oriented technology startups.

Within startups, robotics technology is commonly implemented to handle operational functions such as managing inventory, ensuring quality control, and automating service delivery. AI, on the other hand, is more dominantly used for analytics, chatbot-based customer service, product personalization, and market prediction. Research conducted by (Dirican, 2015) demonstrates that startups with the ability to implement these technologies tend to be more prepared to respond to digital market changes, since these tools support the development of agile, adaptive, and data-oriented organizational systems. Thus, the adoption of robotics and AI aims not only to replace human labor but also to expand the organization's capacity to innovate and improve the effectiveness of business strategies.

Entrepreneurship Skills Development in the Digital Era

Entrepreneurial skills are a set of abilities needed to identify opportunities, innovate, manage risks, and make strategic decisions in a competitive business environment. In the digital era, literature suggests that entrepreneurial skills cannot rely solely on creativity or intuition; they must be combined with digital literacy, technological understanding, and data-driven analytical skills (Adeniyi et al., 2023). Digital entrepreneurial competencies involve the capacity to apply technology for business innovation, organize and interpret customer data, optimize digital marketing platforms, and maintain flexibility and responsiveness amid the continuously evolving digital business (Kraus et al., 2019).

Several determinants contribute to the growth of technology-oriented entrepreneurial skills, including familiarity with intelligent technologies, training in digital entrepreneurship, and practical experience in applying AI-based applications (Gregori & Holzmänn, 2020). Empirical evidence indicates that individuals possessing strong digital literacy are more capable of leveraging robotics and artificial intelligence (AI) to enhance innovative thinking, improve process efficiency, and increase the quality of decision-making. Furthermore, digital entrepreneurial competencies contribute to improved creativity and problem-solving abilities by enabling entrepreneurs to recognize emerging possibilities derived from data and technological resources. These competencies commonly serve as a critical element separating organizations that successfully adapt and maintain market existence from those that eventually lose their competitive viability.

Digital Marketing Innovation and the Role of AI Technology

Digital marketing innovation refers to marketing strategies that utilize digital technology to improve communication effectiveness, expand markets, and create more personalized customer experiences. AI significantly drives marketing innovation through its ability to process real-time customer data, understand individual preferences, and provide relevant recommendations (Nambisan, 2017). Various studies demonstrate that AI can strengthen marketing strategies through automated segmentation, message personalization, consumer behavior prediction, and campaign optimization based on measurable performance.

The contributes of robotics extends to experiential marketing, including the deployment of service robots and interactive technological solutions in promotional events. In technology startups, digital marketing innovation is often realized using machine learning for demand forecasting, automate customer journeys, create intelligent content, and integrate chatbots into customer service. Literature written by (Nair & Gupta, 2021) given that technology can strengthen brand image, increase engagement, and significantly increase conversion rates compared to traditional marketing. Thus, digital marketing innovation is a crucial variable bridging the

Table 1. Construct Indicators and Measurement Sources

Variable	Indicator	Source
Adoption of Robotics and AI Technology	1. Level of intelligent robotics use in business operations	(Huang & Rust, 2021)
	2. Level of AI-based work process automation	(Davenport et al., 2020)
	3. Utilization of AI for data analysis and decision-making	(Shrestha et al., 2019)
Developing Digital Entrepreneurship Capability	1. Digital innovation capabilities	(Nambisan, 2017)
	2. Creativity in digital business	(Kraus et al., 2019)
	3. Digital market analysis capabilities	(Nambisan, 2017)
	4. Technology-based decision-making	(Kraus et al., 2019)
Digital Marketing Innovation	1. Developing technology-based marketing strategies	(Hollebeek et al., 2022)
	2. Using AI for marketing personalization	(Davenport et al., 2020)
	3. Implementing digital marketing tools (SEO, SEM, digital CRM)	(Omar et al., 2020)
Entrepreneurial Performance	1. Business growth	(Wiklund & Shepherd, 2005)
	2. Increased turnover	(Lumpkin & Dess, 1996)
	3. Increased market share	(Et.al, 2021)
	4. Customer satisfaction	(Homburg et al., 2005)
	5. Business competitiveness	(Wiklund & Shepherd, 2005)
Digital Entrepreneurship Literacy	1. Level of understanding of digital technology	(Upadhyay et al., 2023)
	2. Technology-based entrepreneurship training	(Rae, 2006)
Technology Infrastructure	1. Availability of internet and digital networks	(Nambisan, 2017)
	2. Access to technology and digital devices	(Schulze-Horn et al., 2020)
	3. Financial and ecosystem support	(Spigel, 2017)

influence of intelligent technology on improving business performance.

Entrepreneurial Performance as a Strategic Outcome

Entrepreneurial performance reflects the overall success of a business, covering dimensions such as growth, profitability, market share, competitiveness, and customer satisfaction. Existing research highlights the important role of technological factors in improving entrepreneurial performance, notably in startups where innovation capabilities are a primary driver of success (Gregori & Holzmänn, 2020; Solikhah et al., 2024). Robotics and AI technologies support operational improvements, enable faster and more accurate decisions, and expand marketing strategy opportunities, ultimately contributing to higher performance.

Research by (Dess et al., 1997) confirms that technology-driven marketing innovation is a key determinant of performance. Startups that leverage AI in market mapping and service personalization tend to exhibit higher revenue growth and better customer retention rates. Similarly, digital entrepreneurial competencies are regarded as strategic internal capabilities that improve a startup's ability to respond effectively to emerging market opportunities and intensifying competitive pressures. Thus, connections among technology, skills, marketing innovation, and entrepreneurial performance is relevant for empirical research.

Digital Literacy and Technology Infrastructure

Various literature emphasizes that the effectiveness of robotics and AI utilization is significantly influenced by the digital literacy of business actors. Higher levels of digital literacy enable individuals to better comprehend technological potential, make more effective use of it, and reduce the likelihood of unsuccessful implementation (Adeniyi et al., 2024). Furthermore, technology-based entrepreneurship education helps shape innovative mindsets, digital competencies, and adaptive behaviors that meet the demands of modern industry (Spigel, 2017). Technological infrastructure support is also a crucial factor. Startups require fast internet access, adequate technological tools, and ecosystem support such as business incubators or digital funding (see Table 1). Robust infrastructure enables intelligent technology to operate optimally and magnify its impact on innovation and performance. Therefore, digital literacy and infrastructure are often positioned as moderating

variables that strengthen the relationship between technology adoption and business outcomes.

Population and Sample/Informants

Technology startups located in the Yogyakarta area constitute the population of the research. Respondents were startup managers, founders, or directors who play a role in strategic decision-making related to technology use and marketing strategies.

A purposive sampling technique was employed because the study required respondents who possessed adequate knowledge and experience regarding the implementation of digital technologies within startup organizations (Campbell et al., 2020). The inclusion criteria were: (1) occupying a managerial, founder, or director position; (2) having direct involvement in business development and technology-related decisions; and (3) possessing sufficient understanding of organizational innovation and digital business practices. Respondents who did not meet these criteria were excluded from the study. The survey was distributed to 250 eligible respondents representing 135 technology startups in Yogyakarta, resulting in 200 valid responses and a response rate of 80.0%. The participating startups operated across several sectors, including information technology and software development (38%), digital commerce and financial technology (27%), digital creative industries (18%), education technology (10%), and other technology-based services (7%). Regarding the respondent profile, 45% were founders, 35% were managers, and 20% were directors, with all respondents actively involved in strategic business development and technology-related decision-making within their organizations. The final sample size exceeded the minimum requirement for Partial Least Squares Structural Equation Modeling (PLS-SEM), ensuring adequate statistical power for hypothesis testing and structural model estimation.

Research Location

The research was conducted among technology startups located in Yogyakarta, Indonesia. This region was selected because it represents one of Indonesia's emerging startup ecosystems, supported by universities, business incubators, innovation communities, and increasing digital transformation initiatives. Yogyakarta provides a relevant context for examining how robotics and artificial intelligence adoption, technological infrastructure, and digital entrepreneurship

literacy contribute to marketing innovation and entrepreneurial performance within technology-based enterprises.

Instrumentation or Tools

Structured survey instruments were employed using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) (Joshi et al., 2015). The questionnaire consisted of 20 measurement items distributed across six constructs: Adoption of Robotics and Artificial Intelligence Technology (3 items), Technology Infrastructure (3 items), Digital Entrepreneurship Literacy (2 items), Digital Marketing Innovation (3 items), Digital Entrepreneurial Capability (4 items), and Entrepreneurial Performance (5 items). The measurement items were adapted from validated studies and refined for the technology startup context. Representative items included AI utilization in business decisions, adequacy of digital infrastructure, digital entrepreneurship knowledge, digital marketing innovation, digital opportunity exploitation, and business growth. The questionnaire was translated using a translation back-translation procedure and pilot-tested with 30 startup practitioners to ensure clarity and content validity. Before participating, respondents provided informed consent and were assured that participation was voluntary, responses remained anonymous and confidential, and the data would be used solely for academic research.

Prior to the main survey, the questionnaire was reviewed to ensure clarity, readability, and suitability for the startup context. Participation was voluntary, and respondents were informed that all information would be treated confidentially and used solely for academic purposes.

Data Collection Procedures

Data were collected through an online questionnaire distributed to startup managers, founders, and directors who satisfied the inclusion criteria. The survey was conducted over a period of three months (April – June 2025). Before completing the questionnaire, respondents were provided with information regarding the purpose of the study and informed consent procedures. After the data collection process was completed, all responses were screened for completeness and consistency prior to statistical analysis. Only valid and complete questionnaires were included in the final dataset.

Data Analysis

The collected data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS software (Wong, 2013). PLS-SEM was selected because the study aimed to simultaneously examine multiple relationships among latent constructs within a predictive research framework. In addition, PLS-SEM is appropriate for complex research models involving multiple endogenous variables and performs effectively in exploratory and theory-development studies.

Result and Discussion

Prior to evaluating the structural model, the research instrument was initially assessed through validity and reliability testing based on the distributed questionnaires. SmartPLS 4.0 was employed to examine the loading factor values of indicator for validity evaluation purposes. Indicators are categorized as valid when their loading factor values exceed 0.50 (see Table 2).

The measurement model was evaluated by examining indicator reliability, convergent validity, internal consistency reliability, discriminant validity, and collinearity using SmartPLS 4.0. Indicator reliability was assessed through

outer loadings, with values above 0.50 considered acceptable for exploratory research and values above 0.70 regarded as preferable (Wong, 2013). Validity testing confirms that all indicators are acceptable, as each variable demonstrates loading factor values above the 0.5 threshold. Therefore, the data are considered acceptable, enabling all indicators to be included in the next phase of analysis. Convergent validity was further confirmed by Average Variance Extracted (AVE) values exceeding 0.50, while internal consistency reliability was established through Composite Reliability values above 0.70 and Cronbach's Alpha values above 0.70. Discriminant validity was assessed using the Fornell–Larcker criterion and the HTMT ratio, whereas multicollinearity was examined using Variance Inflation Factor (VIF) values, all of which satisfied the recommended thresholds (see Table 3).

The reliability assessment indicates that all constructs demonstrate satisfactory internal consistency, with Cronbach's Alpha and Composite Reliability values exceeding the recommended threshold of 0.70. Furthermore, all Average Variance Extracted (AVE) values are greater than 0.50, confirming adequate convergent validity. These results indicate that the measurement model is reliable and valid, supporting the use of all constructs for subsequent structural model analysis.

Path Analysis Research Model Testing

In Partial Least Squares (PLS), weight estimates for latent variable scores are obtained from the inner and outer models, where the outer model represents how each indicator is linked to its corresponding construct. Structural model is subsequently evaluated to analyze the relationships among constructs (Wong, 2013). The results obtained from the model evaluation are summarized in Figure 2.

Furthermore, the acceptance or rejection of each hypothesis is determined by the obtained significance probability, the significance level value is $\alpha = 5\%$ (0.05) (Wong, 2013). The empirical outcomes obtained through the analysis are methodically organized and presented in tabular form below (see Table 4).

The bootstrapping output from the SmartPLS structural model analysis indicates that most relationships among the investigated variables show statistically significant effects. Robotics and artificial intelligence (AI) technology adoption demonstrates a positive and significant effect on digital marketing innovation ($\beta = 0.501$; $T = 4.715$; $p < 0.001$), but does not significantly influence digital entrepreneurial capability ($\beta = 0.035$; $T = 0.462$; $p = 0.644$). Technology infrastructure positively affects both digital marketing innovation ($\beta = 0.249$; $T = 2.580$; $p = 0.010$) and digital entrepreneurial capability ($\beta = 0.561$; $T = 6.679$; $p < 0.001$). Digital entrepreneurship literacy does not significantly influence digital marketing innovation ($\beta = 0.140$; $T = 1.569$; $p = 0.117$), but has a positive and significant effect on digital entrepreneurial capability ($\beta = 0.335$; $T = 4.206$; $p < 0.001$). Digital marketing innovation positively influences entrepreneurial performance ($\beta = 0.262$; $T = 2.679$; $p = 0.008$), while digital entrepreneurial capability also has a significant positive effect on entrepreneurial performance ($\beta = 0.579$; $T = 7.641$; $p < 0.001$). In addition, the structural model was evaluated using the coefficient of determination (R^2), effect size (f^2), predictive relevance (Q^2), and inner Variance Inflation Factor (VIF). The results indicate satisfactory explanatory power and predictive relevance, while all inner VIF values were below the recommended threshold, suggesting that multicollinearity was not a concern in the structural model. Overall, the structural model demonstrates acceptable predictive capability and supports the proposed research framework.

Table 2. Validity Test Results

Variable	Item	Loading Factor	Information
Adoption of Robotics and AI Technology (ADOP)	ADOP1	0.857	Valid
	ADOP2	0.772	Valid
	ADOP3	0.902	Valid
Technology Infrastructure (INFR)	INFR1	0.856	Valid
	INFR2	0.817	Valid
	INFR3	0.813	Valid
Digital Entrepreneurship Literacy (LT)	LT1	0.810	Valid
	LT2	0.832	Valid
Digital Marketing Innovation (INOV)	INOV1	0.808	Valid
	INOV2	0.809	Valid
	INOV3	0.771	Valid
Digital Entrepreneurship Capability (KAPA)	KAPA1	0.789	Valid
	KAPA2	0.776	Valid
	KAPA3	0.780	Valid
	KAPA4	0.744	Valid
Entrepreneurship Performance (KK)	KK1	0.761	Valid
	KK2	0.697	Valid
	KK3	0.761	Valid
	KK4	0.818	Valid
	KK5	0.800	Valid
Acceptable Limits		> 0,5	Accepted

Table 3. Reliability Test Results

Variable	Item	Construct Reliability	AVE
Adoption of Robotics and AI Technology (ADOP)	ADOP1	0.882	0.715
	ADOP2		
	ADOP3		
Technology Infrastructure (INFR)	INFR1	0.868	0.687
	INFR2		
	INFR3		
Digital Entrepreneurship Literacy (LT)	LT1	0.805	0.674
	LT2		
Digital Marketing Innovation (INOV)	INOV1	0.839	0.634
	INOV2		
	INOV3		
Digital Entrepreneurship Capability (KAPA)	KAPA1	0.855	0.596
	KAPA2		
	KAPA3		
	KAPA4		
Entrepreneurship Performance (KK)	KK1	0.878	0.591
	KK2		
	KK3		
	KK4		
	KK5		

Adoption of Robotics and Artificial Intelligence Technology Has a Positive Impact on Digital Marketing Innovation

Implementation of robotics and artificial intelligence (AI) technologies has been shown to positively influence digital marketing innovation. These findings suggest that greater

utilization of intelligent technologies in startup operations enhances a company's ability to develop innovative, technology-based marketing strategies. Robotics and AI enable companies to analyze consumer data more accurately, identify market behavior patterns, and enhance the effectiveness of marketing communication strategies through real-time optimization (Et.al, 2021). With the support of this technology, businesses are able to develop marketing content that is more personalized, relevant, and responsive to customer needs (Omar et al., 2020). This is crucial in the competitive startup ecosystem, as technology-based marketing innovation can increase promotional effectiveness,

expand digital market reach, and strengthen interactions between companies and consumers.

The incorporation of artificial intelligence into digital marketing activities enhances an organization's capacity to provide highly customized promotional content while streamlining the automation of marketing communication processes (Dirican, 2015). AI technology enables companies to leverage big data analytics, product recommendation systems, and chatbots to enhance customer experiences in a more interactive and responsive manner. Thus, the incorporation of robotics and artificial intelligence extends beyond merely functioning as tools for operational automation, as it also acts as a fundamental catalyst in fostering more efficient, responsive, and customer-centric digital marketing innovations within the continuously evolving digital business landscape.

Adoption of Robotics and Artificial Intelligence Technology Does Not Have a Significant Effect on Digital Entrepreneurial Capability

Adoption of robotics and artificial intelligence technology does not have a significant impact on digital entrepreneurship capabilities. This is indicated by a path coefficient value of 0.035, accompanied by a T-statistic of 0.462 and a P-value of 0.644, which is above the 0.05 significance level. These findings indicate the extent to which the utilization of robotics and AI technology in technology startups has not directly improved the digital entrepreneurship capabilities of entrepreneurs. This may occur because the use of intelligent technology often focuses on operational efficiency, work process automation, or data processing, thus not being fully integrated into the development of strategic entrepreneurial capabilities such as business model creativity, technology-based decision-making, or innovative exploration of digital opportunities (Davenport et al., 2020).

Furthermore, this insignificant relationship may also be influenced by human resource readiness and varying levels of digital literacy within startups. Even though robotics and AI technology are available, digital entrepreneurship capabilities still require managerial competencies, entrepreneurial experience, and strong data interpretation skills to strategically leverage the technology (Huang & Rust, 2021). This result contradicts the findings of (Upadhyay et al., 2023), the effectiveness of digital technology adoption is significantly shaped by human capacity in embedding such technologies into organizational decision-making and innovation activities. Therefore, strengthening digital entrepreneurial capability necessitates not only technological investment but also the enhancement of human resource skills alongside the establishment of an innovation driven organizational culture.

Technological Infrastructure Has a Positive Impact on Digital Marketing Innovation

Analysis indicates that technological infrastructure has a positive and significant influence on digital marketing innovation. This is evidenced by a path coefficient of 0.249, a T-statistic of 2.580, and a P-value of 0.010, which falls below the 0.05 threshold. This findings show higher availability and better quality of a startup's technological infrastructure are associated with a stronger ability to develop digital marketing innovation. Adequate technological infrastructure, such as a stable internet network, cloud-based computing systems, and integrated digital platforms, enables companies to manage customer data more effectively and develop marketing strategies that are more closely aligned with market demands (Spigel, 2017). With such technological backing, startups can utilize a range of digital marketing instruments like data analytics platforms, channels, and automation systems to develop more targeted and innovative communication strategies.

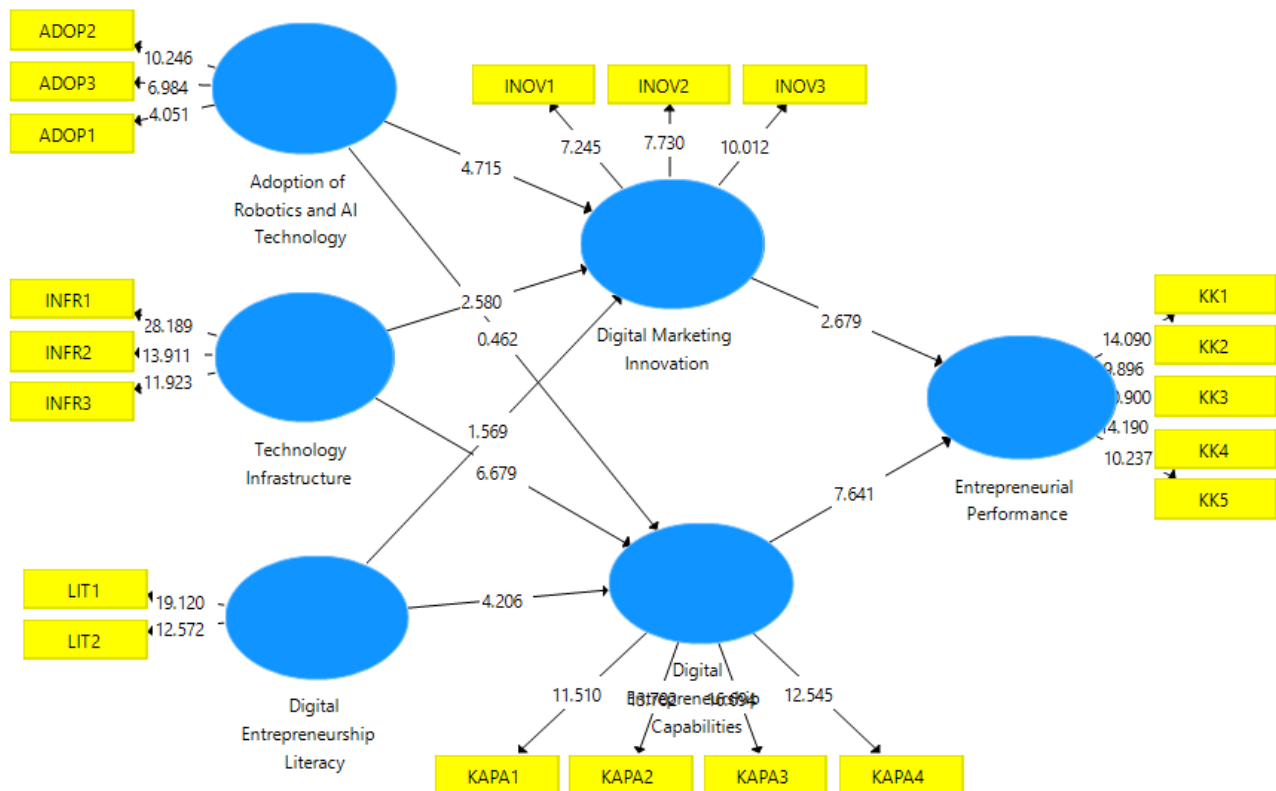


Figure 2. SmartPLS Path Analysis

Table 4. Path Model Significance Test Results

Variable	Original Sample (O)	Sample average (M)	Standard Deviation (STDEV)	T-Statistic (O/STDEV)	P	Information
ADOP → INOV	0.501	0.481	0.106	4.715	0.000	Accepted
ADOP → KAPA	0.035	0.025	0.076	0.462	0.644	Not Accepted
INFR → INOV	0.249	0.248	0.096	2.580	0.010	Accepted
INFR → KAPA	0.561	0.564	0.084	6.679	0.000	Accepted
LIT → INOV	0.140	0.139	0.089	1.569	0.117	Not Accepted
LIT → KAPA	0.335	0.338	0.080	4.206	0.000	Accepted
INOV → KK	0.262	0.0245	0.098	2.679	0.008	Accepted
KAPA → KK	0.579	0.578	0.076	7.641	0.000	Accepted

Furthermore, a robust technological infrastructure also encourages companies to be more proactive in exploring various digital marketing opportunities. A strong infrastructure enables the integration of various digital marketing platforms, simplifying the process of personalizing marketing messages, managing digital content, and evaluating marketing campaign performance in real time. This provides a competitive advantage for startups in facing increasingly dynamic market competition. In line with research by (Nair & Gupta, 2021), who emphasize adequate digital technology infrastructure is important to facilitating innovation, data-driven digital marketing strategies. This infrastructure enables organizations to optimally leverage digital technology to improve customer engagement and broaden their market reach more effectively.

Technological Infrastructure Positively Influences Digital Entrepreneurship Capabilities

This study shows a path coefficient of 0.561, a T statistic of 6.679, and a P value of 0.000, which is below of 0.05. This shows stronger a startup's technological infrastructure, the greater its capacity to develop digital entrepreneurial capabilities. Technological infrastructure, such as a stable

internet network, cloud-based computing systems, and access to various digital platforms, enables entrepreneurs to quickly obtain market information, analyze business data more accurately, and develop technology-based business strategies (Nambisan, 2017). With this infrastructural support, startups are able to strengthen their innovativeness in designing digital business models, accelerate organizational decision-making processes, and improve adaptive capacity in responding to rapidly changing and dynamic business environments.

Furthermore, adequate technological infrastructure also serves as a critical foundation for building digital entrepreneurial competencies. Access to digital technology not only simplifies business operations but also opens up opportunities for entrepreneurs to explore innovative products, services, and data-driven marketing strategies (Schulze-Horn et al., 2020). A robust infrastructure enables the integration of various digital systems, supporting collaboration, information management, and the development of business ideas more effectively. This research finding is consistent with the study by (Nambisan, 2017), emphasizes that the presence of digital technological infrastructure constitutes a crucial determinant in improving both organizational and individual capacity to utilize technology for innovation purposes as well as to

reinforce entrepreneurial competencies within the digital context.

Digital Entrepreneurship Literacy Has a Positive Impact on Digital Marketing Innovation

Digital entrepreneurship literacy does not significantly influence digital marketing innovation. This is indicated by a T-statistic of 1.569 and a P-value of 0.117, which exceeds the 0.05 threshold. Accordingly, H5 is not supported, indicating that digital entrepreneurship literacy alone is insufficient to directly stimulate digital marketing innovation. These results suggest that the degree of digital entrepreneurship literacy possessed by startup managers remains inadequate to directly foster innovative marketing practices. Although entrepreneurs possess knowledge of digital technologies, the implementation of marketing innovation still depends on other supporting factors, such as technological infrastructure, data analytics capabilities, organizational resources, and practical experience in executing digital marketing strategies (Kraus et al., 2019). This finding also explains why digital entrepreneurship literacy significantly enhances digital entrepreneurial capability (H_6), as literacy primarily strengthens entrepreneurs' knowledge, skills, and decision-making competencies rather than directly generating marketing innovation. Therefore, digital entrepreneurship literacy should be viewed as an enabling capability that supports innovation indirectly through improved entrepreneurial capability, rather than as a direct driver of digital marketing innovation.

Furthermore, digital marketing innovation in technology startups is often more influenced by the technology used, resource availability, and the dynamics of the highly competitive digital market. While digital entrepreneurship literacy provides entrepreneurs with the knowledge base to understand technological opportunities, the marketing innovation process requires experimental skills, strategic creativity, and adequate technological support. Research by (Upadhyay et al., 2023), indicates that digital literacy functions as a fundamental knowledge base for technology utilization; however, its effective application is highly contingent upon organizational conditions, experiential learning, and the technological readiness of entrepreneurs. Consequently, the advancement of digital marketing innovation is not solely dependent on digital entrepreneurial literacy, but also requires the presence of a supportive technological ecosystem and well-aligned implementation strategies.

Digital Entrepreneurship Literacy Has a Positive Impact on Digital Entrepreneurship Capabilities

Digital entrepreneurship literacy has a positive and significant influence on digital entrepreneurial capabilities. This is demonstrated by a path coefficient of 0.335, along with a T-statistic of 4.206 and a P-value of 0.000, indicating statistical significance as it is below the 0.05 cutoff value. These findings suggest higher level digital entrepreneurship literacy possessed by startups, the greater their capacity to develop digital-based entrepreneurial capabilities. Digital entrepreneurship literacy enables entrepreneurs to understand various digital technology concepts, utilize digital platforms in business activities, and identify technology-based market opportunities (Rae, 2006). With this understanding, startups can improve their ability to design innovative business models, analyze digital consumer behavior, and make strategic decisions that are more adaptive to changes in the business environment.

Furthermore, digital entrepreneurship literacy also acts as an essential foundation for developing entrepreneurial competencies in digital transformation period. Knowledge of data-driven technologies and strategic business practices

allows entrepreneurs to utilize technological resources more efficiently in generating organizational value. Accordingly, digital entrepreneurship literacy does not merely enhance technical understanding, but also strengthens the capability to generate innovation, create value, and build sustainable business ventures. These results align with (Gregori & Holzmann, 2020), highlight digital literacy as a core competency that equips individuals with the ability to comprehend, assess, and effectively utilize digital technologies in diverse activities, including the enhancement of entrepreneurial capabilities within the digital business context.

Digital Marketing Innovation Has a Positive Impact on Entrepreneurial Performance

Digital marketing innovation exerts a positive and significant influence on entrepreneurial performance. This is supported by a path coefficient of 0.262, a T-statistic of 2.679, and a P-value of 0.008, indicating statistical significance as lower than the 0.05. These findings suggest greater levels of digital marketing innovation adopted by startups are associated with higher entrepreneurial performance. Digital marketing innovation enables firms to leverage a range of digital technologies, including social media, data analytics, and online marketing platforms, to enhance customer engagement and broaden market reach (Hollebeek et al., 2022). By adopting innovative marketing, firms become more capable of conveying product value effectively, strengthening customer loyalty, and enhancing their competitive positioning within an increasingly dynamic digital marketplace (Solikhah et al., 2023).

Furthermore, digital marketing innovation also enables startups to optimize the use of technology in delivering a more personalized and responsive customer experience. By leveraging technologies such as consumer behavior analysis, content personalization, and digital marketing platforms, companies can develop more targeted and efficient marketing strategies. This impacts sales growth, customer satisfaction, and overall business competitiveness. Study by (Omar et al., 2020) show emphasize digital marketing innovation allows firms to exploit technological resources and customer data in order to make effectiveness marketing strategies and upgrade overall business performance within the digital economy context.

Digital Entrepreneurship Capabilities Have a Positive Influence on Entrepreneurial Performance

The results of the analysis demonstrate that digital entrepreneurial capability significantly and positively contributes to entrepreneurial performance outcomes. This is evidenced by a path coefficient of 0.579, a T-statistic of 7.641, and a P-value of 0.000, which falls below the 0.05 threshold. The results indicate that stronger digital entrepreneurial capability within startups is associated with improved levels of entrepreneurial performance. Digital entrepreneurial capability reflects the entrepreneur's ability to utilize digital technology to identify market opportunities, develop innovative business models, and make data-driven strategic decisions (Kim & Jin, 2024). With these capabilities, startups can improve operational efficiency and expand market coverage.

Furthermore, digital entrepreneurial capability holds a vital role in facilitating innovation processes and the development of sustainable business strategies. Entrepreneurs with strong digital competencies tend to exhibit higher adaptability toward technological changes and evolving consumer demands, thereby enabling them to design and implement more efficient strategies in marketing and product development. This competency further allows firms to effectively utilize a range of digital platforms to improve customer engagement and reinforce their competitive standing in the marketplace. This research finding aligns with (Kim & Jin, 2024), digital

entrepreneurial capabilities enable companies to leverage digital technology to create new business value, increase innovation, and strengthen entrepreneurial performance within the digital economy ecosystem.

Limitations and Cautions

This research is constrained by a number of limitations that must be carefully considered when drawing conclusions from its results. To begin with, this study examined exclusively technology startups within the Yogyakarta area; therefore, its findings may not fully reflect the circumstances of startups across other regions with differing digital ecosystem characteristics. Therefore, generalizing the results requires caution, especially when applied to industrial or regional contexts with varying levels of technological development and ecosystem support.

Furthermore, this study adopted data gathered via a questionnaire instrument that captures respondents' perceptual assessments. This approach may lead to subjective bias, as respondents' answers largely depend on each individual's understanding and experience in utilizing robotics and applying artificial intelligence (AI) within their business activities. Moreover, this research employed a cross-sectional design, which merely captures conditions at a particular point in time. Therefore, it cannot explain the dynamics of changes in technology's influence on entrepreneurial capabilities and marketing innovation in the long term.

Furthermore, this study only examined a few key variables: robotics and AI adoption, technological infrastructure, digital entrepreneurship literacy, digital entrepreneurship capabilities, digital marketing innovation, and entrepreneurial performance. It's possible that other variables could influence this relationship, such as organizational culture, entrepreneurial orientation, digital transformation readiness, and government policy support. Accordingly, this study is regarded as a preliminary contribution that still requires additional refinement and broader development through future research endeavors.

Recommendations for Future Research

Future studies are recommended to expand the research scope by incorporating a larger number of technology startups from diverse regions across Indonesia, and potentially extending the analysis to an international context. In addition, future investigations are encouraged to employ a mixed-methods design use quantitative and qualitative methodologies, thereby facilitating a more in-depth and comprehensive exploration of how startups deploy intelligent technologies within their operational and marketing strategies.

Moreover, subsequent research could extend the analytical model by adding variables that may shape the relationship between technology adoption and entrepreneurial performance, including organizational readiness for digital transformation, an innovation-oriented

organizational culture, entrepreneurial orientation, and support from the broader digital ecosystem. Although these variables may potentially function as mediators or moderators, such indirect or moderating effects were not examined in the current study and therefore cannot be inferred from the present findings. Future research could investigate these mechanisms to provide a more comprehensive understanding of how robotics and AI adoption influences digital entrepreneurial capability, marketing innovation, and entrepreneurial performance. Furthermore, future scholarly investigations are encouraged to examine emerging technological paradigms within the evolving digital business ecosystem, thereby enriching the literature on digital entrepreneurship and marketing innovation.

Conclusion

This study investigates the influence of robotics and Artificial Intelligence (AI) technology adoption on the enhancement of digital entrepreneurial capability, digital marketing innovation, and entrepreneurial performance among technology startups in Yogyakarta. The empirical findings reveal that robotics and AI adoption exerts a positive and statistically significant effect on digital marketing innovation, but does not significantly influence digital entrepreneurial capability. These results indicate that technology startups predominantly leverage intelligent technologies to strengthen and optimize digital marketing strategies rather than directly fostering entrepreneurial capability development. Furthermore, technological infrastructure demonstrates a positive and significant effect on both digital marketing innovation and digital entrepreneurial capability, underscoring the critical role of robust digital infrastructure in facilitating the growth and advancement of technology-driven enterprises. In addition, digital entrepreneurship literacy significantly enhances digital entrepreneurial capability but does not have a significant effect on digital marketing innovation. Finally, both digital marketing innovation and digital entrepreneurial capability positively and significantly contribute to entrepreneurial performance. Overall, six of the eight proposed hypotheses were supported, while two hypotheses (H2 and H5) were not supported, consistent with the PLS-SEM results.

In addition, both digital marketing innovation and digital entrepreneurial capabilities are found to significantly and positively affect entrepreneurial performance. These results imply that the performance of technology startups is not determined solely by technological adoption, but is also strongly shaped by entrepreneurs' capacity to build digital competencies and formulate innovative marketing approaches. Overall, this research contributes to the theoretical enrichment of digital entrepreneurship and technological transformation literature, while simultaneously providing practical insights for startups in strategically utilizing robotics and artificial intelligence to improve marketing innovation and enhance entrepreneurial performance within the digital economy context.

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