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Cultivating Sustainable Tourism Technopreneurs: A Serial Mediation Analysis of AI-Augmented Ideation and Business Model Innovation in Vocational Education

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Abstract

The rapid smartization of the tourism industry, driven by generative artificial intelligence (AI), has redefined the competencies required for future technopreneurs, yet the mechanism through which digital preparedness translates into sustainable outcomes remains under-researched in vocational contexts. This study proposes and tests a serial mediation model examining the interplay between digital foundations (literacy and self-efficacy), AI-augmented Ideation, ethical awareness, and sustainable business model innovation (SBMI). Utilizing a quantitative approach, data were collected from 200 vocational tourism students in Indonesia and analyzed via Partial Least Squares Structural Equation Modeling (PLS-SEM). The results reveal that digital literacy and AI self-efficacy significantly drive technopreneurial readiness only when sequentially mediated by creative Ideation and strategic filters. Specifically, the path from AI-augmented Ideation to technopreneurship is optimized through the serial role of Ethical AI Awareness and SBMI, illustrating that technological efficiency must be balanced with normative responsibility and value reconfiguration. These findings have critical implications for vocational higher education, suggesting that curricula must move beyond technical training to foster the ethical and strategic capabilities necessary for a resilient, green hospitality ecosystem.

Keywords: *AI Self-Efficacy, Sustainable Tourism, Technopreneurship, Vocational Education, Serial Mediation, Business Model Innovation*

INTRODUCTION

The global tourism landscape is currently undergoing a structural metamorphosis driven by the pervasive integration of intelligent technologies and digital transformation (Muhammad et al., 2025). This evolution is no longer a peripheral development but a fundamental shift where digital tools redefine consumption practices and firm survival strategies (Chu, 2023). The emergence of generative artificial intelligence (AI), particularly models such as ChatGPT, has precipitated a paradigm shift in how information is synthesized and service experiences are curated (Sigala et al., 2024). Within this dynamic ecosystem, the fusion of metaverse technologies, augmented reality, and virtual reality is not only enhancing marketing strategies but also redefining the boundaries of entrepreneurial education (Achuthan et al., 2025; Ogutu et al., 2023).

Parallel to this technological surge is an intensifying mandate for environmental and social responsibility. The pursuit of the United Nations' Sustainable Development Goals has compelled the hospitality industry to scrutinize the role of digital transformation in bolstering environmental

sustainability (Bekele et al., 2024). Achieving this equilibrium requires more than adopting new software; it necessitates sustainable business model innovation to mediate the relationship between digital advancements and environmental outcomes. Consequently, the contemporary tourism business model must foster creative and critical thinking, encouraging a transition toward more resilient and innovative practices.

Vocational Higher Education institutions occupy a pivotal position in preparing a future-ready workforce capable of navigating these complexities (Achuthan et al., 2025). For students in tourism and hospitality, the development of essential competencies—ranging from digital literacy to entrepreneurial mindset—is crucial for fostering innovation in a market-oriented environment (Akbari et al., 2022; Harb et al., 2025). Furthermore, as technological advancements continue to reshape the industry, there is an urgent need for vocational curricula to adapt by integrating digital inclusion and smartization strategies (Kochuma et al., 2024; Francesco Santarsiero et al., 2024). This pedagogical shift aims to enhance competitive advantage by empowering students with the transformational entrepreneurship skills required to lead in a disrupted market (Ahmed et al., 2025).

However, the rapid adoption of AI-driven systems poses significant challenges regarding ethical standards, data privacy, and the maintenance of human-centric values [4], [5]. While AI can significantly enhance operational efficiency, the tourism industry must balance automation with the human element to ensure long-term customer trust and satisfaction. Consequently, the concept of the 'sustainable tourism technopreneur' must be understood not merely as an aggregation of technical competencies and environmental awareness, but as a distinct professional identity. This identity represents a unique ontological position within the hospitality sector, characterized by leaders who intrinsically fuse algorithmic proficiency with ecological stewardship. Rather than treating digitalization and sustainability as separate operational variables, the sustainable technopreneur embodies an integrated ethos where technological innovation is fundamentally governed by normative responsibility and human-centric value creation. In this context, future practitioners must possess not only high AI self-efficacy but also an acute awareness of the ethical implications of the technologies they deploy (Achuthan et al., 2025; Shin et al., 2026).

Despite the growing body of literature on AI in tourism, a significant research gap remains regarding the specific mechanism by which digital preparedness translates into sustainable technopreneurial outcomes within the vocational context. Existing studies often treat technological adoption and sustainability as parallel tracks rather than a serialized process of cognitive and strategic development. There is a lack of empirical evidence exploring how AI-augmented Ideation catalyzes ethical awareness and subsequent business model innovation. This research addresses this void by proposing a serial mediation model that examines how digital literacy and AI self-efficacy drive sustainable tourism technopreneurship through the sequential filters of Ideation, ethics, and strategic innovation. By focusing on vocational tourism students, this study provides a theoretical framework for aligning technological proficiency with the holistic principles of sustainability and responsibility.

THEORETICAL BACKGROUND

Sustainable Tourism Technopreneurship

The global hospitality sector currently operates at a confluence of intensive technological smartization and an urgent mandate for environmental accountability (Kochuma et al., 2024; Muhammad et al., 2025). Within this environment, sustainable tourism technopreneurship functions as a holistic construct, synthesizing innovative digital capabilities with the triple objectives of economic stability, social equity, and environmental preservation (Bekele et al., 2024). This strategic shift departs from conventional profit-maximization models by framing

digital transformation as a primary catalyst for environmental sustainability, largely achieved through the structural reconfiguration of organizational frameworks. Consequently, emerging tools such as artificial intelligence and predictive analytics are no longer viewed as mere operational appendages but as critical assets for ensuring long-term resilience and firm survival in volatile markets (Chu, 2023; Priatmoko et al., 2025).

Implementing such a technopreneurial approach necessitates rigorous alignment with the United Nations' Sustainable Development Goals (SDGs), particularly regarding resource efficiency and climate resilience (Bekele et al., 2024; Lampoltshammer et al., 2023). Contemporary tourism enterprises must navigate the inherent tension between immediate productivity gains and the burgeoning consumer demand for personalized, ethical service delivery (Rapeepan Pitakaso et al., 2025). Research indicates that sustainable business model innovation serves as a vital linking mechanism, converting latent digital potential into measurable environmental benefits and broader social value (Bekele et al., 2024). Such innovation ensures that technological advancement remains consistent with the core values of the tourism industry while fostering trust and long-term performance.

Beyond operational metrics, the recent experience of global health crises and systemic disruptions has redefined the social role of tourism entities (Szromek & Polok, 2022). Transformational entrepreneurship provides a pathway for maintaining a competitive edge during periods of instability, allowing organizations to adapt through open innovation and digital-first recovery strategies (Ahmed et al., 2025; Szromek & Polok, 2022). Grounded in the Triple Bottom Line framework, sustainable technopreneurship offers a comprehensive platform for future leaders to generate value that is both technologically sophisticated and ecologically responsible (Elkington, 1998).

Literacy and AI Self-Efficacy in Vocational Education

The pedagogical imperative within vocational higher education has shifted toward bridging the widening divide between traditional hospitality training and the rapid smartization of the global tourism industry (Kochuma et al., 2024; Francesco Santarsiero et al., 2024). Digital literacy is the primary prerequisite for this transition, functioning not merely as a technical skill set but as a comprehensive framework for digital inclusion and operational adaptability (Achuthan et al., 2025; Kochuma et al., 2024). As industry sectors grapple with technological disruption, vocational institutions must prioritize cultivating these foundational skills to ensure that future professionals can balance high-level innovation with ethical safeguards and societal standards (Achuthan et al., 2025; Sattlegger, 2024). This digital preparedness is particularly critical in specialized tourism contexts, where workforce insufficiencies can directly impair firm competitiveness and service quality (Fang & Liou, 2024).

Beyond technical proficiency, the capacity to thrive in an AI-driven environment is heavily contingent upon AI self-efficacy—the cognitive readiness and confidence of students to manipulate intelligent systems and metaverse technologies for entrepreneurial growth (Achuthan et al., 2025; Shin et al., 2026). Psychological readiness of this nature allows students to perceive generative tools and immersive virtual technologies as facilitators of business opportunities rather than as complex disruptions (Achuthan et al., 2025). In the vocational sector, fostering such confidence is essential for developing the competencies required by diverse groups, including women homepreneurs and young entrepreneurs, who must navigate highly competitive, technology-heavy markets (Harb et al., 2025; Muhammad et al., 2025).

The integration of these digital foundations into the curriculum encourages a shift from rote learning toward the development of market-orientation capabilities and ambidextrous innovation (Akbari et al., 2022). By grounding students in robust digital literacy, institutions enable the creative and critical thinking necessary for meaningful business model innovation. Ultimately, the synergy between a student's technical literacy and their psychological belief in

their AI capabilities forms the bedrock upon which sustainable, transformational entrepreneurship is built, providing a clear pathway to competitive advantage in the smart tourism era (Ahmed et al., 2025; Akbari et al., 2022). This developmental process is fundamentally anchored in the belief that an individual's conviction in their ability to execute tasks is the most significant predictor of their eventual behavioral success (Bandura, 1977).

AI-Augmented Ideation

The nascent phase of technopreneurial development, traditionally characterized by manual brainstorming and intuitive forecasting, is being radically reconstructed through the integration of generative intelligence (Shin et al., 2026; Sigala et al., 2024). This shift, precipitated by the prevalence of large language models and conversational AI, has introduced a new paradigm where information synthesis and creative output are no longer solitary human endeavors. In the context of smart tourism, AI-augmented Ideation functions as a sophisticated catalyst, allowing students to mine vast review datasets and identify latent market gaps with unprecedented precision. By leveraging these intelligent systems, vocational learners can transition from basic conceptualization to the formulation of highly adaptive business practices that lead to sustainable performance.

Within the tourism business model, AI fosters creative and critical thinking, encouraging students to challenge traditional service delivery frameworks. This technological affordance is particularly vital for identifying survival strategies during periods of global crisis, where the ability to integrate big data and AI into daily operations becomes a prerequisite for competitive advantage (Chu, 2023). Furthermore, the use of immersive virtual technologies and metaverse frameworks in entrepreneurial education enriches the ideation process by providing realistic simulations of space exploration, healthcare, or cultural engagement within the tourism sector. Such immersive experiences enable a deeper exploration of innovative practices that are more flexible and content marketing-oriented than those offered by traditional agencies.

However, the efficacy of AI-augmented Ideation is deeply intertwined with the ability to maintain the human element in service design. While AI facilitates content production and optimizes marketing experiences, the creative process must remain anchored in the core values of the tourism industry to ensure customer trust and satisfaction. This synergistic relationship between human creativity and algorithmic power underscores the necessity for vocational curricula to move beyond rote technical training. Instead, the focus must shift to a balanced approach that harnesses AI technologies to drive innovation while addressing critical challenges such as authenticity and data security. This modern approach to creativity aligns with the standard definition, which posits that innovation requires both originality and effectiveness within a specific social context (Runco & Jaeger, 2012).

The Ethical Filter: Awareness, Privacy, and Authenticity

The integration of intelligent systems into the tourism landscape is not without significant friction, as the pursuit of extreme operational efficiency often conflicts with fundamental ethical standards and necessary societal safeguards (Achuthan et al., 2025). For vocational students tasked with designing future-ready business models, navigating this tension is a critical competency. The prevalence of generative AI and large language models has introduced multifaceted challenges regarding data privacy, transparency, and intellectual property rights that were previously non-existent in traditional hospitality management (Ogutu et al., 2023; Shin et al., 2026). Consequently, ethical AI awareness must function as a normative filter, ensuring that technological innovation remains aligned with the core values of responsibility and digital inclusion rather than merely serving as a tool for cost reduction (Achuthan et al., 2025; Kochuma et al., 2024).

A primary concern in adopting AI in tourism marketing and service delivery is the potential erosion of authenticity. While automated content production can optimize customer interactions, maintaining the human element remains paramount for securing customer trust and long-term satisfaction (Priatmoko et al., 2025). In the smart tourism era, the human touch defines the industry's social sustainability, requiring a balanced approach in which algorithmic power does not overshadow genuine hospitality (Priatmoko et al., 2025; F Santarsiero et al., 2024). Furthermore, addressing systemic vulnerabilities in data security is essential to protecting both consumers and enterprises from the risks inherent in digital-first ecosystems (Achuthan et al., 2025; Kritikos et al., 2025).

Ethical reflection also extends to issues of gender equality and systemic bias in algorithmic decision-making (Altinay et al., 2026). Vocational education must therefore equip future technopreneurs with the analytical tools to evaluate the social impact of their digital ventures, prioritizing user-centric design that respects individual rights (Altinay et al., 2026; Stăncioiu et al., 2025). This ethical orientation is fundamentally grounded in the principle that true sustainability cannot exist without social responsibility, as businesses must be accountable to the societies in which they operate (Elkington, 1998). By embedding ethical awareness as a serial mediator in the entrepreneurial process, vocational institutions ensure that AI-driven innovation leads to a more equitable and trustworthy tourism industry.

Sustainable Business Model Innovation (SBMI) as a Strategic Mediator

Converting technological potential into tangible sustainability requires a fundamental reconfiguration of the underlying logic by which tourism enterprises create, deliver, and capture value (Aires et al., 2025; Bekele et al., 2024). Sustainable Business Model Innovation (SBMI) serves as this critical strategic pivot, moving beyond incremental adjustments to pursue a comprehensive integration of digital transformation with environmental performance (Bekele et al., 2024; Chamboko- Mpotaringa et al., 2025). Within the hospitality sector, this innovation mediates the relationship between digital investments and environmental outcomes, ensuring that technology serves as a proactive force for ecological preservation rather than a mere efficiency tool (Bekele et al., 2024). Consequently, the contemporary tourism enterprise must adopt innovative frameworks that mine customer reviews and market data to establish flexible, content-oriented practices that enhance service quality while closing information gaps (Cheng et al., 2024; Chu, 2023).

The efficacy of SBMI is deeply contingent upon the organization's ability to foster creative and critical thinking among its workforce. In vocational contexts, students are challenged to transcend traditional operational roles by utilizing AI and big data to identify market niches—such as the emerging senior tourism market—that require specialized, sustainable service models (Zhang, 2023). Integrating advanced technologies such as AR, VR, and AI into daily operations enables agencies to develop survival strategies that are resilient to major global crises, thereby strengthening their competitive advantage (Chu, 2023; Szromek & Polok, 2022). Furthermore, these innovative models often take the form of open innovation within regional tourism ecosystems, where infrastructure is shared to support broader health or social systems during epidemics (Polukhina et al., 2024; Szromek & Polok, 2022).

Ultimately, SBMI functions as the final strategic filter in the technopreneurial process, aligning economic drivers with social and environmental imperatives (Intakarn et al., 2026; R Pitakaso et al., 2025). By prioritizing sustainable cultural tourism and resource efficiency, business model innovation becomes a key driver of both regional economic development and long-term firm survival (Chu, 2023; Intakarn et al., 2026). This structural evolution ensures that tourism ventures are not only technologically advanced but also capable of simultaneously generating economic value and environmental benefits (Schaltegger & Wagner, 2011). By embedding SBMI as a serial

mediator, vocational institutions provide a roadmap for translating ethical, AI-augmented ideas into stable and responsible commercial realities (Bekele et al., 2024).

Hypotheses Development and Theoretical Framework

The theoretical architecture of this inquiry is anchored in the Dynamic Capabilities Theory, which posits that individuals and organizations must continuously reconfigure their competencies to remain competitive within technology-intensive environments. Within the contemporary tourism domain, this reconfiguration centers on the intersection of digital smartization and environmental stewardship (Kochuma et al., 2024; Muhammad et al., 2025). The proposed framework suggests that vocational students do not achieve sustainable technopreneurship through a singular leap of adoption but rather via a serialized cognitive and strategic journey. This path originates in foundational digital literacy—a critical driver of digital inclusion and operational agility (Kochuma et al., 2024)—and in AI self-efficacy, which provides the psychological conviction necessary to use generative technologies (Achuthan et al., 2025; Shin et al., 2026).

These foundations directly stimulate AI-augmented Ideation, a creative process fundamentally redefined by large language models and conversational AI (Shin et al., 2026; Sigala et al., 2024). However, in a responsible tourism ecosystem, Ideation cannot exist in a strategic vacuum; it must be refined through normative filters and operationalized via business model innovation (Bekele et al., 2024; BUJDOSÓ et al., 2025). Ethical AI awareness serves as a crucial mediator in this sequence, ensuring that innovation respects data privacy, transparency, and authenticity—values paramount to securing long-term customer trust (BUJDOSÓ et al., 2025). Subsequently, Sustainable Business Model Innovation (SBMI) serves as the ultimate strategic catalyst, translating these ethical, AI-driven concepts into commercial realities that generate simultaneous economic, social, and environmental value (Bekele et al., 2024). This structural evolution ensures that tourism ventures remain resilient against global disruptions while contributing to regional development (Chu, 2023; Intakarn et al., 2026).

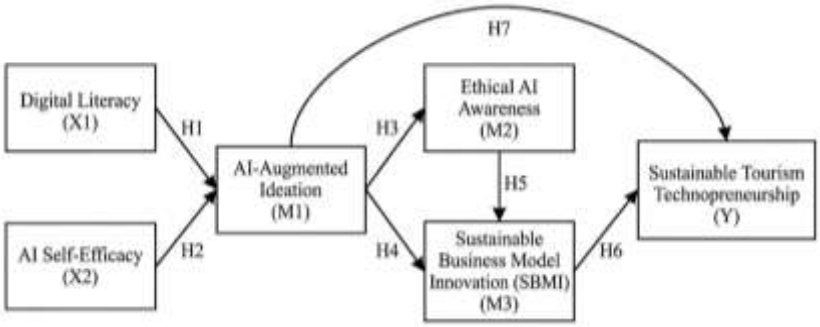


Figure 1. Proposed Theoretical Framework
Source: Research data, 2026

The following hypotheses are formulated based on the theoretical interactions described above and the necessity for a serialized approach to sustainable innovation in vocational education.

Direct and Partial Hypotheses

H1: Digital Literacy has a significant effect on AI-Augmented Ideation.
H2: AI Self-Efficacy has a significant effect on AI-Augmented Ideation.
H3: AI-Augmented Ideation has a significant effect on Ethical AI Awareness.
H4: AI-Augmented Ideation has a significant effect on Sustainable Business Model Innovation (SBMI).

H5: Ethical AI Awareness has a significant effect on Sustainable Business Model Innovation (SBMI).
H6: Sustainable Business Model Innovation (SBMI) has a significant effect on Sustainable Tourism Technopreneurship.
H7: AI-Augmented Ideation has a significant effect on Sustainable Tourism Technopreneurship.

Mediation and Serial Hypotheses
H8: AI-Augmented Ideation mediates the relationship between Digital Literacy and Sustainable Tourism Technopreneurship.
H9: Sustainable Business Model Innovation (SBMI) mediates the relationship between AI-Augmented Ideation and Sustainable Tourism Technopreneurship.
H10: Ethical AI Awareness mediates the relationship between AI-Augmented Ideation and Sustainable Business Model Innovation (SBMI).
H11: Digital Literacy and AI Self-Efficacy influence Sustainable Tourism Technopreneurship through the serial mediation of AI-Augmented Ideation and Sustainable Business Model Innovation (SBMI).
H12: AI-Augmented Ideation influences Sustainable Tourism Technopreneurship through the serial mediation of Ethical AI Awareness and Sustainable Business Model Innovation (SBMI).

METHODS

Research Design and Sampling Strategy

To empirically validate the complex serial mediation paths proposed in this study, a quantitative research design utilizing a cross-sectional survey was implemented. This approach aligns with recent methodological trends in tourism and hospitality research that examine the impact of digital transformation using structural equation modeling. The study focuses on vocational higher education, specifically targeting students enrolled in tourism and hospitality management programs who are actively engaged in entrepreneurship modules. This demographic represents the future workforce tasked with integrating intelligent systems into sustainable business models.

A purposive sampling technique was used to ensure participants had the necessary foundational experience with digital tools and AI applications in a tourism context. Following the sampling rigor observed in contemporary hospitality studies, the sample size was determined to meet the requirements for Partial Least Squares Structural Equation Modeling (PLS-SEM), which is robust for complex models with multiple mediators. Data collection was conducted via a structured digital questionnaire during the 2025/2026 academic year, ensuring that respondents were surveyed during their active ideation and business development phases.

Measurement and Operationalization of Variables

The survey instrument was developed by adapting validated scales from the existing literature to the specific nuances of vocational tourism education. All latent constructs were measured using a five-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). This measurement standard is widely accepted for capturing behavioral intentions and self-efficacy in entrepreneurial studies. The operationalization of the six core variables is summarized in Table 1, highlighting the alignment between current industry requirements and pedagogical objectives.

Table 1. Measurement Constructs and Supporting Literature

Variable	Operational Focus	Supporting Literature
Digital Literacy (X1)	Competency in navigating smartization and digital inclusion.	(Achuthan et al., 2025; Kochuma et al., 2024)

Variable	Operational Focus	Supporting Literature
AI Self-Efficacy (X2)	Psychological conviction in manipulating generative and intelligent systems.	(Achuthan et al., 2025; Shin et al., 2026)
AI-Augmented Ideation (M1)	Synthesis of market data and creative identification of service gaps.	(Sigala et al., 2024)
Ethical AI Awareness (M2)	Recognition of data privacy, security, and human-centric value challenges.	(Achuthan et al., 2025; BUJDOSÓ et al., 2025)
Sustainable Business Model Innovation (M3)	Value reconfiguration to meet environmental and social sustainability goals.	(Bekele et al., 2024)
Sustainable Tourism Technopreneurship (Y)	Development of technology-based ventures with a triple bottom line orientation.	(Bekele et al., 2024; Muhammad et al., 2025)

Source: Research data, 2026

Data Analysis

The empirical analysis uses Partial Least Squares Structural Equation Modeling (PLS-SEM) and is conducted with SmartPLS 4. PLS-SEM was selected as the most objective technique for this study because of its superior performance in estimating complex causal relationships and its ability to handle non-normally distributed data—a common occurrence in student-based behavioral research. The analysis followed a rigorous two-stage evaluation process. The first stage involved assessing the measurement model (outer model) to establish the reliability and validity of the latent constructs. This phase included testing for internal consistency using Cronbach's alpha and Composite Reliability (CR), and for convergent validity using Average Variance Extracted (AVE). Discriminant validity was strictly verified using the Heterotrait-Monotrait (HTMT) ratio, which is currently the most stringent criterion in structural modeling for ensuring that constructs are distinct from one another. The second stage focused on the structural model (inner model) to test the hypothesized serial mediation paths. Path coefficients (β) and their significance levels were derived using a nonparametric bootstrap procedure with 5,000 subsamples. To determine the indirect effects, the study utilized bias-corrected confidence intervals, which allow for a more precise estimation of the serial mediation logic. The predictive power and relevance of the model were assessed using the coefficient of determination (R^2) and Stone-Geisser's Q^2 for all endogenous variables.

RESULTS AND DISCUSSION

Respondent Profile

The empirical phase of this research involved a comprehensive survey of 200 vocational tourism students, whose demographic and academic characteristics establish the baseline for the structural analysis. The gender composition of the sample is relatively balanced, with a slight female majority: 109 females (54.5%) and 91 males (45.5%). This distribution ensures that the insights regarding technopreneurial intent and digital literacy capture perspectives across gender lines within the vocational hospitality landscape.

The age profile of the participants spans the typical undergraduate vocational trajectory, ranging from 18 to 23 years. The data indicate that a significant portion of the respondents are in the later stages of their vocational education, with 44 students (22%) aged 23, followed by 34 students (17%) aged 22, and 33 students (16.5%) aged 21. Students aged 18, 19, and 20 years constitute the remaining 53.5% of the sample. This maturity in age distribution is strategically important, as older students are often more deeply engaged in advanced entrepreneurship modules and industry-linkage projects.

Regarding academic progression, the participants are distributed across three critical levels of vocational study. The largest cohort is in the fourth semester (n = 81), followed by the sixth (n =

63) and second (n = 56) semesters. The high representation of students in their fourth and sixth semesters provides a robust basis for evaluating AI-augmented Ideation, as these individuals are typically transitioning from foundational theory to practical business modeling. Furthermore, the sample encompasses four distinct tourism disciplines. Culinary Arts (n = 55) and Travel Business Management (n = 53) represent the primary majors, complemented by Hotel Management (n = 47) and Destination Management (n = 45). This cross-disciplinary diversity enables a holistic examination of how AI-driven tools are perceived across sectors of the tourism industry.

The technical readiness of the cohort, a pivotal antecedent in this model, was gauged through self-reported AI experience levels. Nearly half of the respondents (n = 99) reported a basic level of experience, while 82 students reported an intermediate level of proficiency. A specialized group of 19 students (9.5%) demonstrated advanced AI experience. This spectrum of technical familiarity—ranging from basic awareness to advanced proficiency—offers a fertile ground for testing the influence of AI self-efficacy on sustainable business model innovation. The baseline data suggest that while AI adoption is prevalent, there remains a significant opportunity for vocational curricula to elevate students from basic literacy to strategic, high-level AI utilization.

Measurement Model Assessment

The evaluation of the measurement model represents a critical prerequisite for structural path analysis, ensuring that the latent constructs are both reliable and valid within the specific context of vocational tourism education. In line with rigorous PLS-SEM psychometric standards, this study assessed indicator reliability, internal consistency, and convergent validity (Hair et al., 2022). As shown in Table 2, all factor loadings for the 20 indicators exceeded the recommended threshold of .708, ranging from .930 to .964. This indicates that the chosen items share more than 50% of their variance with their respective constructs, thereby confirming high indicator reliability across the digital and entrepreneurial scales.

Convergent validity was further substantiated through the Average Variance Extracted (AVE) for all six latent variables. Every construct yielded an AVE value significantly above the .50 benchmark, with Ethical AI Awareness (EAA) at .882 and AI-Augmented Ideation (AAI) peaking at .921. Such results imply that the measurement model captures a substantial proportion of the variance in the underlying phenomena (Bekele et al., 2024). Furthermore, internal consistency was verified through multiple metrics, including Cronbach's alpha and Composite Reliability (CR), all of which surpassed .7. The alignment of these values—specifically the high CR scores (.957 to .972)—demonstrates that the scales developed for vocational learners are exceptionally stable and robust for predictive modeling.

Table 2. Consolidated Measurement Model Results

Construct	Item/Measurement Item Description	Loadings	α	CR	AVE
Digital Literacy (X1)	DL1 Ability to navigate smart tourism digital platforms. DL2 Proficiency in synthesizing digital tourism info. DL3 Competency in hospitality collaborative tools.	.944 .955 .962	.950	.968	.909
AI Self-Efficacy (X2)	ASE1 Confidence in tourism problem-solving via AI. ASE2 Belief in mastering new hospitality AI tech. ASE3 Assurance in AI-driven travel recommendations.	.956 .954 .952	.951	.968	.911
AI-Augmented Ideation (M1)	AAI1 Generating innovative tourism concepts via AI. AAI2 Identifying market gaps through AI synthesis. AAI3 Enhancing brainstorming via generative prompts.	.960 .955 .964	.957	.972	.921

Construct	Item/Measurement Item Description	Loadings	α	CR	AVE
Ethical AI Awareness (M2)	EAA1 Recognizing data privacy risks in AI apps.	.944	.933	.957	.882
	EAA2 Understanding transparency for traveler trust.	.939			
	EAA3 Awareness of biases in travel algorithms.	.933			
Sustainable Business Model Innovation (M3)	SBMI1 Designing revenue models for preservation.	.941	.961	.972	.896
	SBMI2 Integrating circularity in value delivery.	.953			
	SBMI3 Reconfiguring ops to reduce consumption.	.954			
	SBMI4 Creating social value in destination management.	.938			
Sustainable Tourism Technopreneurship (Y)	STT1 Intent to launch technology-based social ventures.	.941	.952	.965	.874
	STT2 Commitment to balancing profit and heritage.	.930			
	STT3 Readiness for eco-friendly tech in startups.	.937			
	STT4 Strategic vision for green hospitality resilience.	.932			

Source: Research data, 2026

To ensure that the constructs were empirically distinct, discriminant validity was tested using the Heterotrait-Monotrait (HTMT) ratio. As illustrated in Table 3, all HTMT values remained below the conservative threshold of .85, indicating that each variable represents a unique theoretical facet within the model. The highest ratio (.788) observed between SBMI and STT reflects a strong but distinct conceptual link between strategic innovation and technopreneurial readiness (Bekele et al., 2024; BUJDOSÓ et al., 2025). Additionally, preliminary collinearity checks using the inner Variance Inflation Factor (VIF) yielded values between 1.000 and 1.391, comfortably below the limit of 3.3, thereby negating concerns regarding multicollinearity during the structural estimation phase.

Table 3. Discriminant Validity Results (HTMT Criterion)

	ASE	AAI	DL	EAA	SBMI
AI-Augmented Ideation (AAI)	.577	-			
Digital Literacy (DL)	.058	.498	-		
Ethical AI Awareness (EAA)	.196	.508	.239	-	
Sustainable Business Model Innovation (SBMI)	.328	.553	.303	.664	-
Sustainable Tourism Technopreneurship (STT)	.369	.642	.310	.630	.788

Source: Research data, 2026

Structural Model Assessment

Following confirmation of a valid measurement model, the structural framework was evaluated to test the hypothesized relationships using a bootstrapping procedure with 5,000 subsamples. This stage is critical for assessing the model's predictive capabilities and the significance of the paths linking digital foundations to sustainable outcomes in vocational tourism education (Hair et al., 2022). The empirical evidence, as detailed in Table 4, indicates that all seven direct hypotheses (H1–H7) were supported at a high level of statistical significance ($p < .001$).

The results underscore the importance of digital preparedness, where both AI self-efficacy ($\beta = .526$, $t = 11.390$) and digital literacy ($\beta = .446$, $t = 9.319$) manifest as strong predictors of AI-augmented Ideation. These findings align with the necessity for foundational digital inclusion to drive the smartization of tourism curricula (Kochuma et al., 2024). Furthermore, the path from AI-augmented Ideation to ethical AI awareness ($\beta = .483$, $t = 8.993$) confirms that the active utilization of generative tools within the tourism business model triggers a critical recognition of data privacy and transparency risks (Bujdosó et al., 2025; Shin et al., 2026).

A pivotal observation in the structural model is the massive influence of sustainable business model innovation (SBMI) on technopreneurial readiness ($\beta = .597$, $t = 12.978$). With a substantial

effect size (f2 = .698), SBMI acts as the primary strategic driver that translates conceptual ideas into stable ventures (Bekele et al., 2024). While the direct path from Ideation to technopreneurship is significant (β = .296), the magnitude of the SBMI path suggests that innovation in value delivery is the most effective mechanism for achieving the triple bottom line goals in vocational settings (Nurjamilah et al., 2024).

Table 4. Structural Path Coefficients and Hypothesis Testing

Hyp.	Path	β	SD	T-stat	P-value	2.5%	97.5%	Decision
H1	DL → AAI	.446	.048	9.319	.000	.350	.537	Supported
H2	ASE → AAI	.526	.046	11.390	.000	.432	.613	Supported
H3	AAI → EAA	.483	.054	8.993	.000	.372	.584	Supported
H4	AAI → SBMI	.295	.056	5.246	.000	.431	.618	Supported
H5	EAA → SBMI	.487	.053	9.172	.000	.380	.591	Supported
H6	SBMI → STT	.597	.046	12.978	.000	.506	.685	Supported
H7	AAI → STT	.296	.054	5.535	.000	.518	.698	Supported

Source: Research data, 2026

The model's predictive power was assessed through the coefficient of determination (R^2) and Stone-Geisser's Q^2. As shown in Table 5, the model explains 63.2% of the variance in sustainable tourism technopreneurship (R2 = .632), which constitutes a moderate to strong explanatory capacity within social science research (Hair et al., 2022). The Q^2 values for all endogenous constructs remain well above zero, with the primary outcome variable reaching .546. These metrics validate the model's predictive relevance, suggesting that integrating AI-driven Ideation and ethical filters effectively anticipates the technopreneurial success of tourism students (Achuthan et al., 2025; BUJDOSÓ et al., 2025).

Table 5. Predictive Power (R^2) and Relevance (Q^2)

Endogenous Construct	R^2	R^2 Adj.	Q^2
AI-Augmented Ideation (AAI)	.502	.497	.458
Ethical AI Awareness (EAA)	.233	.229	.200
Sustainable Business Model Innovation (SBMI)	.463	.458	.411
Sustainable Tourism Technopreneurship (STT)	.632	.629	.546

Source: Research data, 2026

Finally, effect sizes (f2) were calculated to determine the relative contribution of each exogenous construct. The influence of AI self-efficacy on Ideation (f2 = .553) and SBMI on technopreneurship (f2 = .698) is classified as large, reinforcing their roles as the psychological and strategic pillars of the framework. In contrast, the direct effect of Ideation on ethics (f2 = .304) and technopreneurship (f2 = .172) is medium, indicating that while Ideation is necessary, its impact is optimized when channeled through the mediating filters of ethical awareness and business model innovation.

Mediation and Serial Mediation Analysis

The complexity of the vocational technopreneurial journey is most accurately captured through the lens of specific indirect effects, which elucidate the mechanisms through which digital foundations are converted into sustainable outcomes. This research utilized a bootstrapping procedure to test the significance of simple and serial mediation paths (Preacher & Hayes, 2008). As detailed in Table 6, all proposed indirect relationships (H8–H12) were statistically significant at the .001 level, with 95% bias-corrected confidence intervals that strictly excluded zero. These findings provide empirical support for the theoretical assertion that

technology-based Ideation requires sequential filters—both ethical and strategic—to achieve true sustainability goals (Bekele et al., 2024; BUJDOSÓ et al., 2025).

The first layer of mediation analysis confirms that AI-augmented Ideation serves as a vital bridge between digital literacy and AI self-efficacy. The indirect effect of digital literacy on technopreneurship through Ideation (β = .132, t = 4.738) suggests that technical proficiency alone is insufficient; it must be channeled through a creative conceptualization process. Furthermore, the role of Sustainable Business Model Innovation (SBMI) as a mediator between Ideation and technopreneurial readiness is substantial (β = .176, t = 4.884). This confirms that the transition from a mere business idea to a sustainable venture is heavily dependent on the student's ability to reconfigure value delivery for environmental and social benefit (Aires et al., 2025; Bekele et al., 2024).

The most compelling evidence, however, lies in the validation of the full serial mediation paths. The sequence involving ethical awareness—specifically the path from AI-augmented Ideation through Ethical AI Awareness to SBMI (β = .235, t = 6.356)—underscores a critical normative shift in vocational training. This relationship suggests that as students use AI for innovation, they become increasingly aware of data privacy and transparency risks, which, in turn, inform the design of more responsible business models (Bujdosó et al., 2025; Shin et al., 2026). The complete serial chain from digital foundations to sustainability—represented by the path DL → AAI → EAA → SBMI → STT (β = .063, t = 4.763) and ASE → AAI → EAA → SBMI → STT (β = .074, t = 5.110)—empirically proves that sustainable tourism technopreneurship in the smart tourism era is a multidimensional, sequential process.

Table 6. Summary of Specific Indirect and Serial Mediation Effects

Hyp.	Indirect Path	β	SD	T-stat	P-value	2.5%	97.5%	Decision
H8	DL → AAI → STT	.132	.028	4.738	.000	.079	.191	Supported
H9	AAI → SBMI → STT	.176	.036	4.884	.000	.106	.247	Supported
H10	AAI → EAA → SBMI	.235	.037	6.356	.000	.167	.313	Supported
H11	DL → AAI → SBMI → STT	.079	.019	4.219	.000	.045	.118	Supported
H12a	DL → AAI → EAA → SBMI → STT	.063	.013	4.763	.000	.040	.091	Supported
H12b	ASE → AAI → EAA → SBMI → STT	.074	.014	5.110	.000	.049	.105	Supported

Source: Research data, 2026

These serial mediation results reveal a strategic hierarchy: while technology triggers the process, ethics and innovation serve as non-negotiable filters that ensure technopreneurial intentions translate into green, resilient outcomes (Pitakaso et al., 2025). This sequential dependency highlights a bridging mechanism in which technical confidence (ASE) and skills (DL) are effectively harnessed to address the modern hospitality industry's tension between efficiency and responsibility (Bujdosó et al., 2025; Bekele et al., 2024).

Discussion

The empirical evidence from this study confirms that the journey toward sustainable tourism technopreneurship among vocational learners is not a direct consequence of technical proficiency but a sophisticated, sequential progression. The model's substantial predictive power (R^2 = 0.632; significant effect) suggests that integrating digital literacy and AI self-efficacy provides a necessary, albeit insufficient, foundation for modern entrepreneurship. While initial digital preparedness allows students to engage with smartization and digital inclusion (Kochuma et al., 2024), the transition to sustainable outcomes requires a sequential filtering process. The results show that AI-augmented Ideation serves as the primary spark, enabling students to leverage

generative intelligence to identify market gaps and conceptualize innovative service offerings (Sigala et al., 2024).

A critical revelation of this research is the non-negotiable role of Ethical AI Awareness (M2) and Sustainable Business Model Innovation (M3) as mediating filters. The significance of the serial paths (H11 and H12) proves that vocational students do not merely output a sustainable venture from an AI prompt. Instead, the creative affordances of AI trigger a secondary cognitive phase where students must navigate the ethical tensions between algorithmic efficiency and human authenticity (BUJDOSÓ et al., 2025). This ethical awakening is paramount for securing traveler trust and ensuring that technological adoption does not compromise data privacy or institutional transparency (BUJDOSÓ et al., 2025; Shin et al., 2026). Consequently, when these ethical considerations are embedded in a business model's design, the resulting innovation is more likely to satisfy the triple bottom line of economic, social, and environmental performance (Bekele et al., 2024).

The findings of this inquiry echo and expand upon recent discourse regarding the digital transformation of the hospitality sector. The pivotal role of Sustainable Business Model Innovation as a mediator aligns with (Bekele et al., 2024), who posited that digital transformation only bolsters environmental sustainability when innovative organizational frameworks mediate it. However, this study adds a distinctive layer by identifying AI-augmented Ideation as the specific precursor to this innovation in a vocational context. While previous research often focused on the operational survival of firms during global crises (Chu, 2023; Szromek & Polok, 2022), our data highlights a proactive, educational pathway in which students use AI not just for survival but for the deliberate construction of green, resilient startups (Ahmed et al., 2025).

The tension between AI efficiency and the human touch noted in our results resonates with the human-centric warnings presented by (BUJDOSÓ et al., 2025). Their study emphasized that while AI enhances marketing experiences, it risks eroding authenticity if not balanced by ethical standards. Our model empirically validates this by placing Ethical AI Awareness as a prerequisite for high-level business model innovation. Furthermore, the strong influence of AI self-efficacy on Ideation supports the work of (Achuthan et al., 2025), who identified psychological readiness as a key driver for metaverse and AR/VR integration in entrepreneurial education. By validating these relationships within an Indonesian vocational cohort, this research proves that the ideation-ethics-innovation sequence is a globally relevant mechanism for future-proofing the tourism workforce (Kochuma et al., 2024; Francesco Santarsiero et al., 2024).

Theoretical and Practical Implications

Theoretically, this research advances the Dynamic Capabilities Theory by illustrating how vocational learners reconfigure their digital foundations to address the grand societal challenges of sustainability and technological disruption (Lampoltshammer et al., 2023). It moves beyond the static view of skills and frames technopreneurship as a serialized capability. Grounded in the Triple Bottom Line framework, the study demonstrates that sustainable outcomes are achieved when technical confidence (ASE) is filtered through a normative lens (EAA) and a strategic structural reconfiguration (SBMI). This sequential logic provides a more granular understanding of how smartization actually translates into sustainability (Bekele et al., 2024; Kochuma et al., 2024).

Practically, the implications for institutional entities are profound. Curriculum designers must look beyond prompt engineering or basic software training. To cultivate true technopreneurs, education must prioritize modules that bridge the gap between AI utilization and business model logic. Specifically, the high path coefficient from SBMI to technopreneurship suggests that teaching students how to reconfigure value delivery for environmental preservation is more impactful than technical literacy alone. Furthermore, the inclusion of ethical audits in

entrepreneurship modules is essential to ensure that the next generation of tourism leaders maintains the industry's social responsibility and authenticity.

CONCLUSION

This research underscores that sustainable tourism technopreneurship in the vocational sector is a multi-layered developmental process rather than a linear technical adoption. The findings empirically validate that while digital literacy and AI self-efficacy provide the necessary foundational readiness, their impact on sustainable outcomes is fully optimized only when filtered through a sequential chain of creative Ideation, ethical awareness, and strategic business model innovation. The significant serial mediation paths demonstrate that future tourism leaders must not only be proficient in utilizing generative AI but also possess the normative capacity to evaluate the ethical implications of these tools and the strategic agility to reconfigure business models for environmental and social preservation. Ultimately, this study provides a structural blueprint for future-proofing tourism education by aligning technological proficiency with the holistic principles of the Triple Bottom Line.

Despite the robust psychometric and structural validation of the model, several limitations warrant consideration. First, the sample was drawn from a single vocational institution in Indonesia, which may limit the generalizability of the findings to broader geographical or different cultural contexts. Second, the cross-sectional nature of the data captures a snapshot of technopreneurial intent; however, it does not account for the long-term viability of the ventures launched by these students. Future research should employ longitudinal designs to track the transition from educational intent to actual market performance. Furthermore, subsequent studies could integrate multigroup analysis (MGA) to explore how different tourism disciplines (e.g., Culinary Arts vs. Travel Business) moderate the relationships within the serial mediation framework, thereby offering more granular insights for tailored curriculum development.

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