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Educational Capability and the Formation of Technopreneurial Intention: A Multi-Theoretical Integration of Self-Efficacy and Digital Cognition

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Abstract

In the context of digital transformation, higher education increasingly confronts the challenge of explaining how entrepreneurial intention in technology-oriented domains emerges from structured educational processes rather than from skills acquisition alone. This study develops and empirically examines an integrative model that conceptualizes educational capability as the foundation of technopreneurial intention formation, emphasizing experiential learning and digital literacy as core capability resources. Drawing on complementary theoretical perspectives in learning theory, human capital theory, social cognitive theory, the theory of planned behavior, and technology acceptance theory, the model positions self-efficacy and digital cognition as central mechanisms linking educational capability to entrepreneurial intention. Using survey data from 689 university students in Indonesia, the findings show that experiential learning and digital literacy exert both direct and indirect effects on technopreneurial intention through the enhancement of self-efficacy. The results indicate that educational capability operates as a structured process of capability formation that shapes confidence, technological beliefs, and entrepreneurial orientation. By integrating capability-based, psychological, and cognitive perspectives, this study advances a more comprehensive explanation of technopreneurial intention formation within digitally immersed higher education contexts.

1. Introduction

In the global economic landscape, higher education institutions face increasing pressure to produce graduates who are capable of creating jobs rather than merely seeking them—particularly in technology-based sectors, where innovation cycles are rapid and digital capabilities determine competitiveness (Berchin et al., 2021; Shahjahan et al., 2022; Komljenovic, 2022; Hart & Rodgers, 2023; Rehman, 2025). This shift underscores the transformative role of universities as learning environments that cultivate entrepreneurial mindsets, technological fluency, and applied innovation skills among students. Numerous meta-analyses and large-scale studies indicate that entrepreneurial intention is the closest predictor of entrepreneurial behavior; however, the strength of this relationship is highly contingent on contextual factors, capability development, and supportive learning environments (Fayolle & Liñán, 2014; Krueger et al., 2000; Pérez-Macías et al., 2022; Batz Liñeiro et al., 2024; Neneh & Dzomonda, 2024; Ridwan et al., 2025).

For Generation Z—the cohort of digital natives currently pursuing higher education and entering the workforce—the opportunities and challenges of the digital economy have become increasingly tangible. While they are inherently familiar with technology, their success in entrepreneurship depends on the extent to which higher education institutions can transform technological exposure into structured learning processes, practice-based experiences, and the development of robust human capital (Lesinskis et al., 2023; Hossain et al., 2023; Hasan et al., 2024; Onjewu et al., 2025; Ba Awain et al., 2025). Within educational settings, this transformation requires integrating pedagogical models that combine experiential learning and digital literacy to prepare students not only as competent users of technology but also as proactive creators of digital value. On the other hand, digital literacy—defined as the ability to

access, understand, and effectively utilize technology—remains uneven, influencing whether young people can convert technological familiarity into entrepreneurial intentions and actions (Chen et al., 2024; Abdelwahed et al., 2025).

In the context of technopreneurship education, recent empirical evidence indicates that technopreneurial self-efficacy and structured learning experiences contribute positively to technology-based entrepreneurial intentions, particularly when curricula are designed to be participatory, project-based, and capable of fostering optimism toward technology (Sitaridis & Kitsios, 2024; Li et al., 2024). Research in digital entrepreneurship education also demonstrates that embedding digital literacy in pedagogical design enhances entrepreneurial propensity, yet the mechanisms linking this relationship remain insufficiently addressed in an integrated educational model (Hasan et al., 2024; Abaddi, 2024; Zeynalov & Doğantan, 2025). Meanwhile, the theory of planned behavior (TPB) continues to be the dominant framework in entrepreneurial intention studies; however, recent developments highlight the importance of self-efficacy (social cognitive theory/SCT) and technological beliefs (technology acceptance model/TAM) in the digital era, necessitating a more comprehensive theoretical integration (Bandura, 2001; Venkatesh & Bala, 2008; Ajzen, 2020).

This study argues that a comprehensive understanding of technopreneurial intention (TI) among Generation Z in higher education requires integrating five theoretical perspectives that together illuminate the educational process of capability formation. Experiential learning theory (ELT) explains how technopreneurial learning (TL) develops capabilities through cycles of experience and reflection; human capital theory (HCT) positions TL and digital literacy (DL) as forms of skill investment that enhance productivity and learning outcomes; SCT models technopreneurial self-efficacy (TSE) as a psychological mechanism bridging skills and intention; TPB connects perceived behavioral control (through TSE) with intention; and TAM captures how DL influences perceived usefulness and perceived ease of use, which, in turn, shape technology-based entrepreneurial intentions (Davis et al., 1989; Becker, 1992; Kolb, 2014; Ajzen, 2020). This theoretical integration aligns with recent findings in entrepreneurship education emphasizing the importance of experience-based learning designs, coaching/mentoring, and real-world projects in building self-efficacy and intention, while clarifying the pathways through which digital literacy influences technological confidence and entrepreneurial readiness (Hägg & Kurczewska, 2020; Baggen et al., 2022).

Three research gaps motivate this study. First, technopreneurship research typically examines dyadic relationships (e.g., education → intention; self-efficacy → intention) without a process model connecting TL and DL to TSE and TI within a single validated empirical framework (Soomro & Shah, 2020; Soomro et al., 2024; Nguyen & Nguyen, 2024; Ioannou & Retalis, 2025). Second, the technological belief pathway central to TAM is rarely combined with TPB/SCT to reflect how DL shapes perceived usefulness and perceived ease of use, which subsequently strengthen TSE and TI (Al Mamun & Fazal, 2021; Phuong Dung et al., 2023). Third, empirical evidence focusing on Generation Z remains fragmented, despite calls to align experience-based pedagogy and human capital development with the formation of

entrepreneurial intentions in digital contexts (Hamdi et al., 2023; Saeedikiya et al., 2024; Hasan et al., 2025a; Jalil et al., 2025; Herani & Angela, 2025).

Therefore, this study offers novelty by proposing and empirically testing a multi-theoretical model (ELT–HCT–SCT–TPB–TAM) that links TL and DL to TI both directly and indirectly through TSE among Generation Z university students. This approach reconciles experience- and human-capital-based explanations with psychological mechanisms and technological beliefs in a single, integrated model, strengthening the pedagogical understanding of how experiential learning and digital literacy can be harnessed to foster technopreneurial intention in higher education.

Accordingly, the research questions are: (1) How do TL and DL influence TI among Generation Z students?; (2) To what extent does TSE mediate the effects of TL and DL on TI?; and (3) Are the technological beliefs implied by DL consistent with SCT and TPB mechanisms via TSE and perceived behavioral control? To address these questions, this study develops and validates a multi-theoretical framework explaining how TL and DL shape TI directly and through TSE in the context of higher education students. Empirically, the model is tested using PLS-SEM to estimate direct and mediated effects, consistent with current approaches in digital entrepreneurship and technopreneurship education research.

The theoretical contributions of this study are threefold. First, it integrates ELT and HCT to position TL/DL as educational investments that operate through SCT-based TSE to enhance entrepreneurial intentions in line with TPB, with TAM providing the explanatory pathway for technological beliefs—responding to calls to move beyond single-theory models in digital entrepreneurship education. Second, it provides Generation Z–specific evidence that DL's effect on intention operates primarily through technological beliefs and self-efficacy, rather than mere exposure. Third, it models TSE as a partial mediator, bridging divergent findings on the roles of education, self-efficacy, and attitudes in shaping intention. The practical contributions include demonstrating that experience- and action-based learning designs (projects, mentoring, business simulations) are highly effective in building TSE and technology-based entrepreneurial intentions; identifying DL as a relevant policy lever to enhance technological confidence and graduate entrepreneurial readiness; and offering educators guidance to monitor and assess TSE, DL, and TAM constructs to target interventions at the weakest points in intention formation.

This article is structured as follows: The first section introduces the research background and rationale. The second section elaborates the theoretical foundation and hypotheses based on the integration of ELT, HCT, SCT, TPB, and TAM. The third section outlines the research design and measurement. The fourth section reports the measurement and structural model results. The fifth section discusses the findings in light of educational implications. The sixth section presents the conclusions, while the seventh outlines implications, limitations, and directions for future educational research.

2. Literature Review and Hypotheses Development

2.1. Integrating ELT, HCT, SCT, TPB, and TAM: A Coherent Process Model from Learning and Digital Literacy to Technopreneurial Intention

This framework positions TL and DL as two capability-based educational resources that shape TSE and, ultimately, TI among university students. Drawing from ELT, TL is understood as a cycle of experience, reflection, conceptualization, and experimentation that transforms technological exposure into transferable competencies for technology-based value creation. In higher education contexts, ELT highlights how authentic projects, reflective practice, and mentoring activities develop students' psychological readiness and entrepreneurial learning outcomes. Recent evidence in entrepreneurship education shows that experience-based learning designs, project assignments, and mentoring consistently enhance students' entrepreneurial confidence and behavioral outcomes, making them the initial triggers in the model (Morris, 2019; Wong & Chan, 2021).

HCT complements ELT by emphasizing that TL and DL are forms of human capital investment that enhance innovation, adaptability, and employability. TL and DL operate as educational assets that strengthen students' readiness to create digital ventures and pursue entrepreneurial careers. Empirical studies demonstrate that richer measures of entrepreneurial human capital significantly affect firm performance and innovation, reinforcing the capability-building function of TL and DL (Braunerhjelm & Lappi, 2023). In the digital era, DL—including access, proficiency, and critical use—serves as a key component of human capital that fosters resilience, creativity, and entrepreneurial orientation, positioning DL as a central capability in the model (Shatila et al., 2025).

SCT provides the psychological mechanism that bridges capabilities to behavioral intention through TSE. Mastery experiences, vicarious learning, and social persuasion embedded in TL enhance students' self-belief in performing technopreneurial tasks and reinforce motivation to apply technological knowledge. Longitudinal and quasi-experimental evidence has confirmed that self-efficacy exerts a strong influence on start-up performance and entrepreneurial persistence, positioning TSE as a proximal psychological driver within the model (Caliendo et al., 2023). Likewise, SCT-based research indicates that DL influences entrepreneurial outcomes indirectly through efficacy and outcome expectations, supporting TSE's mediating role in linking TL and DL to TI (Vu et al., 2024).

TPB connects TSE to perceived behavioral control and subsequently to TI. Large-scale TPB-based research in higher education has demonstrated that attitudes, subjective norms, and perceived behavioral control are reliable predictors of entrepreneurial intention; when perceived behavioral control is represented through self-efficacy—as in technology-based learning environments—its predictive effect becomes stronger. Recent studies among university students reinforce this relationship, providing empirical grounding for the TSE → TI pathway in digital education contexts (Nguyen et al., 2022; Maheshwari et al., 2023; Batz Liñeiro et al., 2024).

TAM explains why DL is particularly relevant within this integrated framework. DL shapes technological beliefs, specifically perceived usefulness and perceived ease of use, which enhance both TSE and students' positive attitudes toward using technology in learning and venture creation. In educational

practice, DL not only builds technical proficiency but also fosters technological optimism and cognitive readiness for digital entrepreneurship. Recent studies in digital entrepreneurship education confirm that digital training and platform-based learning improve perceived usefulness and perceived ease of use, which in turn enhance entrepreneurial confidence and strengthen TI (Ilyas et al., 2023; Duong et al., 2024; Singh et al., 2024).

Integrating these five theoretical perspectives yields a coherent multi-stage process in which TL and DL (ELT–HCT) form learning-based capabilities that enhance TSE (SCT) through mastery experiences and social support. DL also increases perceived usefulness and perceived ease of use (TAM), reinforcing TSE and shaping favorable attitudes toward technology use. Subsequently, TSE strengthens perceived behavioral control and leads to higher TI (TPB). This framework explains both the direct effects of TL and DL on TI and the indirect effects via TSE, as well as the cognitive pathway from DL to perceived usefulness and perceived ease of use, which ultimately influence TSE and TI.

This synthesis addresses a key gap in technopreneurship education research—namely, the separation between the learning-capability dimension (ELT–HCT), the psychological mechanism (SCT–TPB), and the technological cognition process (TAM). By integrating these elements, the model provides a unified process specification consistent with current empirical evidence across digital learning environments and entrepreneurship curricula (Wong & Chan, 2021; Braunerhjelm & Lappi, 2023; Duong et al., 2024).

In line with this synthesis, Table 1 presents a concise summary of the five theoretical foundations—ELT, HCT, SCT, TPB, and TAM—and their translation into measurable constructs within the proposed research model. Each theoretical lens contributes a distinct yet complementary explanation of how TL and DL influence TSE and TI among Generation Z students in higher education. ELT emphasizes experiential processes as the foundation of TL, HCT positions TL and DL as educational investments that enhance human capital and adaptability, SCT introduces TSE as the psychological bridge linking capability development to behavioral outcomes, TPB operationalizes perceived behavioral control through TSE as a proximal predictor of intention, and TAM clarifies how DL shapes technological beliefs—namely perceived usefulness and perceived ease of use—that ultimately influence TI. By integrating these perspectives, the model ensures theoretical robustness, pedagogical coherence, and empirical clarity, responding to current calls to move beyond single-theory approaches in technopreneurship and entrepreneurship education research.

Table 1
Integration of Theories, Derived Variables, and References

Theory	Brief Explanation	Derived Variables	Sources
ELT	Structured learning through experience, reflection, and experimentation develops transferable competencies and enhances students' entrepreneurial learning outcomes.	TL	Kolb (2014); Abd Rahim et al. (2022); Daniel et al. (2024).
HCT	TL and DL represent educational investments that strengthen human capital, adaptability, and innovation capability among students.	TL, DL	Becker (1992); Shatila et al. (2025).
SCT	Mastery experiences, vicarious learning, and social persuasion cultivate TSE as a psychological mediator linking learning to behavioral outcomes.	TSE	Bandura (2001); Nayak (2024); Tam et al. (2024)
TPB	Perceived behavioral control—operationalized through TSE—directly influences TI, highlighting the educational role of self-efficacy in shaping intention.	TSE, TI	Ajzen (2020); Aga (2023); Ngo et al. (2024)
TAM	DL shapes technological beliefs that foster positive attitudes and strengthen technology-based entrepreneurial intention.	DL, TI	Davis et al. (1989); Dabbous (2023).

2.2. Hypotheses Development

2.2.1. The Effects of TL on TI and TSE

TL is conceptualized as an experiential-based learning approach that immerses students in real situations to solve technology-oriented entrepreneurial problems. Operating through the cycle of experience–reflection–conceptualization–experimentation emphasized in ELT, TL enables students to transform technological exposure into practical competencies (Kolb, 2014; Hägg & Kurczewska, 2020). Within higher education settings, TL integrates field projects, business simulations, mentoring, and incubation activities that nurture reflective, collaborative, and digital adaptation abilities (Neck & Greene, 2011; Nabi et al., 2017; Baggen et al., 2022).

Recent studies have highlighted that TL plays a crucial role in shaping students' entrepreneurial mindset and technological orientation (Hägg, 2021; Bell & Bell, 2020; Ratten & Jones, 2021; Yan et al., 2023; Larsen et al., 2024). Active student engagement in contextual learning experiences strengthens opportunity perception, analytical capability, and readiness for digital innovation. From the TPB perspective, TL may influence TI through enhanced positive attitudes toward entrepreneurship, supportive social norms, and perceived behavioral control. Cross-country empirical evidence also confirms that project-based learning significantly increases entrepreneurial intention among digital-generation students (Walter & Block, 2016; Nowiński et al., 2020; Liguori & Winkler, 2020; Ashraf et al., 2025).

Nevertheless, the literature indicates variations in the direct effect of TL on TI. Several studies have found that this relationship may weaken when psychological variables such as self-efficacy, intrinsic motivation, or social support are considered (Rauch & Hulsink, 2015; Lyons & Zhang, 2018; Hahn et al., 2020; Hasan et al., 2025b). However, recent research in digital entrepreneurship education demonstrates that when TL is implemented with constructive alignment—namely, the integration of authentic experiences, guided reflection, and continuous assessment—its effect on TI increases significantly (Nabi et al., 2021; Baggen et al., 2022; Li et al., 2024). Based on the integration of ELT and TPB, as well as consistent empirical evidence, the first hypothesis is proposed as follows:

H1

TL positively affects TI.

Within the framework of SCT, TSE represents students' belief in their capability to accomplish technopreneurial tasks and manage technology-based business challenges (Bandura, 2001). TL plays a pivotal role in strengthening TSE as it provides mastery experiences (direct success experiences), vicarious learning (learning through peers' achievements), and social persuasion (support from mentors and lecturers) that collectively reinforce students' confidence (Pittaway & Cope, 2007; Liguori et al., 2019; Nabi et al., 2021).

Recent studies confirm that TL serves as a strong predictor of TSE in higher education. TL has been shown to enhance self-efficacy perceptions by strengthening reflective abilities, problem-solving capacity, and opportunity recognition (Hägg & Gabrielsson, 2021; Hahn et al., 2020; Bell & Bell, 2020; Ratten & Usmanij, 2021; Otache, 2025; Van Ewijk, 2025). Emerging research also highlights that project-based digital learning and technology-oriented action learning activities expand students' perceived control and psychological resilience (Li et al., 2024; Wang et al., 2025a; Huang et al., 2025). Nevertheless, the effect of TL on TSE is highly sensitive to learning design: without sufficient reflective support, scaffolding, or effective social interaction, learning experiences may create ambiguity and diminish efficacy (Jones & Matlay, 2011; Pittaway et al., 2015; Al Issa, 2025). Therefore, in a reflectively and purposefully designed technopreneurship education context, TL is expected to strengthen students' TSE. Based on the SCT framework and the supporting empirical evidence, the second hypothesis is formulated as follows:

H2

TL positively affects TSE.

2.2.2. The Effects of DL on TI and TSE

DL represents individuals' ability to access, understand, evaluate, and effectively use digital technologies for learning and innovation purposes. Within the HCT framework, DL is categorized as a form of knowledge and skill investment that expands students' productive capacity, particularly in the digital economy context (Becker, 1992; Shatila et al., 2025). The enhancement of DL enables students to utilize

technology as a strategic resource, both in learning processes and in entrepreneurial value creation. From the ELT perspective, experience-based digital learning contributes to strengthening technological literacy and readiness for change (Hägg & Kurczewska, 2020; Nabi et al., 2021; Sitaridis & Kitsios, 2024; Çela et al., 2025).

Recent literature indicates that DL has a direct influence on the formation of TI, particularly through the enhancement of perceived usefulness and perceived ease of use, as explained in TAM (Davis et al., 1989; Venkatesh & Bala, 2008). Students with high levels of DL tend to hold positive views toward technology, feel more confident in using it, and are more prepared to integrate digital tools into entrepreneurial activities (Duong et al., 2024; Ilyas et al., 2023; Singh et al., 2024). Several studies also confirm that DL strengthens self-efficacy, broadens access to entrepreneurial information, and increases the tendency to initiate digital ventures (Nguyen & Nguyen, 2024; Soomro et al., 2024; Abaddi, 2024; Hammoda, 2024; Sánchez-García et al., 2025).

However, the direct effect of DL on TI may vary depending on the depth of digital experience and the learning context. Cross-country studies have found that the effect of DL on TI becomes significant when digital learning is integrated with project-based or problem-based learning approaches (Al Mamun & Fazal, 2021; Li et al., 2024; Raimundo & Rosário, 2024; Widiastuti et al., 2025). In technology-oriented higher education environments, DL functions not only as a technical skill but also as a cognitive enabler that facilitates the perception of usefulness and ease of technology use in value-creation processes. Therefore, based on TAM and HCT, the third hypothesis is proposed as follows:

H3

DL positively affects TI.

Furthermore, the relationship between DL and TSE can be explained through the psychological mechanisms of SCT. Students with high levels of DL are more exposed to dynamic digital environments, enabling them to develop confidence in their ability to manage technology for technopreneurial activities (Bandura, 2001). A strong level of DL enhances mastery experience as students more frequently succeed in overcoming technological challenges; broadens vicarious learning through the observation of successful digital role models; and enriches social persuasion through productive online interactions (Vu et al., 2024; Ip et al., 2024; Duong et al., 2024).

Several contemporary studies support this positive DL–TSE relationship. DL has been shown to enhance students' self-efficacy within digital learning and technology-based entrepreneurship contexts (Hägg & Gabrielsson, 2021; Ratten & Usmanij, 2021; Li et al., 2023; Udekwe & Iwu, 2024; Al Mahdi et al., 2024). In studies of digital platform–based entrepreneurship education, higher DL levels are associated with greater student confidence in identifying opportunities, solving technology-based problems, and making strategic decisions (Phuong Dung et al., 2023; Nguyen & Nguyen, 2024; Soomro et al., 2024; Hammoda, 2024; Satar, 2025). Furthermore, recent findings reveal that DL functions as a psychological enabler that bridges the relationship between experiential learning and digital entrepreneurial readiness (Ilyas et al.,

2023; Singh et al., 2024). Therefore, based on SCT and TAM, the fourth hypothesis is formulated as follows:

H4

DL positively affects TSE.

2.2.3. The Effect of TSE on TI and the Mediating Role of TSE

Within the SCT framework, TSE reflects individuals' belief in their ability to successfully perform technology-based entrepreneurial tasks (Mirhabibi et al., 2025; Wang et al., 2025b). TSE functions as a psychological mechanism that bridges the relationship between learning and entrepreneurial intention, where confidence influences how students process learning experiences, anticipate challenges, and make decisions (Liguori et al., 2019; Nabi et al., 2021). In the context of digital higher education, TPB reinforces this explanation by positioning TSE as a specific form of perceived behavioral control that predicts behavioral intention. Students with high TSE tend to feel more capable of managing risks, exploiting technological opportunities, and acting proactively in entrepreneurial environments (Maheshwari et al., 2023; Batz Liñeiro et al., 2024; Wardoyo et al., 2025).

Empirical evidence from various studies supports the role of TSE as a key predictor of TI. Cross-country research indicates that entrepreneurial self-efficacy exerts a significant direct effect on entrepreneurial intention, both in conventional and digital education contexts (Ratten & Jones, 2021; Li et al., 2023; Gatenet et al., 2024). Recent studies further reveal that within technopreneurship education, students with high TSE tend to display stronger intrinsic motivation, higher learning engagement, and greater readiness to initiate digital ventures (Seo et al., 2024; Al Mahdi et al., 2024). Therefore, based on SCT and TPB, the fifth hypothesis is formulated as follows:

H5

TSE positively affects TI.

Consistent with its mechanistic role in SCT, TSE is also assumed to act as a mediating pathway between learning experiences (TL and DL) and entrepreneurial intention (TI). Through the lenses of ELT and HCT, TL and DL function as capability development sources, while TSE facilitates the conversion of these capabilities into behavioral confidence that drives entrepreneurial intention. Theoretically, experiential learning and digital literacy enrich mastery experiences and cognitive modeling, thereby enhancing self-belief, which in turn strengthens the intention to act (Hägg & Gabrielsson, 2021).

Empirical evidence indicates that the relationship between TL and TI is largely mediated by TSE. Entrepreneurship education studies across diverse cultural contexts have found that the effect of TL on TI diminishes or becomes nonsignificant when TSE is included in the model, indicating either partial or full mediation (Hahn et al., 2020; Nabi et al., 2021; Li et al., 2024). Students who gain authentic learning

experiences tend to develop greater confidence in their capabilities and are therefore more likely to form technology-based entrepreneurial intentions. Similar findings have been observed in digital project-based learning contexts, where TSE significantly mediates the relationship between experiential activities and digital entrepreneurial intention (Baggen et al., 2022; Kim et al., 2023). Accordingly, the sixth hypothesis is proposed as follows:

H6

TSE mediates the relationship between TL and TI.

Furthermore, the enhancement of DL is also hypothesized to have an indirect effect on TI through TSE. From the perspectives of TAM and SCT, DL shapes students' beliefs about the ease and usefulness of technology, which in turn strengthens TSE and ultimately drives the intention to engage in digital entrepreneurship (Venkatesh & Bala, 2008; Ilyas et al., 2023; Duong et al., 2024; Yu et al., 2024; Chahal et al., 2025). As digital literacy improves, students not only become more capable of using technology but also more confident in their capacity to manage digital platforms for innovation and value creation (Nguyen & Nguyen, 2024; Singh et al., 2024).

Contemporary research confirms that DL exerts a strong indirect effect on entrepreneurial intention through TSE. Entrepreneurship education studies in the post-pandemic era demonstrate that improvements in digital literacy enhance students' confidence in using technology as a business tool, which in turn strengthens their entrepreneurial intention (Phuong Dung et al., 2023; Soomro et al., 2024; Hasan et al., 2024; Shatila et al., 2025). Recent findings also confirm that self-efficacy serves as a key mediator linking digital competence to entrepreneurial intention among young generations (Li et al., 2024; Al-Hattami, 2025). Based on the integration of SCT and TAM, the seventh hypothesis is formulated as follows:

H7: TSE mediates the relationship between DL and TI.

2.2.4. Research Model and Hypotheses Summary

Based on the theoretical integration outlined above, this research model conceptualizes TL and DL as two primary capability sources functioning as educational capabilities within the context of technopreneurship education. Drawing on ELT and HCT, TL and DL are regarded as forms of experiential and knowledge investment that enhance students' readiness for innovation. Subsequently, SCT positions TSE as a psychological mechanism that mediates the relationship between the capabilities developed through TL and DL and the resulting TI. Within this model, TPB reinforces the role of TSE as a specific form of perceived behavioral control that directly influences TI, whereas TAM explains the cognitive role of DL in shaping perceptions of technology usefulness and ease of use, thereby promoting greater self-efficacy and entrepreneurial intention.

This model posits that TL and DL not only exert direct effects on TI but also indirect effects through TSE. TL enhances students' reflective experiences, applied skills, and confidence in integrating technology

into business solutions. Meanwhile, DL strengthens TSE by improving students' understanding and confidence in using technology, which ultimately increases their readiness and intention to engage in digital entrepreneurial activities. Accordingly, this model represents an integrative relationship among the five foundational theories (ELT–HCT–SCT–TPB–TAM) that collectively explain the process of TI formation among digital-generation students. Figure 1 illustrates the proposed research framework, while Table 2 summarizes all hypotheses formulated in this study.

Table 2
Summary of Research Hypotheses

Code	Hypothesis	Theoretical Foundation	Direction
H1	TL has a positive effect on TI.	ELT, TPB	Positive
H2	TL has a positive effect on TSE.	ELT, SCT	Positive
H3	DL has a positive effect on TI.	HCT, TAM	Positive
H4	DL has a positive effect on TSE.	SCT, TAM	Positive
H5	TSE has a positive effect on TI.	SCT, TPB	Positive
H6	TSE mediates the relationship between TL and TI.	SCT, ELT	Positive Mediation
H7	TSE mediates the relationship between DL and TI.	SCT, TAM	Positive Mediation

3. Research Method

3.1. Research Design

This study employed a pure quantitative approach using the Partial Least Squares–Structural Equation Modeling (PLS-SEM) method, operated through SmartPLS 4 software. This approach was chosen because it is capable of analyzing complex causal relationships among latent constructs and simultaneously assessing the strength of both direct and indirect effects (Hair et al., 2021). The research model was developed based on the integration of ELT, HCT, SCT, TPB, and TAM, which collectively explain the effects of TL and DL on TI, both directly and indirectly through TSE as a mediating variable. Accordingly, this study seeks to map the formation process of technopreneurial intention among digital-generation students through technology-based learning experiences and digital literacy.

The research was conducted systematically through several stages: formulation of the conceptual model and hypotheses based on a synthesis of theories and recent empirical studies; development of research instruments through the adaptation of measurement items from reputable sources using a back-translation process to ensure semantic equivalence; pilot testing on 45 students, followed by online

data collection and two-stage PLS-SEM analysis consisting of measurement model evaluation and structural model assessment through bootstrapping with 5,000 resamples.

3.2. Participants and Research Sample

The participants of this study consisted of 689 Generation Z students from various public and private universities in West Java Province, Indonesia. Participants were selected using a purposive sampling technique based on several inclusion criteria: (1) active enrollment in entrepreneurship, management, economics, or economic education study programs; (2) completion of courses or training related to digital entrepreneurship or technopreneurship; and (3) prior experience in technology-based business projects or practical activities such as internships, startup incubation programs, or entrepreneurship bootcamps.

Data collection was conducted between June and August 2025, covering pilot testing, participant recruitment, and the full administration of the online survey. The final sample size exceeds the minimum requirement for PLS-SEM analysis involving four latent constructs and seven structural paths (Cohen, 1992; Hair et al., 2021). Based on the “10-times rule,” the sample size is adequate and statistically robust. Of the total respondents, approximately 54% were female and 46% were male, with ages ranging from 18 to 24 years, reflecting the typical demographic profile of Generation Z students engaged in higher education and digital entrepreneurial activities.

3.3. Research Instrument and Data Collection

The research instrument consisted of a structured questionnaire using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The questionnaire was developed by adapting measurement items from reputable international literature (Q1/Q2 journals) that had been previously validated for reliability and validity, and was contextually adjusted to the technopreneurship education environment in Indonesia. The adaptation process followed a two-stage translation procedure (forward–back translation) to ensure semantic equivalence across languages.

The instrument comprised four main latent constructs—TL, DL, TSE, and TI—with a total of 17 measurement indicators. Each construct was developed based on credible academic references: TL was adapted from Hägg and Kurczewska (2020) and Baggen et al. (2022); DL from Venkatesh and Bala (2008) and Duong et al. (2024); TSE from Bandura (2001) and Nabi et al. (2021); and TI from Liñán and Chen (2009) and Li et al. (2024). Each indicator was designed to reflect the reflective dimensions of its respective construct, following the reflective measurement model approach in PLS-SEM.

Prior to the main data collection, a pilot test was conducted involving 45 students who shared similar characteristics with the study sample. The purpose of the pilot test was to evaluate language clarity, respondents’ comprehension level, and the initial reliability of the items. The results indicated that all indicators achieved Cronbach’s alpha values above 0.70, demonstrating satisfactory internal reliability.

The main data collection was conducted online using the Google Form platform. The questionnaire was distributed through official university channels, student forums, and digital entrepreneurship communities. All respondents participated voluntarily and were provided with detailed information about the study's purpose, data confidentiality, and participation rights through an informed consent form. A data screening process was performed to examine completeness and response consistency, ensuring that no duplicate or invalid responses were included. After verification, all data were deemed suitable for further analysis.

3.4. Construct Measurement

All constructs in this study were modeled reflectively and measured using several indicators that were conceptually and empirically aligned with the context of technopreneurship education. Each indicator was designed to capture the latent dimensions of its respective construct, thereby providing a comprehensive representation of the causal relationships among variables within the research model.

The TL construct was measured using three indicators reflecting students' engagement in experiential learning processes, including reflective ability, experimentation, and the application of technology in learning (Hägg & Kurczewska, 2020; Baggen et al., 2022). The DL construct was assessed using four indicators representing students' ability to access, understand, and utilize digital technologies for academic and entrepreneurial activities (Venkatesh & Bala, 2008; Duong et al., 2024). The TSE construct was measured through four indicators evaluating students' self-confidence in identifying opportunities, making technology-based decisions, and managing challenges within the technopreneurship process (Bandura, 2001; Nabi et al., 2021). Meanwhile, the TI construct was captured using four indicators that reflect students' intention, readiness, and determination to pursue a career as technopreneurs (Liñán & Chen, 2009; Li et al., 2024).

The validity and reliability of the constructs were tested in two stages: the evaluation of the measurement model (outer model) and the structural model (inner model). In the first stage, convergent validity was assessed based on the values of outer loadings (> 0.70) and Average Variance Extracted (AVE) (> 0.50), indicating that the indicators within each construct adequately explained the variance of the latent variables. Internal reliability was evaluated using Composite Reliability (CR) and Cronbach's alpha, with a minimum threshold of 0.70 as an indicator of good internal consistency (Hair et al., 2021).

Meanwhile, discriminant validity was examined using two approaches: the Fornell–Larcker criterion and the Heterotrait–Monotrait Ratio (HTMT). The square root of the AVE for each construct was expected to be higher than its correlations with other constructs, while the HTMT values should remain below 0.90 to ensure clear conceptual distinctiveness among constructs (Henseler et al., 2015). All measurement assessments were performed iteratively to ensure that each indicator contributed significantly to the latent construct it represented.

3.5. Data Analysis

Data analysis was conducted using the Partial Least Squares–Structural Equation Modeling (PLS-SEM) approach with the assistance of SmartPLS 4 software. This method was selected for its capability to estimate complex causal relationships among latent constructs and to test mediation effects simultaneously with a moderate sample size (Hair et al., 2021). Moreover, PLS-SEM is suitable for predictive research and for studies aimed at developing new theoretical models, which aligns with the characteristics of the present study.

The analysis procedure was conducted in two main stages: evaluation of the measurement model and evaluation of the structural model. The first stage aimed to ensure that each construct exhibited adequate validity and reliability. Indicators with outer loadings below 0.70 were considered for removal if they did not contribute significantly to construct validity. The Average Variance Extracted (AVE) value ≥ 0.50 and Composite Reliability (CR) ≥ 0.70 were used as criteria to determine convergent validity and internal reliability. Subsequently, discriminant validity was assessed using the Fornell–Larcker criterion and the Heterotrait–Monotrait Ratio (HTMT), with an HTMT value below 0.90 considered acceptable (Henseler et al., 2015).

The second stage involved the evaluation of the structural model, which included testing path coefficients, the coefficient of determination (R^2), and predictive relevance (Q^2). The significance of the structural paths was assessed using the bootstrapping procedure with 5,000 resamples, as recommended in the PLS methodological literature (Hair et al., 2021). In addition to examining direct relationships among constructs, this procedure was also employed to test the mediating effects of TSE in the relationships TL → TSE → TI and DL → TSE → TI. Mediation effects were determined based on the significance of indirect paths and the Variance Accounted For (VAF) value, with the threshold range of 20–80% indicating partial mediation.

Subsequently, predictive analysis (PLSpredict) was employed to evaluate the model's ability to predict dependent variables in an out-of-sample context. The Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) values obtained from the PLS model were compared with those generated by the linear OLS regression to assess the model's predictive superiority. In addition, the model's Goodness-of-Fit (GoF) was evaluated using the Standardized Root Mean Square Residual (SRMR) value, with a threshold of less than 0.08 indicating an acceptable level of model fit.

The results from all stages of analysis were then interpreted integratively based on the theoretical framework of ELT–HCT–SCT–TPB–TAM, to explain the formation process of TI through the roles of TL, DL, and TSE. This approach not only ensured statistical accuracy but also reinforced the theoretical contribution of the study to the literature on entrepreneurship education and digital technopreneurship.

3.6. Ethical Considerations

This study received ethical approval from the Research and Community Service Institute of Universitas Kuningan, Indonesia (Approval No. 154/LPPM.IP/UNIKU/2025) prior to data collection and was conducted in accordance with the Declaration of Helsinki. Participation was voluntary, and informed

consent was obtained electronically from all participants before they accessed the survey. Participants were assured of confidentiality, anonymity, and their right to withdraw at any time without penalty. All data were used solely for academic purposes and reported in aggregate form.

4. Results

4.1. Respondent Characteristics

The study involved 689 Generation Z university students from various public and private higher education institutions in West Java Province, Indonesia (Table 3). The majority of respondents were between 19 and 22 years old, with 57.9% female and 42.1% male participants. Most students were enrolled in programs in economics, management, and entrepreneurship education, and had completed courses related to digital entrepreneurship, project-based learning, and technopreneurship.

In addition to general demographic characteristics, the study also identified academic and digital behavior attributes relevant to the research variables, such as the level of digital literacy, experience with technology-based projects, and interest in technopreneurial careers. These characteristics further support the suitability of the respondents with the study's objective, which focuses on the formation of TI through TL, DL, and TSE.

Table 3
Respondent Characteristics (n = 689)

Characteristic	Category	Frequency (f)	Percentage
Gender	Male	290	42.1
	Female	399	57.9
Age (years)	18–19	105	15.2
	20–21	318	46.2
	22–23	206	29.9
	≥ 24	60	8.7
Study Program	Economics/Management	361	52.4
	Economic Education	213	30.9
	Information Technology & Digital Business	115	16.7
Course in Digital Entrepreneurship	Yes	615	89.3
	No	74	10.7
Level of Digital Literacy (Self-assessed)	Low	62	9.0
	Moderate	392	56.9
	High	235	34.1
Experience in Technology-Based Projects (PBL)	Never	84	12.2
	1–2 times	376	54.6
	≥ 3 times	229	33.2
Technopreneurial Career Interest	Low	78	11.3
	Moderate	316	45.8
	High	295	42.8

The data distribution indicates that the majority of respondents possessed moderate to high levels of digital literacy (91%), and more than half had participated in at least one technology-based project (87.8%). This finding confirms that the study population had substantial exposure to digital learning contexts, making it relevant for examining the effects of TL and DL on TSE and TI.

Furthermore, the relatively high proportion of students expressing interest in technopreneurial careers (42.8%) demonstrates a strong potential among Generation Z to develop digital entrepreneurial

intentions, thereby underscoring the importance of experiential and technology-based entrepreneurship education in higher education institutions.

4.2. Measurement Model

Figure 2 presents the measurement model, illustrating the reflective indicators and their corresponding outer loadings for each latent construct (TL, DL, TSE, and TI). Measurement model analysis was conducted to ensure that each construct demonstrated adequate validity and reliability prior to testing the structural relationships. All outer loadings exceeded the recommended threshold of 0.70, indicating strong item reliability.

As presented in Table 4, all indicators exhibited outer loading values above 0.70, thereby meeting the criterion for convergent validity. The Average Variance Extracted (AVE) values ranged from 0.62 to 0.71, while the Composite Reliability (CR) values ranged from 0.93 to 0.96, indicating excellent internal reliability. In addition, the Cronbach's Alpha values for all constructs exceeded the minimum threshold of 0.70, confirming strong internal consistency across all constructs in the study.

Discriminant validity was assessed using two approaches: the Fornell–Larcker criterion and the Heterotrait–Monotrait Ratio (HTMT). As shown in Table 5, the square root of the AVE for each construct was higher than its correlations with other constructs, thereby satisfying the Fornell–Larcker criterion. Meanwhile, the HTMT values presented in Table 6 were all below the threshold of 0.85, confirming that each construct was conceptually distinct and free from discriminant overlap.

Accordingly, based on the results of convergent validity, internal reliability, and discriminant validity analyses, all constructs (TL, DL, TSE, and TI) were deemed valid and reliable for further analysis in the structural model evaluation stage.

Note

Numbers on the arrows represent standardized outer loadings (all > 0.70). TL = Transformative Learning; DL = Digital Literacy; TSE = Technopreneurial Self-Efficacy; TI = Technopreneurial Intention.

Table 4
Measurement Model Evaluation

Construct	Items	Outer Loadings	Cronbach's α	CR	AVE
TL	TL1	0.84	0.92	0.94	0.67
	TL2	0.86			
	TL3	0.88			
	TL4	0.83			
DL	DL1	0.78	0.93	0.95	0.70
	DL2	0.86			
	DL3	0.88			
	DL4	0.87			
TSE	TSE1	0.84	0.94	0.96	0.71
	TSE2	0.89			
	TSE3	0.87			
	TSE4	0.88			
	TSE5	0.86			
TI	TI1	0.88	0.93	0.95	0.68
	TI2	0.90			
	TI3	0.87			
	TI4	0.85			

Table 5
Discriminant Validity (Fornell–Larcker Criterion)

Construct	TL	DL	TSE	TI
TL	0.82			
DL	0.66	0.84		
TSE	0.61	0.63	0.85	
TI	0.57	0.60	0.69	0.83

Table 6
Heterotrait–Monotrait Ratio (HTMT)

Constructs	TL	DL	TSE	TI
TL	—	0.74	0.70	0.65
DL		—	0.68	0.67
TSE			—	0.73
TI				—

4.3. Structural Model Evaluation and Mediation Results

The structural model evaluation was conducted to test the causal relationships among the constructs (TL, DL, TSE, and TI) and to confirm the mediating role of TSE as proposed in the research model. Prior to hypothesis testing, all structural paths were examined for multicollinearity, and the Variance Inflation Factor (VIF) values were found to be below 3, indicating the absence of collinearity issues among the latent constructs.

The coefficient of determination (R^2) indicated that TSE was explained by TL and DL by 59.8%, while TI was explained by TL, DL, and TSE by 66.3%. The Stone–Geisser's Q^2 values for the endogenous constructs were also positive ($Q^2_TSE = 0.41$; $Q^2_TI = 0.47$), demonstrating good predictive relevance of the model (Hair et al., 2021). Therefore, the structural model met the criteria for relevance and predictive validity for hypothesis testing.

The bootstrapping analysis (5,000 resamples) results are presented in Table 7, showing the estimated path coefficients, *t*-statistics, *p*-values, and mediation effects. The findings revealed that TL had a significant direct effect on TI (β = 0.241, $t = 4.912$, $p < 0.001$) and on TSE (β = 0.428, $t = 9.203$, $p < 0.001$). Similarly, DL significantly influenced both TI (β = 0.317, $t = 6.125$, $p < 0.001$) and TSE (β = 0.351, $t = 7.824$, $p < 0.001$). In addition, TSE showed a positive and significant effect on TI (β = 0.289, $t = 5.037$, $p < 0.001$).

The indirect effects revealed that TSE partially mediated the relationships between TL → TI (β_ind = 0.124, $t = 3.925$, $p < 0.001$) and DL → TI (β_ind = 0.102, $t = 3.641$, $p < 0.001$). This partial mediation indicates that while TL and DL directly influence TI, part of their effects is transmitted through the enhancement of TSE. These findings support the integrated theoretical framework of SCT and TPB, which posits that TSE strengthens perceived behavioral control and entrepreneurial intention within digital technopreneurship contexts.

Overall, the results reinforce the positioning of TL and DL as educational capabilities that play dual roles —as direct predictors of TI and as indirect antecedents through the enhancement of TSE. Accordingly, the empirical model provides strong evidence supporting the theoretical integration of ELT, HCT, SCT, TPB, and TAM in explaining the formation of technopreneurial intention among Generation Z students.

Table 7
Structural Model Results and Mediation Effects

Hypothesis Path	Effect (β)	t-value	p-value	Decision
H1: TL → TI	0.241	4.912	< 0.001	Supported
H2: TL → TSE	0.428	9.203	< 0.001	Supported
H3: DL → TI	0.317	6.125	< 0.001	Supported
H4: DL → TSE	0.351	7.824	< 0.001	Supported
H5: TSE → TI	0.289	5.037	< 0.001	Supported
H6: TL → TSE → TI	0.124	3.925	< 0.001	Supported
H7: DL → TSE → TI	0.102	3.641	< 0.001	Supported

5. Discussion

The findings confirm that TL and DL play a crucial role in shaping TI among Generation Z university students, both directly and indirectly through the enhancement of TSE. The empirical results demonstrate that all hypothesized relationships are significant: TL → TI (H1), TL → TSE (H2), DL → TI (H3), DL → TSE (H4), TSE → TI (H5), as well as the two partial mediation effects of TL → TSE → TI (H6) and DL → TSE → TI (H7). This pattern validates the theoretical consistency among experiential learning, human capital investment, psychological self-efficacy mechanisms, perceived behavioral control, and technology-related beliefs within a unified model.

Conceptually, the significant results for H1 and H2 reinforce the validity of ELT in the context of technopreneurial learning, where students actively engaged in the experience–reflection–experimentation cycle are more capable of internalizing digital entrepreneurship as a lived practice rather than declarative knowledge. Project-based and incubation-oriented learning that emphasizes reflection and experimentation has been shown to enhance entrepreneurial thinking readiness while simultaneously strengthening TSE. This aligns with recent perspectives suggesting that experiential learning promotes cognitive transformation and self-regulated competence (Hägg & Gabrielsson, 2021; Baggen et al., 2022). Hence, TL functions not merely as a pedagogical stimulus but as a mechanism for developing psychological capital that cultivates students' confidence in managing risk, innovation, and digital business processes (Seo et al., 2024; Wang et al., 2025b).

The findings related to H3 and H4 strengthen the relevance of DL as a form of human capital investment, as explained by HCT. Students with higher levels of digital literacy exhibit stronger technopreneurial intentions and greater confidence in utilizing technology as a value-creation tool. This suggests that DL is not merely a technical ability but also a representation of adaptive capacity and an innovation-oriented mindset that differentiates technopreneurs from passive technology users (Duong et al., 2024; Shatila et al., 2025). Empirically, these results support the earlier findings of Venkatesh and Bala (2008) and more

recent studies indicating that the integration of digital literacy into entrepreneurship curricula accelerates the internalization of 21st-century skills, including problem solving, data-driven thinking, and digital collaboration (Zeynalov & Doğantan, 2025).

The direct effect of DL → TI (H3) further reinforces the position of TAM as a cognitive foundation for the development of digital entrepreneurial intention. Students with stronger perceptions of the perceived usefulness and perceived ease of use of technology demonstrate higher readiness to implement technology-driven business ideas. This mechanism highlights that beliefs regarding the utility and usability of technology foster greater self-efficacy, which in turn enhances TI (Ilyas et al., 2023; Singh et al., 2024).

The findings for H5, which indicate a positive relationship between TSE and TI, reinforce the theoretical consistency of SCT and TPB, wherein self-efficacy functions as a proximal determinant of behavioral intention. Students with higher levels of TSE not only exhibit greater confidence in identifying technopreneurial opportunities but also demonstrate stronger decision-making capacity, tolerance for uncertainty, and ability to implement digital innovations. These results align with recent studies showing that technopreneurial self-efficacy directly influences entrepreneurial intention and performance in technology-based ventures (Caliendo et al., 2023; Vu et al., 2024; Nguyen et al., 2022). Furthermore, TSE serves as a psychological bridge linking learning experiences to behavioral intentions, emphasizing the crucial role of educational processes that cultivate mastery experience and vicarious learning (Pittaway et al., 2015; Nabi et al., 2021).

The two significant mediation relationships—H6 (TL → TSE → TI) and H7 (DL → TSE → TI)—offer substantial theoretical contributions by highlighting TSE as a psychological mechanism that connects learning and digital literacy to entrepreneurial intention. These partial mediation effects indicate that while TL and DL exert direct influences on TI, part of their effects is transmitted through the enhancement of TSE. This means that experiential learning and digital literacy mastery do not automatically strengthen entrepreneurial intention unless accompanied by increased self-belief in one's technopreneurial capabilities. Such a pattern is consistent with the SCT–TPB framework, wherein self-efficacy amplifies perceived behavioral control and expands one's intentionality to act (Ajzen, 2020; Bandura, 2001).

These findings enrich the theoretical discourse by demonstrating a functional integration between learning frameworks (ELT–HCT) and psychological mechanisms (SCT–TPB–TAM) within the context of digital entrepreneurship education. Whereas prior studies often examined these variables in isolation, this study confirms that the effects of TL and DL on TI operate through a combination of human capital development and psychological empowerment. This aligns with recent perspectives on capability-based education, which emphasize the importance of authentic learning experiences and technology integration in building students' digital career readiness (Hossain et al., 2023; Hasan et al., 2024; Onjewu et al., 2025).

From a pedagogical standpoint, the findings also offer a critical reflection on entrepreneurship education practices in Indonesia. The implementation of TL without sufficient reflective depth or mentor guidance may yield a weak effect on self-efficacy formation. Similarly, improving DL without an entrepreneurial context tends to produce technical skills without strategic orientation. Therefore, the integration of TL and DL into the curriculum should be explicitly directed toward strengthening TSE through project-based learning, digital incubation, and peer mentoring strategies. This approach aligns with the principles of Education 5.0, which position students as co-creators of learning and emphasize empathy-driven, collaborative, and technology-enabled learning experiences (Komljenovic, 2022; Hart & Rodgers, 2023).

In summary, the overall findings of this study not only affirm the empirical robustness of the integrative ELT–HCT–SCT–TPB–TAM model but also demonstrate its practical relevance within the context of Indonesian higher education, which is undergoing a transition toward a digital ecosystem. The model reveals that TI cannot be developed instantly through business training alone; rather, it requires the orchestration of meaningful learning experiences, strong digital literacy, and the cultivation of self-efficacy as the core of entrepreneurial readiness among young generations.

Ultimately, these findings provide both theoretical and empirical foundations for expanding future research on technopreneurial intention, particularly by incorporating contextual variables such as the digital learning environment, institutional support, and innovation culture within universities. This serves as a conceptual bridge to the next section, which formulates the conclusions, implications, and future research recommendations derived from these results.

6. Conclusion

This study concludes that the formation of TI among Generation Z students results from the dynamic interaction between TL, DL, and TSE as an underlying psychological mechanism. The empirical findings demonstrate that both TL and DL significantly influence TI, directly and indirectly, through TSE as a partial mediator. These results affirm that the two educational capabilities operate simultaneously in shaping students' digital entrepreneurial readiness, while reinforcing TSE as a psychological factor that expands perceived behavioral control, as explained by SCT and TPB. The theoretical integration of ELT, HCT, SCT, TPB, and TAM produces a comprehensive empirical model that elucidates how learning experiences and digital literacy jointly contribute to the systematic and measurable development of technopreneurial intention.

Conceptually, this study extends the digital entrepreneurship literature by providing empirical evidence from the Indonesian higher education context and emphasizing the significance of TL- and DL-based pedagogical approaches in enhancing students' TSE. These findings form the foundation for developing more contextual and learner-centered educational strategies, in which project-based learning, digital mentoring, and incubation programs can be continuously integrated to strengthen technopreneurial intention. Therefore, this research not only contributes theoretically through its empirically validated integrative model but also offers practical implications relevant to educators, policymakers, and higher

education institutions in cultivating a generation of competent technopreneurs in the digital economy era.

7. Implications, Limitations, and Future Research Directions

7.1. Theoretical Implications

This study offers a significant theoretical contribution to the digital entrepreneurship literature by integrating five major theoretical frameworks—ELT, HCT, SCT, the TPB, and the TAM—into a single unified empirical model. The model demonstrates that TL and DL not only function as sources of capability-based education but also serve as key drivers in fostering TSE, which in turn enhances students' TI. The findings expand current understanding of the psychological mechanisms proposed in SCT and TPB by confirming that TSE acts as a proximal driver of technopreneurial intention, mediated by experiential learning and digital literacy. Furthermore, the integration of TAM enriches the cognitive explanation by revealing how perceived usefulness and ease of use of technology reinforce self-efficacy beliefs and digital entrepreneurial orientation. Hence, this study not only validates existing theories but also proposes a cross-theoretical model that explains the formation of technopreneurial intention more holistically and contextually within the digital higher education ecosystem.

7.2. Practical Implications

For educators and learning facilitators, the findings highlight the importance of integrating TL and DL into technology-based entrepreneurship teaching strategies. Lecturers and mentors should facilitate experiential–digital learning processes that emphasize authentic experiences, critical reflection, and interdisciplinary collaboration. Activities such as digital project-based learning, virtual business incubation, and simulation-based mentoring can effectively strengthen TSE, which has been proven to be a key psychological mechanism shaping students' TI. This approach not only reinforces conceptual understanding but also cultivates innovative risk-taking and enhances students' digital confidence.

For higher education institutions and learning organizations, the results emphasize the need to develop adaptive technopreneurial ecosystems that respond to digital disruption. Universities should provide inclusive digital learning infrastructures, expand access to learning management systems, and foster collaboration with digital industries and startups. Such strategies reinforce the internalization of TL and DL while ensuring that students become not only technology users but also value creators through digital innovation.

For curriculum developers and educational policymakers, this study offers empirical grounds for positioning DL as a core competency within entrepreneurship curricula. Technology-based learning should be integrated across disciplines, strengthening the linkages between entrepreneurship theory, digital innovation, and essential soft skills such as collaboration and data literacy. Ministries and accreditation bodies can leverage these findings to formulate national standards for digital

entrepreneurship education that are more application-oriented and aligned with outcome-based education principles.

At the global level and within the future of digital education, the implications underscore the need for technopreneurship pedagogy reform that places TL, DL, and TSE at the core of 21st-century learning transformation. The proposed integrative model can be adapted across developing-country contexts to strengthen youth capacity in facing the digital economy and the evolving global labor market. By combining experiential learning and digital capability building, universities can contribute to the creation of more sustainable and inclusive innovation ecosystems worldwide.

7.3. Limitations

Although this research model obtained strong empirical support, several limitations should be carefully considered. The cross-sectional design limits the ability to examine causal relationships among variables. A longitudinal study would better capture changes in TSE and TI over time, particularly following the implementation of technology-based learning interventions. In addition, the use of self-reported data may lead to potential common method bias, although this issue was minimized through validity and reliability testing. The research scope, which focused only on students in West Java, also affects the generalizability of the results, given the diverse socio-economic conditions, learning cultures, and levels of digital readiness across regions in Indonesia.

7.4. Future Research Directions

Future research could extend this model by incorporating contextual variables such as institutional support, innovation climate, and digital learning engagement as moderators that strengthen the relationships among TL, DL, TSE, and TI. A mixed-method approach is recommended to explore the internalization process of technopreneurial self-efficacy more deeply through students' experiential narratives. Moreover, cross-institutional or cross-country studies may broaden the understanding of how digital culture, educational policy, and technological readiness influence the effectiveness of TL and DL within higher education settings. Such theoretical and methodological enrichment is expected to enhance the external validity of the model and contribute to a more comprehensive global understanding of TI formation in the era of digital transformation in education.

Declarations

Ethics approval and consent to participate

This study received ethical approval from the Research and Community Service Institute of Universitas Kuningan, Indonesia (Approval No. 154/LPPM.IP/UNIKU/2025) and was conducted in accordance with the Declaration of Helsinki. Participation was voluntary, and informed consent was obtained electronically from all participants prior to data collection, with full assurance of confidentiality and the right to withdraw at any time.

Consent for publication

All participants provided consent for the anonymized use of their data for research and publication purposes. No identifiable personal information was collected, and all data were reported in aggregate form to ensure anonymity.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The author declares no competing interests.

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Author Contributions

Conceptualization: I.I. and F.A.T.; Methodology: I.I., N.S., and Y.S.; Data Collection: F.A.T. and Y.S.; Formal Analysis: I.I. and M.H.; Writing—Original Draft: I.I. and F.A.T.; Writing—Review & Editing: M.H.; Supervision: N.S. All authors have read and approved the final manuscript.

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Figures

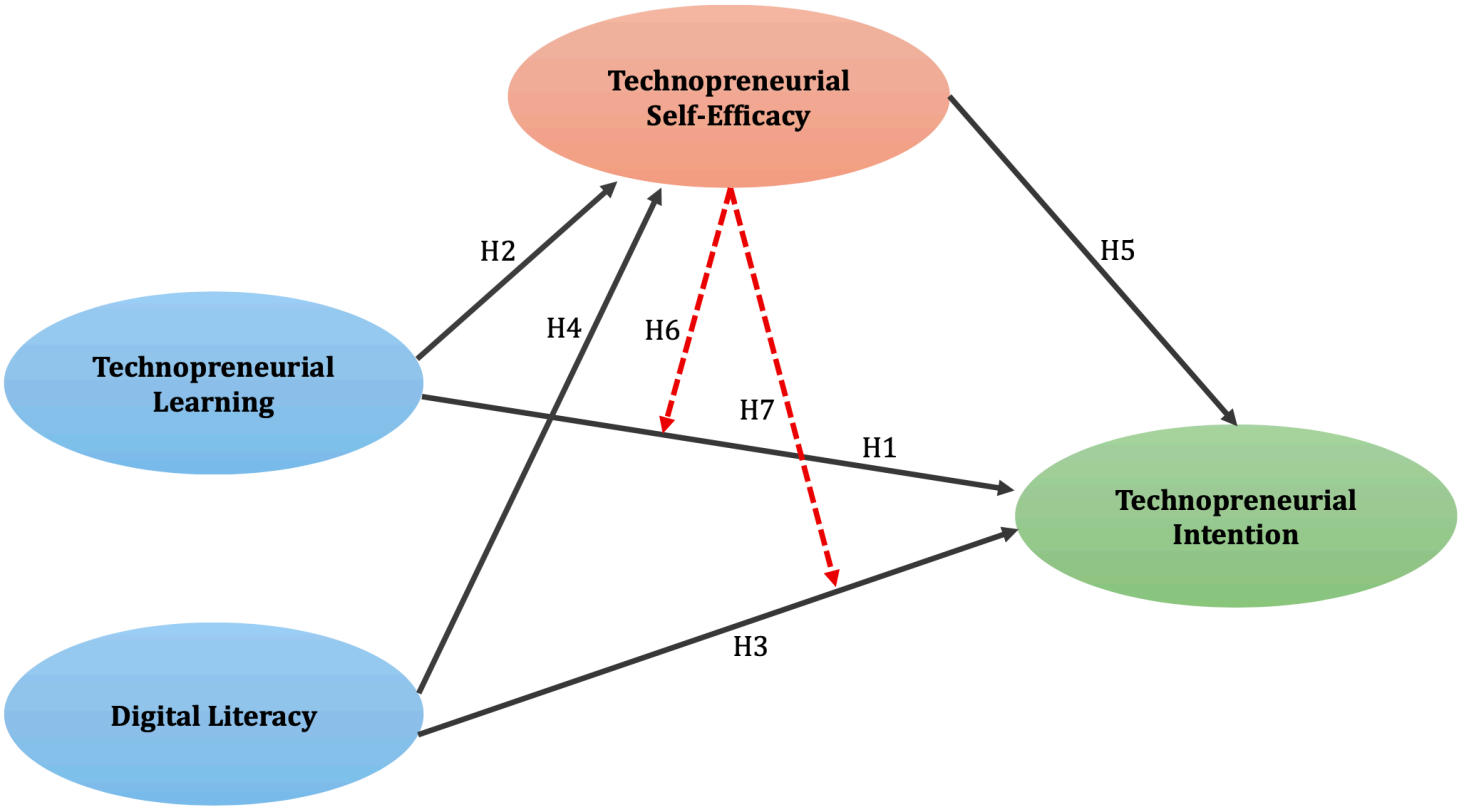


Figure 1

Research Framework

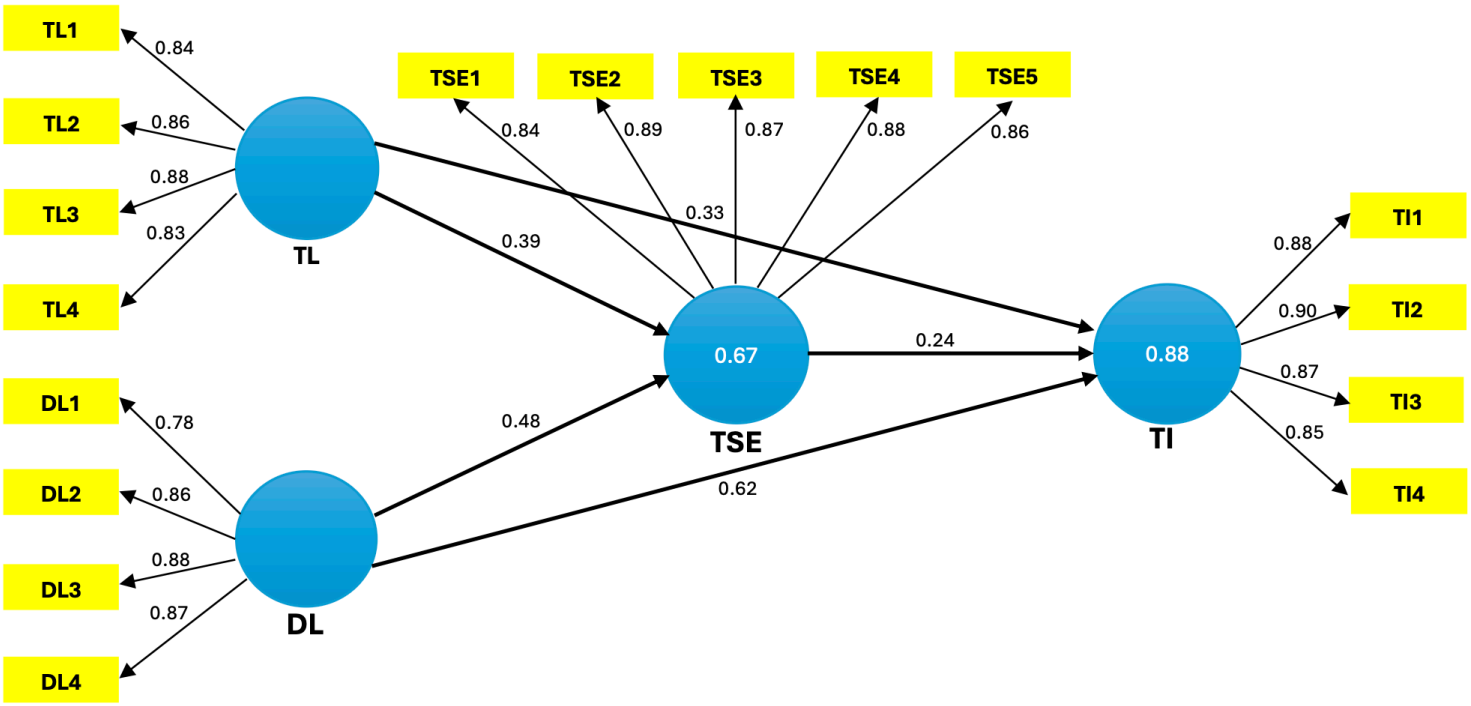


Figure 2

Measurement Model

Note: Numbers on the arrows represent standardized outer loadings (all > 0.70). TL = Transformative Learning; DL = Digital Literacy; TSE = Technopreneurial Self-Efficacy; TI = Technopreneurial Intention.