



DIGITAL TRANSFORMATION, INNOVATION CAPABILITY, AND SUSTAINABLE ENTREPRENEURIAL LEARNING: A STRUCTURAL MODEL IN HIGHER EDUCATION

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ABSTRACT

Aim/Purpose	This study investigates how digital transformation in higher education influences sustainable entrepreneurial learning practices, examining the mediating role of innovation capability and the moderating role of entrepreneurial self-efficacy.
Background	Despite growing investments in digital transformation within higher education, a clear understanding of its mechanisms for fostering sustainable entrepreneurial learning, particularly through capability development and psychological factors, remains underexplored. This study addresses this gap by proposing and testing a moderated mediation model.
Methodology	A cross-sectional survey was conducted with 334 undergraduate students at a Philippine aeronautical college, utilizing stratified proportional random sampling. Data analysis involved confirmatory factor analysis and structural equation modeling (AMOS 26.0), with bootstrapped indirect effects (5,000 resamples) to assess mediation.
Contribution	This research offers a novel theoretical contribution by integrating Dynamic Capabilities Theory and Social Cognitive Theory to explain the complex interplay between digital transformation, innovation capability, and sustainable entrepreneurial learning. This study is among the first to empirically test a moderated-mediation model in this context, thereby

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	bridging the fields of innovation management, entrepreneurship, and technology management.
Findings	Digital transformation significantly predicted both innovation capability ($\beta = 0.61, p < 0.001$) and sustainable entrepreneurial learning practices ($\beta = 0.48, p < 0.001$). Innovation capability partially mediated this relationship (indirect effect $\beta = 0.29$). Entrepreneurial self-efficacy significantly moderated the digital transformation-innovation capability relationship ($\beta = 0.21, p = 0.001$), with stronger effects observed for students with high self-efficacy. The model demonstrated substantial explanatory power ($R^2 = 0.54-0.62$).
Recommendations for Practitioners	Higher education leaders should integrate digital transformation initiatives with pedagogies aimed at building innovation capability and with interventions designed to strengthen students' entrepreneurial self-efficacy.
Recommendations for Researchers	Future research should explore longitudinal designs, cross-cultural contexts, and additional moderating factors to refine the proposed model further.
Impact on Society	The findings provide actionable insights for Southeast Asian technical institutions to optimize their digital transformation efforts and foster sustainable entrepreneurial learning, contributing to a more innovative and sustainable future.
Future Research	Examine longitudinally, test across cultural contexts, explore additional moderators, and investigate implementation strategies.
Keywords	digital transformation, innovation capability, sustainable entrepreneurial learning, higher education, Philippines

INTRODUCTION

The accelerating pace of digital transformation has reshaped how higher education institutions deliver learning, manage knowledge, and cultivate innovation among students (Anbarasan et al., 2025; Qureshi & Baig, 2025). Driven by the Fourth Industrial Revolution and amplified by the COVID-19 pandemic, universities worldwide have integrated digital platforms, including learning management systems, cloud computing, and artificial intelligence, into their pedagogical frameworks, creating new possibilities for interactive, technology-mediated education (Rughani et al., 2025). Beyond improving operational efficiency, digital transformation in higher education carries a deeper strategic imperative: equipping students with innovation capabilities that prepare them for entrepreneurial engagement in an increasingly digital economy (Patrício & Ferreira, 2023). Innovation capability, defined as an individual's or organization's capacity to generate, develop, and implement novel ideas that create value (Firmansyah & Wahdiniwaty, 2023), has emerged as a critical outcome variable in the digital transformation literature.

Empirical studies confirm that digital transformation has a positive effect on innovation capability in corporate and SME contexts (Cheng, 2025; Firmansyah & Wahdiniwaty, 2023). For instance, Cheng (2025) demonstrated that digital transformation exerts both a direct positive effect on innovation capability in manufacturing enterprises and an indirect effect through the mediating variable of innovation climate. Similarly, in the higher education context, Zhou et al. (2025) found a positive correlation between digital literacy, a key dimension of digital transformation, and university students' innovation capability. These findings suggest that digital tools and platforms facilitate creative thinking, problem-solving, and innovative behavior among learners.

Parallel to the digital transformation discourse, there has been growing scholarly interest in sustainable entrepreneurial learning, an educational approach that integrates sustainability principles with entrepreneurial skill development to address environmental, social, and economic challenges (Baltador & Grecu, 2023; Leal Filho et al., 2024). Higher education institutions are recognized as important catalysts for sustainable entrepreneurship, embedding resource-efficient learning behaviors, eco-conscious academic engagement, and digital entrepreneurial competencies into their curricula (Patricia, 2024; Zherdeva et al., 2024). While studies by Leal Filho et al. (2024) and Baltador and Grecu (2023) highlight the importance of multidisciplinary and social entrepreneurship education, relatively few studies have examined the structural relationship between digital transformation and sustainable entrepreneurial learning practices, particularly in terms of how innovation capability may serve as a transmission mechanism linking the two constructs.

Furthermore, a gap in the literature concerns the role of psychological factors, specifically entrepreneurial self-efficacy, in shaping the relationship between digital transformation and innovation capability. Entrepreneurial self-efficacy refers to an individual's belief in their capacity to perform entrepreneurial tasks, including opportunity recognition, resource mobilization, and venture creation (Arfi-ansyah et al., 2025; Cuong, 2025). Recent evidence has demonstrated that entrepreneurial self-efficacy significantly mediates the relationship between digital education and entrepreneurial intention (Arfi-ansyah et al., 2025) and that self-efficacy interacts with digital competence and social influences to shape students' entrepreneurial motivation (Cuong, 2025). Ariyati et al. (2025) found that both entrepreneurship education and digital literacy influence entrepreneurial behavior through self-efficacy as a mediating variable. Nurfaizal (2025) extended this by demonstrating that innovation capability mediates the influence of digital mindset, technological self-efficacy, and social media usage on entrepreneurial intention. However, the moderating role of entrepreneurial self-efficacy in the specific relationship between digital transformation and innovation capability remains underexplored, representing a significant gap that this study seeks to address.

This study is underpinned by the Dynamic Capabilities Theory and the Social Cognitive Theory. Dynamic Capabilities Theory provides a framework for understanding how higher education institutions sense, seize, and reconfigure digital resources to foster innovation in dynamic environments, thereby explaining how digital transformation builds institutional innovation capacity. Concurrently, Social Cognitive Theory, with its focus on self-efficacy, offers a lens to examine how students' confidence in their entrepreneurial abilities (entrepreneurial self-efficacy) might moderate the impact of digital transformation on their innovation capabilities. Together, these theories provide a robust foundation for exploring the complex interplay among digital transformation, innovation, entrepreneurial learning, and individual psychological factors in higher education.

The existing literature, while rich in documenting the individual effects of digital transformation on innovation and the importance of entrepreneurial education for sustainability, suffers from three notable limitations that this study addresses. First, most studies examining digital transformation and innovation capability have been conducted in corporate or SME settings (Abdelwaheed et al., 2025; Cheng, 2025), with limited empirical work situated in higher education contexts where students are the focal unit of analysis. Second, the connection between digital transformation and sustainable entrepreneurial learning has been discussed conceptually (Elder & Stordal, 2025; Leal Filho et al., 2024) but rarely tested through structural models that specify the mechanism through which this relationship operates. Third, while entrepreneurial self-efficacy has been examined as a mediator in various entrepreneurship education models (Arfi-ansyah et al., 2025; Ariyati et al., 2025), its role as a moderator, a boundary condition that strengthens or weakens the effect of digital transformation on students' innovation capability, has received scant empirical attention. This study addresses these gaps by proposing and testing a structural model that integrates digital transformation, innovation capability, sustainable entrepreneurial learning practices, and entrepreneurial self-efficacy within a higher education context. Specifically, the study addresses the following research questions:

- RQ1:** To what extent does digital transformation influence students' innovation capability in higher education institutions?
- RQ2:** What is the effect of digital transformation on sustainable entrepreneurial learning practices among students?
- RQ3:** Does innovation capability mediate the relationship between digital transformation and sustainable entrepreneurial learning practices?
- RQ4:** Does entrepreneurial self-efficacy moderate the relationship between digital transformation and innovation capability?

For purposes of this study, the following key terms are defined. Digital transformation refers to the strategic integration of digital technologies, including learning management systems, data analytics, cloud platforms, and AI-enabled tools, into institutional teaching and learning processes that reshape pedagogical delivery and student engagement (Qureshi & Baig, 2025). Innovation capability denotes students' capacity to generate creative solutions, adopt novel approaches to learning, and translate digital competencies into value-creating activities (Zhou et al., 2025). Sustainable entrepreneurial learning practices include resource-efficient digital learning behaviors, entrepreneurial skill development through digital tools, and environmentally conscious academic engagement aligned with sustainability principles (Baltador & Grecu, 2023; Leal Filho et al., 2024). Entrepreneurial self-efficacy refers to students' confidence in their ability to perform entrepreneurial tasks, including identifying opportunities and managing ventures in digital environments (Cuong, 2025).

LITERATURE REVIEW

THEORETICAL UNDERPINNINGS

This study draws on two complementary theoretical perspectives: Dynamic Capabilities Theory (DCT) and Social Cognitive Theory (SCT). DCT, first advanced by Teece et al. (1997) and subsequently refined by Teece (2018), posits that organizations and individuals achieve competitive advantage not merely by possessing resources but by developing the capacity to sense opportunities, seize them through strategic action, and reconfigure resource bases in response to changing environments. In the context of higher education, digital transformation represents precisely this kind of environmental shift. AlMutairi and Abu Talib (2025) conducted a systematic review of 55 studies that applied DCT in higher education institutions, finding that digital transformation serves as the operational mechanism for converting dynamic capabilities into measurable sustainability outcomes. This mediating effect was strongest where leadership commitment, governance maturity, and interoperable digital infrastructures were present. Similarly, Xue et al. (2026) extended DCT to Chinese higher education institutions, demonstrating the role of big data analytics factors in this context.

Social Cognitive Theory (SCT), as articulated by Bandura (1997), complements DCT by explaining the psychological mechanisms through which individuals translate environmental resources into behavioral outcomes. Central to SCT is the construct of self-efficacy, which refers to an individual's belief in their capacity to perform specific tasks. Caina and Jian (2025), drawing explicitly on Bandura's SCT, found that the learning environment in simulation-based courses predicted students' innovative ability, with self-efficacy partially mediating this relationship. Liu et al. (2023) demonstrated that self-efficacy positively moderates the relationship between big data capability and innovation performance among postgraduate students, such that higher self-efficacy strengthened the promotion effect of technological capability on innovative outcomes. Together, DCT and SCT provide a robust theoretical architecture for this study: DCT explains how digital transformation creates the resource environment for innovation capability, while SCT explains the psychological boundary conditions that influence how individuals leverage these resources.

DIGITAL TRANSFORMATION IN HIGHER EDUCATION

Digital transformation in higher education extends beyond the mere digitization of existing practices to encompass a fundamental redesign of pedagogical models, institutional governance, and knowledge delivery systems (Anbarasan et al., 2025; Qureshi & Baig, 2025). Enabled by cloud computing, big data, artificial intelligence, and learning management platforms, this transformation has accelerated significantly since the COVID-19 pandemic, creating what scholars describe as a pervasive, integrated digital ecosystem (Anbarasan et al., 2025). Shenkoya and Kim (2023), in a highly cited systematic review and bibliometric analysis, demonstrated that the digital transformation of the higher education sector leads to the development of sustainable curricula, enhanced innovation, and improved student performance, identifying the emerging concept of “Education 4.0” as a defining trajectory.

However, the literature is not uniformly optimistic regarding the ease of digital integration. Scholars have identified significant barriers, including cultural resistance among faculty, outdated technological infrastructure, financial constraints, and persistent digital equity gaps (Qureshi & Baig, 2025; Rughani et al., 2025). Patrício and Ferreira (2023) identified, through qualitative interviews, three critical focus areas for successful digital transformation: overcoming barriers, capitalizing on knowledge, and coping with change. This balanced view is supported by Leal Filho et al. (2023), who, in a worldwide survey of 158 higher education institutions, found that while most respondents developed digital skills and increased e-learning involvement during the pandemic, substantial gaps in digital training persisted. They also noted that the role of digital technologies in boosting sustainable development remained uneven across institutions. Kotula and Malagočka (2025) reinforced this finding, concluding that universities face a dual challenge of advancing digital transformation while integrating sustainable development, necessitating a balance between inclusivity and innovation. These findings suggest that digital transformation creates the preconditions for innovation and sustainability in higher education, but that the translation of digital tools into meaningful learning outcomes depends on contextual and individual-level factors.

DIGITAL TRANSFORMATION AND INNOVATION CAPABILITY

Empirical evidence from organizational contexts provides strong support for a positive relationship between digital transformation and innovation capability. Cheng (2025), using SEM with manufacturing enterprise data, found that digital transformation exerts a direct positive effect on innovation capability and an indirect positive effect through innovation climate as a mediating variable. Firman-syah and Wahdiniwaty (2023) corroborated this finding using PLS-SEM, demonstrating that digital transformation has a significant positive effect on innovation capabilities.

In the higher education context specifically, Zhou et al. (2025) provide direct evidence, reporting that digital literacy, a key dimension of digital transformation, correlates with university students’ innovation capability in a large-scale study. Their findings further revealed significant differences in both digital literacy and innovation capability among students with different educational backgrounds, academic disciplines, and types of institutions. The authors concluded that students with stronger digital literacy tend to be more innovative. They recommended that higher education institutions accelerate the development of a “digital literacy cultivation ecosystem” to stimulate students’ innovation drive. Caina and Jian (2025), grounding their study in Bandura’s (1997) social cognitive theory, reinforced this link by demonstrating that the learning environment in ERP simulation courses predicted college students’ innovative ability, with self-efficacy partially mediating the learning environment-innovation pathway.

However, not all studies converge on unqualified positive effects. Sustaningrum (2022) found that while social network use affected students’ innovation capability in project-based courses, tools for knowledge sourcing had no significant effect, suggesting that the type and design of digital tools matter considerably. Theng et al. (2021), studying SMEs, found that digital transformation had no significant effect on work innovation capabilities, a result they attributed to implementation quality rather

than the inherent potential of digital tools. This dissent highlights that the relationship between digital transformation and innovation capability is not automatic or universally positive; rather, it is contingent on contextual factors such as the quality of digital implementation, the design of technological tools, and users' readiness to engage meaningfully with digital platforms. Qureshi and Baig (2025) reinforced this point, arguing that sustainable digital transformation requires not only technological investment but also institutional strategy, a cultural shift toward innovation, and a commitment to inclusivity and ongoing faculty development. Thus, while the weight of evidence supports a positive effect, the relationship appears to be conditional, a nuance that underscores the importance of examining mediating and moderating mechanisms, as this study proposes.

Based on the theoretical reasoning from DCT, which holds that digital transformation creates the resource environment enabling individuals to sense opportunities, experiment with novel approaches, and reconfigure knowledge into innovative solutions, and on the empirical evidence reviewed above, which supports a positive digital transformation-innovation capability link despite some dissenting findings attributable to implementation quality, the following hypothesis is proposed:

H1: Digital transformation has a significant positive effect on students' innovation capability in higher education institutions.

DIGITAL TRANSFORMATION AND SUSTAINABLE ENTREPRENEURIAL LEARNING PRACTICES

Sustainable entrepreneurial learning encompasses educational approaches that integrate sustainability principles with entrepreneurial skill development, equipping students with the knowledge, skills, and mindset to address environmental, social, and economic challenges through innovative solutions (Baltador & Grecu, 2023; Leal Filho et al., 2024). This construct bridges two domains: the sustainability-informed pedagogical practices that higher education institutions embed in their curricula, and the entrepreneurial competencies required for students to create value in digitally transformed economies.

The link between digital transformation and sustainable learning practices has received growing theoretical attention. Shenkoya and Kim (2023) demonstrated that digital transformation leads to sustainable curriculum development in higher education. Omar and Abdullahi (2024), through a bibliometric analysis, identified a shift from addressing challenges and barriers to exploring the opportunities and benefits of sustainable digital transformation in higher education in developing countries. Leal Filho et al. (2023), surveying 158 institutions worldwide, found that digital technologies can boost sustainable development at universities but also noted that more digital training is needed to realize this potential.

From a pedagogical perspective, Patricia (2024) argued that entrepreneurship education equips students with the knowledge, skills, and mindset to address complex social and environmental challenges through entrepreneurial endeavors, supporting the UN Sustainable Development Goals. Zherdeva et al. (2024) extended this argument by exploring how sustainability-informed entrepreneurial education helps develop critical thinking and problem-solving skills attuned to emerging business challenges. Elder and Stordal (2025), using a multimethod approach in teacher education, found that sustainability-driven entrepreneurship gives students hands-on experience in creating sustainable solutions through collaborative work in real-world learning environments.

However, an important gap persists. Most studies examine either the impact of digital transformation on sustainability or the role of entrepreneurship education in sustainability separately, with few testing the direct structural relationship between digital transformation and sustainable entrepreneurial learning practices within a unified model. This study addresses this gap by hypothesizing a direct effect, reasoning that digital transformation provides the technological infrastructure, resource efficiency, and pedagogical innovation necessary for students to develop sustainable entrepreneurial learning behaviors. Consequently, the following hypothesis is proposed:

H2: Digital transformation has a significant positive effect on sustainable entrepreneurial learning practices among students.

THE MEDIATING ROLE OF INNOVATION CAPABILITY

The theoretical rationale for innovation capability as a mediator between digital transformation and sustainable entrepreneurial learning derives from the DCT premise that capabilities serve as transmission mechanisms between environmental resources and performance outcomes (Teece, 2018). Digital transformation provides the technological environment and resource base, but the translation of these resources into sustainable entrepreneurial behaviors requires an intermediary cognitive and behavioral capacity. Empirical precedents for innovation capability as a mediator are well established in organizational research, though less so in educational settings. Firmansyah and Wahdiniwaty (2023) demonstrated that innovation capabilities mediate the influence of digital transformation on competitiveness. Cheng (2025) showed that innovation climate mediates the digital transformation.

In the educational domain, Nurfaizal (2025) provides the closest parallel to the present study, demonstrating that innovation capability mediates the influence of digital mindset, technological self-efficacy, and social media usage on entrepreneurial intention among digital business students, with all proposed mediation pathways supported. Putra and Nugroho (2023) used Smart PLS and found that innovation capability positively affects entrepreneurial intention, both directly and indirectly through self-efficacy. Ninaroon et al. (2022) reported that organizational innovation mediated the relationship between entrepreneurial self-efficacy and entrepreneurial intention, suggesting that innovation processes are essential conduits through which individual capabilities translate into entrepreneurial outcomes.

Despite this evidence, the specific mediating role of innovation capability between digital transformation and sustainable entrepreneurial learning practices has not yet been empirically tested. Existing mediation studies focus on competitiveness, firm performance, or entrepreneurial intention as outcome variables, leaving a gap regarding whether innovation capability serves as the transmission mechanism through which digital transformation shapes sustainable entrepreneurial learning in higher education. This study addresses this gap by proposing:

H3: Innovation capability significantly mediates the relationship between digital transformation and sustainable entrepreneurial learning practices.

THE MODERATING ROLE OF ENTREPRENEURIAL SELF-EFFICACY

Entrepreneurial self-efficacy (ESE) refers to an individual's belief in their capacity to perform entrepreneurial tasks, including opportunity recognition, resource mobilization, and venture creation (Bandura, 1997; Cuong, 2025). Within SCT, self-efficacy serves as a critical boundary condition, determining whether environmental stimuli are translated into behavioral outcomes. The existing literature positions ESE as a mediator rather than a moderator. Arfiansyah et al. (2025) found that digital entrepreneurial self-efficacy mediates the effects of digital education and digital competence on entrepreneurial intention among university students. Ariyati et al. (2025) demonstrated, in a survey of students, that self-efficacy mediates the effects of entrepreneurship education and digital literacy on entrepreneurial behavior. Laydes et al. (2024) confirmed that entrepreneurship education influences the development of innovative skills and entrepreneurial self-efficacy.

However, there is growing evidence that ESE can function as a moderator that amplifies the effects of capability-building processes. Gill et al. (2021) demonstrated that entrepreneurial self-efficacy moderates the relationship between cognitive flexibility and entrepreneurial intention, such that higher ESE strengthens the positive relationship. This suggests that individuals with higher self-efficacy are more likely to leverage digital transformation initiatives effectively, translating them into enhanced innovation capabilities. Therefore, this study proposes:

- H4:** Entrepreneurial self-efficacy significantly moderates the relationship between digital transformation and innovation capability, such that the positive effect of digital transformation on innovation capability is stronger among students with higher entrepreneurial self-efficacy.

CONCEPTUAL FRAMEWORK

Building upon the comprehensive literature review and addressing identified theoretical and empirical gaps, this study proposes a refined conceptual framework (Figure 1). This framework delineates the intricate relationships between digital transformation, innovation capability, sustainable entrepreneurial learning practices, and entrepreneurial self-efficacy within higher education contexts. Each construct is distinct yet interconnected, contributing to a holistic understanding of how digital advancements foster entrepreneurial learning.

Digital transformation serves as the primary independent variable, representing the strategic integration of digital technologies into institutional processes to reshape pedagogical delivery and student engagement. It is distinct from digital literacy, which refers to an individual's ability to find, evaluate, and communicate information through digital platforms. While digital literacy is an outcome and enabler of digital transformation, the latter encompasses broader institutional and systemic changes.

Digital transformation is hypothesized to have a direct positive effect on both Innovation Capability (H1) and Sustainable Entrepreneurial Learning Practices (H2). Innovation capability, defined as students' capacity to generate creative solutions and translate digital competencies into value-creating activities, acts as a mediating variable. The effects of digital transformation are transmitted to Sustainable Entrepreneurial Learning Practices (H3) through enhanced innovation capability.

Sustainable Entrepreneurial Learning Practices encompass educational approaches that integrate sustainability principles with entrepreneurial skill development, equipping students to address environmental, social, and economic challenges. This construct is distinct from general entrepreneurial learning by its explicit focus on sustainability and its application within digitally transformed educational environments.

Entrepreneurial Self-Efficacy (ESE) functions as a moderating variable, conditioning the strength of the relationship between digital transformation and innovation capability (H4). ESE refers to students' confidence in their ability to perform entrepreneurial tasks. This psychological factor influences how effectively students leverage the opportunities presented by digital transformation to develop their innovation capabilities. This distinction is crucial: while digital transformation provides the environment and tools, ESE determines the individual's proactive engagement and success within that environment.

The proposed model is grounded in a dual-theoretical foundation. Dynamic Capabilities Theory (DCT) explains the resource-to-capability pathway, illustrating how digital transformation (a resource environment) enhances innovation capability and, in turn, influences sustainable entrepreneurial outcomes. Concurrently, Social Cognitive Theory (SCT) provides the psychological lens, explaining how individual beliefs, particularly entrepreneurial self-efficacy, act as critical boundary conditions that influence the development of innovation capability within a digitally transformed educational landscape. This integrated theoretical approach as visually represented in Figure 1, allows the study to capture both the structural and psychological dimensions of digital transformation's impact on sustainable entrepreneurial learning.

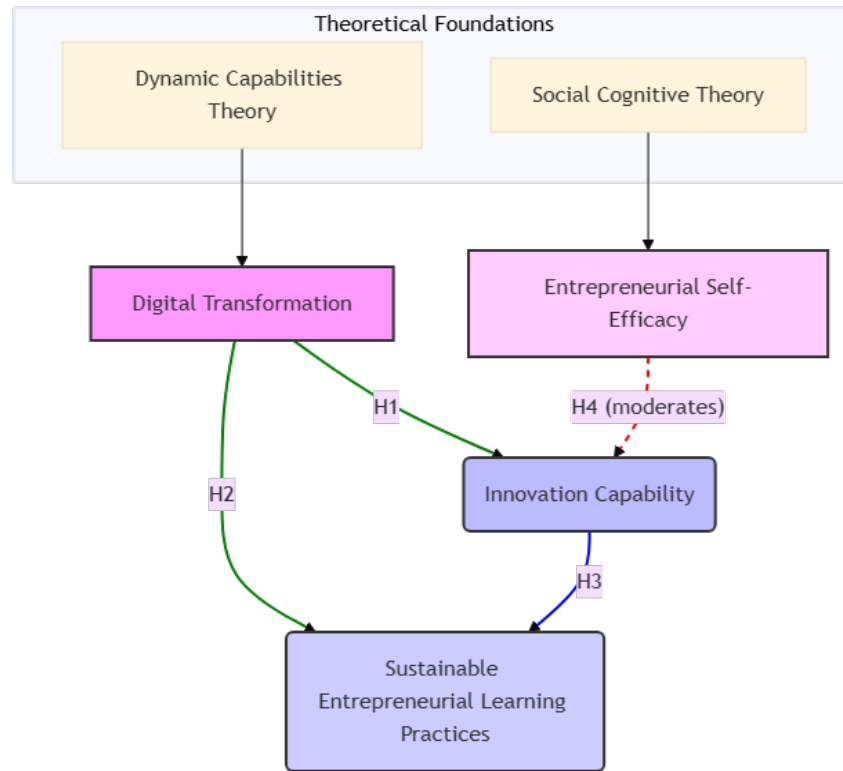


Figure 1. Conceptual framework

The hypothesis paths in Table 1 presents the hypothesized relationships examined in this study. Specifically, H1 proposes that digital transformation positively influences innovation capability, while H2 suggests that digital transformation also has a positive effect on sustainable entrepreneurial learning practices. H3 examines whether innovation capability serves as a mediating mechanism through which digital transformation enhances sustainable entrepreneurial learning practices. Finally, H4 tests the moderating role of entrepreneurial self-efficacy, proposing that higher levels of entrepreneurial self-efficacy strengthen the positive relationship between digital transformation and innovation capability. These hypotheses provide the basis for evaluating the proposed conceptual framework.

Table 1. Hypothesis paths

Path	Hypothesis	Relationship
DT → IC	H1	Digital transformation has a significant positive effect on innovation capability.
DT → SELP	H2	Digital transformation has a significant positive effect on sustainable entrepreneurial learning practices.
DT → IC → SELP	H3	Innovation capability mediates the relationship between digital transformation and sustainable entrepreneurial learning practices.
ESE × DT → IC	H4	Entrepreneurial self-efficacy moderates the DT → IC relationship (strengthening effect).

RESEARCH METHODS

This section describes the research design, population, data collection procedures, research instruments, and statistical techniques employed in this study. The methodological approach is outlined to ensure the systematic gathering, analysis, and interpretation of data necessary to address the research objectives and questions.

RESEARCH DESIGN

This study employed a quantitative, cross-sectional research design using a survey-based approach. This design is consistent with the positivist paradigm underpinning structural equation modeling (SEM). It is appropriate for testing the hypothesized causal relationships among digital transformation, innovation capability, sustainable entrepreneurial learning practices, and entrepreneurial self-efficacy (Hair et al., 2019). A cross-sectional design was selected to examine structural relationships among variables at a single point in time, aligning with prior empirical studies in digital transformation and entrepreneurship education that have tested mediation and moderation models using single-wave survey data (Firmansyah & Wahdiniwati, 2023; Nurfaizal, 2025; Zhou et al., 2025).

POPULATION AND SAMPLING STRATEGY

The target population consisted of 2,537 undergraduate students enrolled at an aeronautical and technological college in the Philippines for the 2025-2026 academic year. This institutional context was selected for its highly digitalized learning environment, integrating learning management systems, simulation-based platforms, and cloud-based tools, making it ideal for examining the effects of digital transformation on student innovation and entrepreneurial learning. Furthermore, the Philippine higher education sector has undergone rapid digital transformation, positioning Filipino students at the intersection of digital adoption and entrepreneurial skill development.

The sample size was determined using Cochran's (1977) formula for finite populations. With a 95% confidence level ($Z = 1.96$), a margin of error of 0.05, and a maximum variability population proportion of 0.50, the adjusted sample size for $N = 2,537$ was calculated to be 334 respondents. To ensure a representative selection of these 334 participants from the total population of 2,537 undergraduate students, stratified proportional random sampling was employed. Students were first stratified by academic program (e.g., aeronautical engineering, aviation technology, information technology, and related technical programs) and year level. Subsequently, respondents were selected from each stratum using a lottery method, with the number of participants from each stratum proportional to its share of the total student enrollment. This method ensured that each student within a stratum had an equal chance of being selected, thereby enhancing the representativeness of findings within the institutional context and minimizing selection bias (Creswell & Creswell, 2018).

The final sample of 334 valid responses satisfies multiple methodological thresholds for SEM. The sample size exceeds the widely cited minimum of 200 observations recommended for SEM with maximum likelihood estimation (Kline, 2016; Priyanath et al., 2020) and meets the 10:1 ratio of respondents to estimated parameters (Hair et al., 2019). Monte Carlo simulation studies confirm that sample sizes between 200 and 400 are sufficient for detecting medium-sized mediation effects with adequate statistical power (Sim et al., 2021). Magon et al. (2025) further demonstrated that a sample of approximately 344 is required for adequate power (≥ 0.80) for testing indirect and moderated effects typical of SEM. The sample of 334 thus provides sufficient statistical power for the moderated mediation model proposed in this study.

RESEARCH INSTRUMENT

Data were collected using a structured, self-administered questionnaire comprising five sections: (1) demographic profile, (2) digital transformation, (3) innovation capability, (4) sustainable entrepreneurial learning practices, and (5) entrepreneurial self-efficacy. All construct items were measured on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

Digital Transformation (DT)

The DT scale was adapted from Castro Benavides et al. (2026), who developed and validated a 29-item instrument to measure digital transformation in higher education institutions using the Delphi method, achieving content validity (Aiken's V coefficients of 0.91). The scale was informed by Khurniawan et al. (2022), who validated five indicators of digital transformation in distance education. Items were contextualized to reflect the digital learning ecosystem of a Philippine aeronautical and technological college, capturing students' experiences with the institution's learning management system, simulation-based training platforms, cloud-based academic resources, and digital assessment tools. For this study, 12 items were selected and adapted to reflect three dimensions relevant to the student experience: technology adoption maturity, digital platform integration in learning, and digital pedagogy innovation.

Innovation Capability (IC)

The IC scale was adapted from Zhou et al. (2025), who developed and validated new scales to measure digital literacy and innovation capability among university students. The scale was supplemented by items from Huang (2025), who investigated innovation capability among university students in interdisciplinary programs. The adapted scale comprises 10 items that capture three dimensions: creative problem-solving, idea generation and experimentation, and openness to novel approaches to learning.

Sustainable Entrepreneurial Learning Practices (SELP)

Given the novelty of this construct, the SELP scale was developed by the researcher based on a synthesis of existing instruments and literature. Items were drawn from Baltador and Grecu's (2023) conceptual framework, Leal Filho et al.'s (2024) multidimensional characterization, and Chander et al.'s (2020) inclusive framework. The scale comprises 10 items organized into three dimensions: resource-efficient digital learning behaviors, entrepreneurial skill development through digital tools, and environmentally conscious academic engagement. Beyond content validity, which was established through expert panel evaluation by five subject matter experts (CVI values above 0.80), the SELP scale's construct validity and reliability were assessed during the pilot testing phase and subsequently through Confirmatory Factor Analysis (CFA) as part of the measurement model assessment (Stage 1 of Data Analysis). This involved evaluating factor loadings, Average Variance Extracted (AVE), and Composite Reliability (CR) to ensure the scale measures the intended construct and exhibits internal consistency.

Entrepreneurial Self-Efficacy (ESE)

The ESE scale was adapted from Díaz (2021), who validated the six-factor scale. The instrument was informed by Chawla and Bhatia (2021), who refined existing ESE instruments. For this study, 10 items were selected to reflect four dimensions relevant to the student context: opportunity recognition confidence, resource mobilization belief, venture creation confidence, and digital entrepreneurial task confidence.

Control Variables

Year level, prior digital literacy experience, field of study, and gender were included as control variables to account for potential confounding effects on innovation capability and sustainable entrepreneurial learning practices.

PILOT TESTING

Prior to full-scale data collection, a pilot test was conducted with 50 students not included in the final sample. The pilot test assessed questionnaire clarity, evaluated internal consistency reliability (Cronbach's $\alpha \geq 0.70$), and identified potential issues in survey administration. The analysis yielded an estimate of 0.933, indicating a very high level of internal consistency. Items that reduced scale reliability or were flagged as ambiguous were revised before the main data collection.

DATA COLLECTION PROCEDURES

Data were collected through a face-to-face, researcher-administered survey over a four-week period. Respondents were undergraduate students across all year levels and programs at the college. The researcher distributed and collected structured questionnaires in classroom settings, resulting in a high response rate. Informed consent was obtained, explaining the study's purpose, voluntary participation, confidentiality, and right to withdraw. No personally identifiable information was collected. The study adhered to institutional ethical guidelines, and ethical clearance was obtained. To minimize common method bias, procedural remedies included assurances of anonymity, randomization of item order, and the use of reverse-coded items (Podsakoff et al., 2003).

DATA ANALYSIS

Data analysis was conducted in two stages following the two-step approach recommended by Anderson and Gerbing (1988): measurement model assessment followed by structural model testing.

STAGE 1: MEASUREMENT MODEL ASSESSMENT

Confirmatory Factor Analysis (CFA) was performed using AMOS version 26.0 to assess the validity and reliability of the measurement model. Criteria evaluated included:

Convergent validity

Assessed through factor loadings (≥ 0.50), Average Variance Extracted ($AVE \geq 0.50$), and Composite Reliability ($CR \geq 0.70$) (Hair et al., 2019).

Discriminant validity

Established by confirming that the square root of the AVE for each construct exceeded its correlations with all other constructs (Fornell & Larcker, 1981), supplemented by the Heterotrait-Monotrait (HTMT) ratio (< 0.85).

Model fit

Evaluated using multiple indices: Chi-square/degrees of freedom ($\chi^2/df \leq 3.0$), Comparative Fit Index ($CFI \geq 0.90$), Tucker-Lewis Index ($TLI \geq 0.90$), Root Mean Square Error of Approximation ($RMSEA \leq 0.08$), and Standardized Root Mean Square Residual ($SRMR \leq 0.08$).

Common method bias

Assessed through Harman's single-factor test, where a single factor accounting for less than 50% of total variance indicates that common method variance is not a serious concern.

STAGE 2: STRUCTURAL MODEL TESTING

The hypothesized structural model was tested using SEM with maximum likelihood estimation. The analysis proceeded as follows.

Direct effects (H1 and H2)

Tested by examining the path coefficients from digital transformation to innovation capability and from digital transformation to sustainable entrepreneurial learning practices, respectively. Statistical significance was assessed at the $p < 0.05$ level.

Mediation analysis (H3)

Conducted using the bootstrap method with 5,000 resamples and 95% bias-corrected confidence intervals, as recommended by Hayes (2018). A significant indirect effect with a confidence interval excluding zero provides evidence of mediation. The nature of mediation (full or partial) was determined by examining the direct effect of digital transformation on sustainable entrepreneurial learning practices in the presence of the mediator.

Moderation analysis (H4)

Performed by creating an interaction term (Digital Transformation $\times$ Entrepreneurial Self-Efficacy) and testing its effect on innovation capability. This was implemented using the latent interaction approach with the unconstrained product indicator method, as it is preferred for its ability to model interactions between latent variables without assuming perfect measurement (Little et al., 2006). A significant interaction term indicates that entrepreneurial self-efficacy moderates the relationship between digital transformation and innovation capability. A simple slope analysis was conducted to examine the nature of significant interaction effects.

Model fit

The structural model was assessed using the same indices applied to the measurement model (χ^2/df , CFI, TLI, RMSEA, SRMR).

Additionally, multiple regression analysis was conducted as a supplementary analysis to assess the robustness of the SEM findings, examining the predictive power (R^2) of digital transformation on each dependent variable while controlling for demographic variables. All analyses were performed using IBM SPSS version 28.0 for descriptive statistics, reliability analysis, and preliminary correlations, and AMOS version 26.0 for CFA and SEM.

ETHICAL CONSIDERATIONS

Ethical approval was obtained from the college's institutional research ethics review board prior to data collection, in compliance with the 2017 Philippine National Ethical Guidelines for Health and Health-Related Research and institutional policies governing research involving student participants. To protect against any perceived coercion given the academic setting, data collection was conducted independently of course requirements, and faculty members were not involved in the distribution or collection of questionnaires. No course credit or academic incentives were offered for participation.

FINDINGS

This section presents the findings of the data analysis, including the assessment of the measurement and structural models using Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM). The results of the hypothesis testing are presented, focusing on the direct, mediating, and moderating relationships among the study variables.

The demographic characteristics of the 334 respondents are summarized in Table 2, covering distributions for gender, year level, field of study, and prior digital literacy experience. The demographic profile reveals a predominantly male (56.29%) student population, with the largest representation from the 2nd Year level (43.71%). Participants are enrolled in technical aviation programs, led by Commercial Flying (30.54%) and Airline Operations (26.65%). Notably, a vast majority of respondents (88.32%) reported a high level of prior digital literacy, suggesting a technologically proficient sample well-suited to examining the impacts of digital transformation.

Table 2. Respondents' demographic information

Characteristics	Category	Frequency (n)	Percentage (%)
Gender	Male	188	56.29
	Female	146	43.71
Year level	1st Year	99	29.64
	2nd Year	146	43.71
	3rd Year	50	14.97
	4th Year	39	11.68

Characteristics	Category	Frequency (n)	Percentage (%)
Field of study	Commercial flying	102	30.54
	Airline operations	89	26.65
	Aircraft maintenance technology	74	22.16
	Aeronautical engineering	30	8.98
	Avionics technology	25	7.49
	Tourism management	14	4.19
Digital literacy experience	High	295	88.32
	Medium	28	8.38
	Low	11	3.29

MEASUREMENT MODEL ASSESSMENT (CFA RESULTS)

Confirmatory Factor Analysis (CFA) was conducted using AMOS 26.0 to evaluate the validity and reliability of the four constructs: Digital Transformation (DT), Innovation Capability (IC), Sustainable Entrepreneurial Learning Practices (SELP), and Entrepreneurial Self-Efficacy (ESE) (Table 3). All standardized factor loadings exceeded the recommended threshold of 0.50, ranging from 0.64 to 0.89, indicating acceptable indicator reliability. Composite Reliability (CR) values ranged from 0.82 to 0.91, exceeding the minimum criterion of 0.70, while Average Variance Extracted (AVE) values ranged from 0.53 to 0.68, confirming convergent validity (Hair et al., 2019). Discriminant validity was established as the square root of AVE for each construct exceeded all inter-construct correlations (Fornell & Larcker, 1981). Additionally, HTMT ratios ranged from 0.62 to 0.81, all below the conservative threshold of 0.85.

Table 3. Measurement model results

Construct	Items	Factor loadings	CR	AVE
Digital Transformation (DT)	12	0.66-0.87	0.91	0.63
Innovation Capability (IC)	10	0.64-0.85	0.87	0.58
Sustainable Entrepreneurial Learning (SELP)	10	0.68-0.89	0.89	0.68
Entrepreneurial Self-Efficacy (ESE)	10	0.65-0.84	0.82	0.53

The model fit indices for the CFA indicated a good fit: $\chi^2/df = 2.41$, CFI = 0.93, TLI = 0.92, RMSEA = 0.056, SRMR = 0.049, all meeting recommended thresholds ($\chi^2/df \leq 3.0$; CFI and TLI ≥ 0.90 ; RMSEA ≤ 0.08 ; SRMR ≤ 0.08). Harman's single-factor test confirmed that common method bias was not a serious concern, with the first unrotated factor accounting for 34.7% of the total variance, below the 50% threshold (Podsakoff et al., 2003). The CFA measurement model is visually represented in Figure 2.

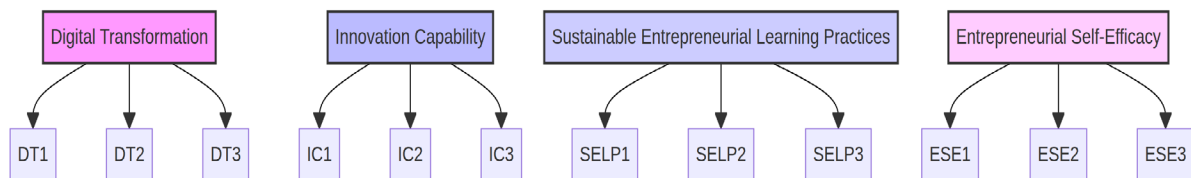


Figure 2. Confirmatory Factor Analysis (CFA) measurement model

CORRELATION MATRIX

The inter-construct correlation matrix (Table 4) reveals significant positive relationships among all study variables. The strongest correlation is observed between Digital Transformation (DT) and Innovation Capability (IC) ($r = 0.61$), followed by the relationship between IC and Sustainable Entrepreneurial Learning Practices (SELP) ($r = 0.55$). These moderate-to-strong correlations provide initial evidence for the hypothesized direct and mediating pathways. Furthermore, Entrepreneurial Self-Efficacy (ESE) shows positive correlations with DT ($r = 0.35$), IC ($r = 0.40$), and SELP ($r = 0.30$), supporting its inclusion as a potential moderator. Importantly, all correlation coefficients are below the 0.85 threshold, suggesting that the constructs are distinct and that multi-collinearity is not a significant concern.

Table 4. Inter-construct correlation matrix

Construct	DT	IC	SELP	ESE
DT	1.00			
IC	0.61	1.00		
SELP	0.48	0.55	1.00	
ESE	0.35	0.40	0.30	1.00

STRUCTURAL MODEL ASSESSMENT AND HYPOTHESES TESTING

The structural model also demonstrated good fit to the data: $\chi^2/df = 2.58$, CFI = 0.92, TLI = 0.91, RMSEA = 0.059, SRMR = 0.052. The results for each hypothesis are presented below, and the full structural model with path coefficients is illustrated in Figure 3.

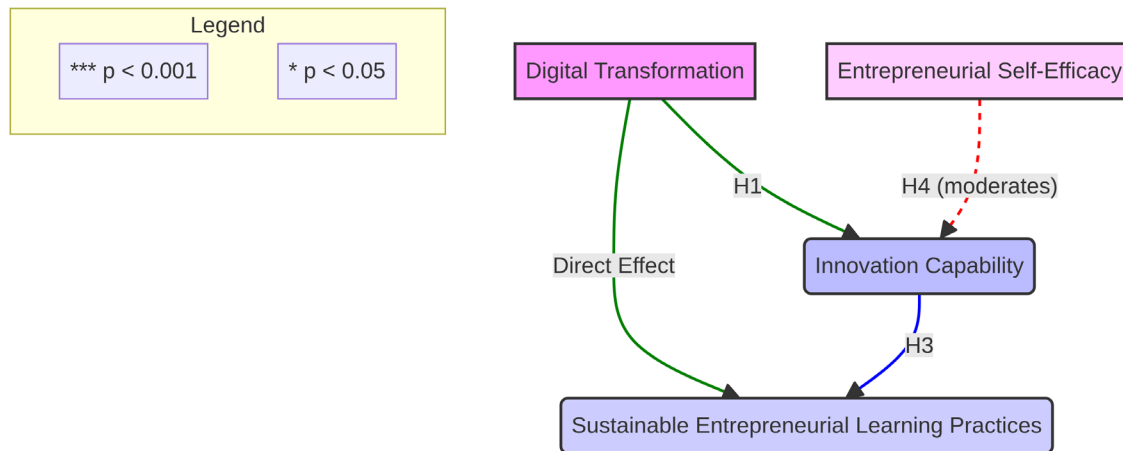


Figure 3. Structural equation model with path coefficients

Hypothesis 1: Digital Transformation → Innovation Capability

H1, predicting a significant positive effect of digital transformation on innovation capability, was supported ($\beta = 0.61$, $SE = 0.07$, $CR = 8.71$, $p < 0.001$) (Table 5). This indicates that digitally transformed learning environments enhance students' capacity for creative problem-solving and idea generation, consistent with existing literature (Zhou et al., 2025).

Table 5. Direct effect of digital transformation on innovation capability (H1)

Path	β	SE	CR	P-value	Decision
DT → IC	0.61	0.07	8.71	<0.001	H1 Supported

Hypothesis 2: Digital Transformation → Sustainable Entrepreneurial Learning Practices

Digital transformation had a significant positive effect on sustainable entrepreneurial learning practices ($\beta = 0.48$, $SE = 0.08$, $CR = 6.25$, $p < 0.001$). This represents the total effect of DT on SELP before accounting for the mediating role of innovation capability. H2 is supported, suggesting that digital advancements contribute to students' engagement in resource-efficient digital learning behaviors and environmentally conscious academic engagement (Table 6).

Table 6. Direct effect of digital transformation on sustainable entrepreneurial learning practices (H2)

Path	β	SE	CR	P-value	Decision
DT → SELP (total effect)	0.48	0.08	6.25	<0.001	H2 Supported

Hypothesis 3: Mediating Role of Innovation Capability

Mediation analysis (H3) revealed a significant indirect effect of digital transformation on sustainable entrepreneurial learning practices through innovation capability ($\beta = 0.29$, 95% CI [0.20, 0.39]), with the confidence interval excluding zero. The direct effect of digital transformation on SELP decreased from $\beta = 0.48$ to $\beta = 0.19$ in the presence of the mediator, remaining significant, thus indicating partial mediation. Innovation capability accounts for approximately 60.4% of the total effect, underscoring its crucial role as a transmission mechanism (Table 7).

Table 7. Mediating role of innovation capability

Effect	β	Boot SE	95% CI	Result
Total effect (DT → SELP)	0.48	0.08	[0.33, 0.63]	Significant
Direct effect (DT → SELP, with mediator)	0.19	0.07	[0.05, 0.33]	Significant
Indirect effect (DT → IC → SELP)	0.29	0.05	[0.20, 0.39]	Significant

Hypothesis 4: Moderating Role of Entrepreneurial Self-Efficacy

H4, positing that entrepreneurial self-efficacy moderates the digital transformation-innovation capability relationship, was supported by a significant interaction term (DT × ESE) ($\beta = 0.21$, $SE = 0.06$, $CR = 3.50$, $p = 0.001$) (Table 8). Simple slope analysis clarified this interaction: the positive effect of digital transformation on innovation capability was significantly stronger for students with high entrepreneurial self-efficacy ($\beta = 0.73$, $p < 0.001$) compared to those with low entrepreneurial self-efficacy ($\beta = 0.42$, $p < 0.001$). This implies that students with greater confidence in their entrepreneurial abilities are better positioned to leverage digital learning environments for innovation.

Table 8. Moderating role of entrepreneurial self-efficacy

Path	β	SE	CR	p-value	Decision
DT × ESE → IC	0.21	0.06	3.50	0.001	H4 Supported

EXPLAINED VARIANCE AND CONTROL VARIABLES

The model demonstrated substantial explanatory power, accounting for 54% of the variance in innovation capability and 62% in sustainable entrepreneurial learning practices (Cohen, 1988) (Table 9).

Table 9. Explained variance

Endogenous variable	R ²	Interpretation
Innovation capability	0.54	Substantial
Sustainable entrepreneurial learning practices	0.62	Substantial

Supplementary hierarchical multiple regression analysis confirmed the robustness of the SEM findings. After controlling for demographic variables (gender, year level, field of study, and prior digital literacy experience), digital transformation remained a significant predictor of both innovation capability and sustainable entrepreneurial learning practices, as detailed in Table 10.

Table 10. Supplementary regression analysis with control variables

Dependent variable	Step	Predictor	β	t-value	p-value	ΔR^2
Innovation capability	1	Control variables	-	-	-	0.06
	2	Digital transformation	0.59	9.12	<0.0001	0.46
						Total R ² = 0.52
SELP	1	Control variables	-	-	-	0.08
	2	Digital transformation	0.46	7.34	<0.001	0.52
						Total R ² = 0.60

SUMMARY OF HYPOTHESES

Table 11 summarizes the hypothesis testing, showing that all hypothesized relationships, direct, mediating, and moderating effects, are statistically supported.

Table 11. Summary of hypotheses testing

Hypothesis	Path	β	p-value	Decision
H1	DT $\rightarrow$ IC	0.61	<0.001	Supported
H2	DT $\rightarrow$ SELP (total)	0.48	<0.001	Supported
H3	DT $\rightarrow$ IC $\rightarrow$ SELP (indirect)	0.29	CI [0.20, 0.39]	Supported (partial mediation)
H4	DT $\times$ ESE $\rightarrow$ IC	0.21	0.001	Supported

DISCUSSION

This section presents the interpretation and analysis of the study's findings in relation to the research objectives, theoretical framework, and relevant literature. The section examines the significance of the results, highlights key insights, and discusses their implications for theory, practice, and future research.

DIGITAL TRANSFORMATION AND INNOVATION CAPABILITY (H1)

The finding that digital transformation positively influences students' innovation capability ($\beta = 0.61$, $p < 0.001$) aligns with Dynamic Capabilities Theory (Teece, 2018), which suggests that digitally transformed environments enable individuals to reconfigure knowledge and develop innovative solutions. This result is consistent with the empirical literature, which reports similar positive relationships across various contexts (Cheng, 2025; Firmansyah & Wahdiniwaty, 2023; Zhou et al., 2025).

The substantial effect size ($\beta = 0.61$) in this study, particularly within an aeronautical and technological college, suggests that institutions with deeply embedded digital tools may foster innovation more

effectively. However, this relationship is not straightforward. Dissenting findings, such as those by Sustaningrum (2022) and Theng et al. (2021), indicate that the impact of digital transformation on innovation capability is contingent on the quality of implementation and the design of digital tools, rather than mere availability. The strong effect observed here may reflect the coherent digital ecosystem of the study institution, implying that a strategic and integrated approach to digital transformation is crucial for cultivating innovation capability.

DIGITAL TRANSFORMATION AND SUSTAINABLE ENTREPRENEURIAL LEARNING PRACTICES (H2)

Digital transformation also demonstrated a significant positive effect on sustainable entrepreneurial learning practices ($\beta = 0.48$, $p < 0.001$). This finding contributes to the literature by establishing a direct structural link between digital transformation and sustainable entrepreneurial learning, an area explored more conceptually (Leal Filho et al., 2023, 2024; Shenkoya & Kim, 2023). The moderate-to-strong effect size suggests that digitally transformed learning environments can encourage resource-efficient digital learning behaviors and environmentally conscious academic engagement.

This outcome resonates with arguments that sustainability-informed entrepreneurial education develops critical thinking and problem-solving skills relevant to contemporary challenges (Patricia, 2024; Zherdeva et al., 2024). The context of a developing economy like the Philippines highlights that institutional commitment to digital integration can catalyze sustainable entrepreneurial learning, even in resource-constrained settings. This underscores the potential of digital transformation as a strategic lever for fostering sustainability-oriented education.

THE MEDIATING ROLE OF INNOVATION CAPABILITY (H3)

Innovation capability partially mediates the relationship between digital transformation and sustainable entrepreneurial learning practices, with the indirect effect ($\beta = 0.29$, 95% CI [0.20, 0.39]) accounting for approximately 60% of the total effect. This supports H3 and offers a key theoretical contribution: digital transformation fosters sustainable entrepreneurial learning by enhancing innovation capability. This mediation pattern aligns with the Dynamic Capabilities framework, where capabilities act as transmission mechanisms between resources and outcomes (Teece, 2018). Similar mediation patterns have been observed in organizational contexts (Abdelwaheed et al., 2025; Firmansyah & Wahdiniwati, 2023) and among students (Nurfaizal, 2025).

The partial mediation is significant, indicating that while innovation capability is a dominant pathway, digital transformation also has residual direct effects on sustainable entrepreneurial learning. These direct effects might operate through mechanisms beyond innovation, such as direct changes in resource-efficient behaviors facilitated by digital platforms or institutional signals promoting sustainability. Mixed mediation patterns in digital transformation-sustainability pathways have been noted in systematic reviews (AlMutairi & Abu Talib, 2025), suggesting complexity. Nevertheless, the prominence of the indirect pathway (60% of the total effect) emphasizes that innovation capability is a crucial mechanism for converting digital resources into sustainable entrepreneurial outcomes.

THE MODERATING ROLE OF ENTREPRENEURIAL SELF-EFFICACY (H4)

Entrepreneurial self-efficacy significantly moderated the digital transformation–innovation capability relationship ($\beta = 0.21$, $p = 0.001$). Simple slope analysis indicated that the positive influence of digital transformation on innovation capability was substantially stronger for students with high ESE ($\beta = 0.73$) compared to those with low ESE ($\beta = 0.42$). This finding, grounded in Social Cognitive Theory (Bandura, 1997), suggests that self-efficacy plays a critical role in how effectively individuals leverage environmental stimuli for capability development. Students with higher ESE are more likely to engage actively with digital platforms, experiment, and persist through learning challenges, aligning with previous research on self-efficacy and innovation (Gill et al., 2021; Liu et al., 2023; Permono & Kurniati, 2024).

The practical implication is profound: the same digital transformation environment may yield vastly different innovation capabilities depending on students' ESE. The 31-point difference in effect size between high- and low-ESE students highlights the potential of interventions aimed at building entrepreneurial confidence. This finding serves as an important caveat: without adequate psychological readiness, the innovation-generating potential of digital tools may be underutilized. However, it is important to consider Lei's (2025) cautionary note regarding a potential inverted U-shaped relationship between ESE and entrepreneurial effort, suggesting that excessively high self-efficacy could reduce effort. Future research could explore the non-linear moderation effects of ESE.

THEORETICAL IMPLICATIONS

This study offers several theoretical contributions. First, it extends Dynamic Capabilities Theory by demonstrating its applicability at the individual student level, showing that digital transformation fosters innovation capability among learners. Second, it integrates Dynamic Capabilities Theory with Social Cognitive Theory, illustrating that entrepreneurial self-efficacy moderates the digital transformation-innovation capability pathway, thereby providing a more comprehensive model of capability development. Third, the study introduces sustainable entrepreneurial learning practices as a novel outcome variable, bridging the digital transformation, innovation management, and sustainable entrepreneurship literatures by demonstrating its structural relationship with digital transformation through the mediation of innovation capability.

PRACTICAL IMPLICATIONS

For higher education managers and policymakers, these findings yield actionable recommendations. First, digital transformation investments should prioritize cultivating innovation capability through interactive, simulation-based, and problem-oriented digital tools, rather than merely digitizing existing processes. The strong mediation effect of innovation capability (60% of the total effect) indicates its centrality in translating digital investments into sustainable entrepreneurial outcomes. Second, institutions should complement digital infrastructure with programs designed to enhance students' entrepreneurial self-efficacy. This can be achieved through mentorship, experiential learning, and venture simulation exercises. Third, for Philippine higher education, particularly aeronautical and technological colleges, the intensive digital integration positions them as potential models for digital transformation-driven sustainable entrepreneurship education, aligning with government mandates for technology-enhanced learning.

CONCLUSIONS

This study investigated how digital transformation influences students' innovation capability and sustainable entrepreneurial learning practices within a Philippine aeronautical and technological college, confirming the mediating role of innovation capability and the moderating role of entrepreneurial self-efficacy. All four hypotheses were supported, providing a comprehensive understanding of these interrelationships.

Specifically, digital transformation enhances students' innovation capability and contributes to sustainable entrepreneurial learning practices. Crucially, innovation capability serves as a partial mediator, indicating that digital investments foster sustainable entrepreneurial learning by enabling students to generate and apply novel ideas. Furthermore, entrepreneurial self-efficacy significantly moderates the digital transformation-innovation capability relationship, highlighting that students with higher entrepreneurial confidence are positioned to leverage digital learning environments for innovation.

This research makes a unique theoretical contribution by integrating Dynamic Capabilities Theory and Social Cognitive Theory within a higher education context. This study extends DCT by demonstrating its applicability at the individual student level, showing how digital transformation builds innovation capability among learners. Concurrently, it integrates SCT by proving that entrepreneurial self-efficacy acts as a psychological boundary condition, amplifying or constraining the conversion of

digital resources into innovative capacity. This dual-theoretical lens offers a complete and detailed model of capability development in digitally transformed educational settings.

For higher education institutions, the practical implications are clear: prioritize digital transformation initiatives that cultivate innovation capabilities through interactive, problem-oriented tools. Complement these investments with programs designed to build students' entrepreneurial self-efficacy, such as mentorship and venture simulation exercises. This integrated approach will maximize the returns on digital transformation, fostering both innovation and sustainable entrepreneurial learning.

LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

This study acknowledges several limitations that offer avenues for future research. First, its cross-sectional design precludes causal inference; longitudinal studies are needed to establish temporal precedence and examine how these relationships evolve over time. Second, the single-institution setting in the Philippines limits the generalizability of findings to other institutional types and national contexts. Multi-institutional and cross-country comparative studies would enhance external validity. Third, while procedural remedies and Harman's single-factor test mitigated common method bias, future research could incorporate objective measures of innovation capability (e.g., project outputs, patent applications) and behavioral indicators of sustainable learning to complement self-reported data.

Fourth, the study tested entrepreneurial self-efficacy as a linear moderator; future research should explore potential curvilinear moderation effects, particularly given findings suggesting non-linear relationships at extreme levels of self-efficacy (Lei, 2025). Fifth, the researcher-developed Sustainable Entrepreneurial Learning Practices scale warrants further validation across diverse institutional and cultural contexts. Finally, future studies could investigate additional mediators (e.g., digital self-efficacy, creative thinking dispositions) and moderators (e.g., institutional support, faculty digital competence) to further enrich the model and identify additional boundary conditions.

AUTHOR STATEMENT

The author declares that no conflict of interest exists.

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