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Educational insights into digital entrepreneurship: the influence of personality and innovation attitudes

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Abstract

Digital entrepreneurship implies a radical transformation of economic paradigms, allowing new entrepreneurs to create a more sustainable, creative, and connected future. This study explores the influence of higher education students' personality traits on their innovative digital attitude and digital entrepreneurial intention. It also explores the moderating role of digital entrepreneurial education in the relationship between innovative digital attitude and digital entrepreneurial intention. To this end, a sample of 417 higher education students residing in Portugal was collected through a questionnaire made available online, and the partial least square method was applied to a formulated research model. The results reveal that an innovative digital attitude positively influences the digital entrepreneurial intention of higher education students in Portugal. The Big-Five personality traits directly affect innovative digital attitudes but not their digital entrepreneurial intention. However, this relationship becomes significant when the relationship between personality traits and digital entrepreneurial intention is mediated by an innovative digital attitude. Furthermore, the intensifying role of digital entrepreneurial education was demonstrated in converting students' innovative digital attitudes into their digital entrepreneurial intention. Thus, this study indicates that personality traits, which are still scarcely addressed in entrepreneurship, can be an explanation of innovative digital attitudes and predictors of digital entrepreneurial intention, as well as the important role of digital entrepreneurial education in boosting digital entrepreneurship.

Keywords: Digital entrepreneurship, Personality traits, Digital entrepreneurial intention, Innovative digital attitude, Digital entrepreneurial education

Introduction

The emergence of digital entrepreneurship has far-reaching implications for the economy and society, marking the beginning of an era defined by innovation, growth, and connectivity (Soltanifar et al., 2020). Fernandes et al. (2023) highlight how digital developments, driven by entrepreneurial agents harnessing digital technologies, are addressing critical sustainability challenges and reshaping traditional business models. The digitization of the economy has brought about significant transformations, offering unprecedented opportunities for value creation and market disruption. As digital

entrepreneurship continues to evolve, it is essential to recognize its profound impact on economic structures, social dynamics, and the overall fabric of society (Paul et al., 2023).

Digital entrepreneurship encompasses entrepreneurial opportunities that are created and pursued through the utilization of technological innovations (George et al., 2021). The concept of digital entrepreneurship is characterized by the integration of digital technologies into entrepreneurial activities, enabling individuals to identify and exploit opportunities in the digital landscape (Gomes & Lopes, 2023; Shen et al., 2018). Antonizzi and Smuts (2020) and Nambisan et al. (2019) have contributed to defining the characteristics of digital entrepreneurship, emphasizing the interconnected nature of digital transformation and entrepreneurial ventures. Understanding these characteristics is crucial in comprehending the evolving landscape of entrepreneurship in the digital age. Digital technologies play a pivotal role in shaping the trajectory of entrepreneurship and driving innovation within the business landscape (Faisal et al., 2023). The impact of digital technologies on entrepreneurial activities extends beyond mere facilitation to fundamentally transforming how entrepreneurs create value, engage with customers, and operate in the market (Soltanifar et al., 2020). Shen et al. (2018) and Elia et al. (2020) indicate that digital entrepreneurship not only involves the strategic use of digital tools but also influences traditional conceptualizations of entrepreneurship. By leveraging digital technologies, entrepreneurs can access new sources of competitive advantage, reach global markets, and adapt to the dynamic demands of the digital economy (Fernandes et al., 2023). This fusion of entrepreneurial agency with digital technologies highlights the dynamic nature of digital entrepreneurship and its ability to drive meaningful change in the business ecosystem.

In recent years, Portugal has seen a significant increase in the number of digital startups, reflecting a growing trend in digital entrepreneurship (Peralta, 2023). According to the data, there are currently 4073 startups in Portugal, collectively generating 2.3 billion euros in turnover (Startup Portugal, 2023). This increase in digital entrepreneurship highlights the dynamic and innovative scenario of the entrepreneurial ecosystem in the country. The increase in startups not only contributes to economic growth but also promotes a culture of innovation and technological advancement in Portugal's business environment (Portugal Digital, 2023).

The investment and funding landscape for digital entrepreneurship in Portugal plays a crucial role in supporting the growth and sustainability of startups (Nacionalidade Portuguesa, 2022). With the characterization of the entrepreneurial ecosystem and data on foreign investment, Portugal has managed to attract funding and resources to nurture its digital entrepreneurship sector (Rosa & de Almeida, 2017). Government initiatives, such as Startup Portugal created in 2016, have been instrumental in providing strategic support and guidance to entrepreneurs in the country (AMA, 2024). In addition, the National Incubator Network has played a key role in identifying and connecting incubators and accelerators to further support the development of digital startups (Portugal Digital, 2022). It should be noted that Portugal is the 13th fastest broadband country, improving connectivity for digital entrepreneurs, and the 11th country with the best fiber optic connection (Startup Portugal, 2024).

Personality traits play a crucial role in shaping digital entrepreneurship. Sobaih and Elshaer (2022) have shown that the big five personality traits, which include openness

to experience, conscientiousness, extraversion, agreeableness, and neuroticism, have a direct impact on entrepreneurial behavior in the digital realm. Entrepreneurs who score high in openness to experience are more likely to embrace innovative ideas and technologies (Nguyen et al., 2023), which is essential for success in digital entrepreneurship. Conscientious individuals tend to exhibit strong organizational skills and reliability, which are vital for managing digital ventures. Extraverts, with their social skills and assertiveness, often excel in networking and collaboration (Antoncic & Auer Antoncic, 2023), key components in the digital entrepreneurial ecosystem.

The innovative digital attitude is instrumental in shaping digital entrepreneurship. The innovative digital attitude refers to an individual's predisposition towards embracing and applying digital innovations in their entrepreneurial activities (Nkwei et al., 2023). Entrepreneurs with a strong innovative digital attitude are not only more likely to adopt new digital tools and strategies, but also to leverage them effectively to gain a competitive edge. This attitude fosters a culture of continuous learning and adaptation, which is essential in the fast-paced digital landscape (Alhammedi et al., 2023; Chotipurk et al., 2023).

The interconnection between personality traits and innovative digital attitude is significant in the context of digital entrepreneurship. Sobaih and Elshaer (2022) indicate that certain personality traits can enhance an individual's innovative digital attitude, thereby boosting their entrepreneurial potential in the digital space. For instance, individuals with high openness to experience are naturally inclined towards innovation and are more likely to develop a strong innovative digital attitude. Similarly, extraversion can enhance an entrepreneur's ability to engage with digital communities and networks, further strengthening their innovative digital attitude (Nguyen et al., 2023). Understanding this interplay can help in designing targeted interventions to foster both the personality traits and the innovative attitudes needed for digital entrepreneurship. This holistic approach can ultimately lead to more successful and innovative digital ventures.

A pronounced research gap exists regarding the role of personality traits in shaping innovative digital attitudes specifically among higher education students. While some studies have explored the broader determinants of digital entrepreneurial intentions (Mir et al., 2023; Younis et al., 2020), few have directly investigated how personality traits uniquely influence students' propensity for digital innovation. This gap is significant because understanding the nuances of personality traits can provide deeper insights into how students develop a propensity for digital innovation. For instance, traits like openness to experience and conscientiousness may play crucial roles in fostering a positive attitude toward digital innovation, yet these influences remain largely underexplored within the context of higher education. Furthermore, existing studies frequently neglect the combined impact of multiple personality traits on innovative digital attitudes, thereby limiting the scope and applicability of current models (Al-Qadasi et al., 2023).

The exploration of specific personality traits and their influence on digital entrepreneurial intention (DEI) is similarly underdeveloped. Although it is well-established that attitudes toward entrepreneurship significantly impact digital entrepreneurial intention, the role of individual personality traits within this framework, especially among higher education students, remains insufficiently explored (Alkhalaileh et al., 2023). Puerta Gómez et al. (2024) identified certain traits, such as risk-taking and proactiveness, as

potentially influential, yet there is a notable scarcity of empirical studies examining how other personality traits impact digital entrepreneurial intention specifically within college student populations. This gap in research is significant because without targeted investigation, educational institutions may lack critical insights needed to effectively foster an entrepreneurial mindset among students. Additionally, examining how these traits interact with external factors, such as environmental and situational influences, in the context of higher education, could provide a more holistic view of what drives digital entrepreneurial intentions.

Another critical gap in the literature is the lack of comprehensive models specifically focused on integrating personality traits, innovative digital attitude, and digital entrepreneurial intention among higher education students. Existing research tends to examine these elements in isolation, thereby overlooking potential synergistic effects that may arise from their interplay in student populations (Xanthopoulou & Sahinidis, 2024). However, without integrated models, it is challenging to understand these complex relationships fully. Additionally, most studies fail to consider the moderating effects of attitudes on the relationship between personality traits and digital entrepreneurial intention among college students, a factor crucial for developing targeted interventions within educational institutions (Lechuga Sancho et al., 2020). Developing such student-centered, comprehensive models could significantly advance the field by offering a more nuanced understanding of the pathways leading to digital entrepreneurial success among future entrepreneurs. Two important questions must, therefore, be answered: (RQ1) What is the influence of higher education students' personality traits on innovative digital attitude? and (RQ2) What is the influence of higher education students' personality traits on digital entrepreneurial intention?

This study aims to explore the influence of higher education students' personality traits on innovative digital attitude and digital entrepreneurial intention and the moderating role of digital entrepreneurship education on this association.

Significant contributions to knowledge across various critical domains are made by the study. Theoretically, it emphasizes the critical role of personality traits in shaping attitudes towards digital entrepreneurship amid the pervasive influence of digitalization on societal dynamics. Practically, the study underscores the importance of enhancing graduates' personal traits to align with industry demands and foster their adaptability, innovation, and entrepreneurial potential. It also advocates for the development and reinforcement of digital entrepreneurship education initiatives to equip students with necessary skills and mindsets. Finally, it stresses the importance of creating support programs that empower students to effectively initiate and manage digital ventures, thereby enhancing their success in the digital economy.

Literature review

The Meta-Theoretical Model of Motivation and Personality (3 M Model) provides a comprehensive framework for understanding the interplay between motivation and personality traits within a hierarchical structure. Developed by Mowen (2000), the model aims to integrate various motivational and personality theories into a cohesive system. It adopts a multi-level approach, starting from elemental traits at the base, which progressively influence compound traits, situational traits, and surface traits. This hierarchical

structure allows for a nuanced interpretation of how fundamental personality aspects can shape complex behaviors and motivations across different contexts. Notably, the 3 M Model has been applied in a multitude of fields, from consumer behavior to tourism, demonstrating its broad utility and robustness in explaining various human actions (Schneider & Vogt, 2012).

At the core of the 3 M Model are its primary components, which include elemental traits, compound traits, situational traits, and surface traits. Elemental traits form the foundational level and consist of inherent personality characteristics such as extroversion or neuroticism (Mowen, 2000). The 3 M Model places significant emphasis on the roles of motivation and personality, proposing that these elements are deeply interwoven in driving human behavior. Motivation, in this context, is seen as the dynamic force that activates and directs behavior, often influenced by underlying personality traits (Bone & Mowen, 2006; Kang & Johnson, 2015). For example, an individual's propensity for adventure (a compound trait) may fuel their motivation to seek out novel and challenging experiences, which in turn can manifest in behaviors such as travel or extreme sports (Schneider & Vogt, 2012). By mapping out these intricate relationships, the 3 M Model not only elucidates the mechanisms of motivation and personality, but also provides a predictive framework for understanding how these elements interact to shape actions. This understanding is crucial for fields like digital innovation and entrepreneurial intention, where personality traits can significantly impact an individual's motivation to engage in entrepreneurial activities or adopt innovative technologies (Darmanto et al., 2022). What's more, it also allows for a detailed examination of how ingrained personality traits translate into concrete actions, providing important insights for studying behaviors such as digital innovative attitude and digital entrepreneurial intention.

Digital entrepreneurial education

Digital entrepreneurial education represents a burgeoning field that bridges the gap between digital entrepreneurship and traditional entrepreneurship education (Sitaridis & Kitsios, 2024). It is essential to understand the definition and scope of this area to appreciate its significance in modern educational contexts. Digital entrepreneurial education encompasses the integration of digital technologies and platforms into entrepreneurship curricula, aiming to prepare students for the challenges of the digital economy (Paul et al., 2023). This field is characterized by its focus on developing digital skills, fostering innovative thinking, and enabling students to leverage digital tools for entrepreneurial endeavors. Several components are identified in digital entrepreneurial education, including digital business models, e-commerce strategies, and online marketing techniques (Sitaridis & Kitsios, 2024).

The role and impact of digital tools and platforms in entrepreneurial education are profound and multifaceted (Lesinskis et al., 2023). These digital resources have transformed how entrepreneurship education is delivered, making it more accessible and interactive for learners. Digital tools such as online learning platforms, virtual simulations, and collaborative software have been integrated into entrepreneurial education to enhance the learning experience (Duong et al., 2024). These tools not only provide flexibility and convenience, but also enable students to experiment with real-world business scenarios in a controlled environment. Furthermore, digital platforms

facilitate networking and collaboration among students and entrepreneurs, fostering a community of practice that extends beyond the classroom (Secundo et al., 2020).

The digital entrepreneurial educations are composed of various stakeholders, including educational institutions, industry partners, and policymakers, all of whom play critical roles in shaping the landscape of digital entrepreneurial education (Bejjani et al., 2023). The integration of digital tools within these ecosystems has led to innovative pedagogical approaches and new educational models that are more aligned with the needs of the digital economy (Secundo et al., 2020). The digital entrepreneurial educations not only provide students with the technical skills necessary for digital entrepreneurship, but also cultivate an entrepreneurial mindset that encourages innovation and adaptability (Secundo et al., 2020). As digital entrepreneurial education continues to evolve, it is imperative to explore these ecosystems further to understand their impact on entrepreneurship education and broader economic development.

Innovative digital attitude and digital entrepreneurial intention

Understanding the concepts of innovative digital attitude and digital entrepreneurial intention is fundamental in comprehending their interrelationship. Innovative digital attitude refers to an individual's mindset and disposition toward embracing digital tools and technologies to innovate and solve problems creatively (Mancha & Shankaranarayanan, 2021). It encompasses attributes such as openness to new digital possibilities, a proactive approach to adopting technology, and a continuous learning attitude toward digital advancements. On the other hand, digital entrepreneurial intention pertains to an individual's intention to engage in entrepreneurial activities within the digital domain, such as starting an online business or creating digital solutions. Digital entrepreneurial intention is driven by factors like recognition of digital opportunities, perceived feasibility, and personal motivation to succeed in the digital marketplace (Al-Ayed, 2024; Yousaf et al., 2021). Understanding these constructs helps in identifying how one's innovative attitude toward digital technologies can foster entrepreneurial intentions in the digital space.

While research has highlighted a positive correlation between innovative digital attitude and digital entrepreneurial intention among students, it often lacks depth in exploring contextual and moderating factors, which are critical to understanding this relationship more holistically. Alkhalaileh et al. (2023) suggest that students with a positive attitude toward digital innovation are more likely to demonstrate a strong intention to engage in digital entrepreneurial activities. However, there is limited exploration of how diverse personality traits, external influences (such as academic environment or social networks), or varying levels of technological proficiency may mediate or moderate this relationship. Additionally, the proactive and innovative mindset associated with an innovative digital attitude drives students to explore and capitalize on digital business prospects, increasing their confidence and readiness to embark on digital entrepreneurial ventures (Law & Breznik, 2017; Mir et al., 2023). This relationship underscores the importance of fostering an innovative digital attitude among students to cultivate a robust entrepreneurial ecosystem in the digital age.

H1 The innovative digital attitude of higher education students positively affects their digital entrepreneurial intention.

Personality traits

Personality traits describe aspects of human behavior that account for the variations in how individuals react to similar situations (Bharti et al., 2024). These traits are shaped by a person's unique, implicit, and idiosyncratic knowledge, principles, opinions, insights, and knowledges—factors that are inherently difficult to replicate (Xanthopoulou & Sahinidis, 2024). Additionally, personality traits can serve as catalysts, influencing entrepreneurs' risk perception and decision-making processes (Kautonen et al., 2015; Mahfud et al., 2020). The Big-Five personality traits—openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism—directly influence entrepreneurial behavior in digital context (Sobaih & Elshaer, 2022), a focus that this article will explore in depth.

Agreeableness

Agreeableness characterizes persons who are driven, altruistic, empathetic, self-assured, and oriented towards social harmony, demonstrating compassion towards others and a concern for overall welfare (Dalvi-Esfahani et al., 2020; McCrae & Costa, 1985). They tend to help others, display helpful and easygoing behavior, and are encouraging and compassionate (Duong, 2022). Additionally, their willingness to embrace and contribute to innovative digital solutions is significantly enhanced, making agreeableness a critical factor in the adoption and development of new digital technologies (Malo-Cerrato et al., 2023). Moreover, agreeableness plays a significant role in fostering entrepreneurial intentions (Jain et al., 2023). Furthermore, agreeableness may empower entrepreneurs to build trust with customers and partners, especially in the growing landscape where ethical practices and compassion are valued alongside efficiency (Bandera & Passerini, 2020). Despite this reasoning, the advent of progressive digital technologies and structures has profoundly transformed entrepreneurship (Nambisan et al., 2019), highlighting a pressing need to deepen understanding across multiple interconnected digital domains.

H2a Higher levels of agreeableness of higher education students positively influence their innovative digital attitude.

H3a Higher levels of agreeableness of higher education students positively influence their digital entrepreneurial intention.

H4a Higher levels of agreeableness of higher education students positively influence their digital entrepreneurial intention when mediated by their innovative digital attitude.

Extraversion

Extraversion is often defined by an energetic style characterized by social engagement, assertiveness, positivity, and the desire to influence others, with extraverted persons

seeking social connections, thriving in dynamic environments, and aspiring to leadership roles (Bandera & Passerini, 2020). This trait enhances their ability to interact effectively with others, share ideas, and pursue new opportunities in the digital realm, fostering a strong inclination towards digital innovation (Malo-Cerrato et al., 2023). Extraversion has been found to strongly associate with enthusiasm for entrepreneurial endeavors and is predicted to positively and directly influence the growth of entrepreneurial intentions (Díaz-Casero et al., 2012). Furthermore, individuals with this personality trait demonstrate a greater propensity towards entrepreneurial intentions (Costa et al., 1984). The energetic style associated with extraversion is shown to improve individuals' effectiveness in social interaction, promote digital innovation, and impact the development of entrepreneurial intentions, with a potential for further enhancement when coupled with an innovative digital attitude. However, notable cases, such as self-admissions from popular YouTubers who identify as introverts (Yeh et al., 2020), indicate a need for further clarification on the role of extraversion within digital entrepreneurship spheres.

H2b Higher levels of extraversion of higher education students positively influence their innovative digital attitude.

H3b Higher levels of extraversion of higher education students positively influence their digital entrepreneurial intention.

H4b Higher levels of extraversion of higher education students positively influence their digital entrepreneurial intention when mediated by their innovative digital attitude.

Conscientiousness

Conscientiousness encompasses elements such as decision-making, adherence to norms, responsible and analytical action, and organized planning (Bandera & Passerini, 2020). Studies have consistently shown a relationship between conscientiousness and both intentions and behaviors, particularly within online environments (Conner & Abraham, 2001; Shropshire et al., 2015). Moreover, conscientiousness has strong connections to various aspects of online contexts (Tseng et al., 2021). And so, it is likely to have a positive and influential relationship with innovative digital intention. Additionally, entrepreneurs prioritize traits associated with conscientiousness over making impulsive decisions, aiming to achieve outcomes aligned with their goals effectively (Bandera & Passerini, 2020), as conscientiousness has been positively linked to entrepreneurial intention (Baum & Locke, 2004). Consequently, conscientious students exhibit traits such as thoroughness, responsibility, and strategic thinking, which not only foster a positive attitude towards digital innovation but also strengthen their drive towards engaging in entrepreneurial activities. Nevertheless, conscientiousness is sometimes viewed as having limited relevance in influencing entrepreneurs' personalities (Singh & Basri, 2024), highlighting a need for further investigation to develop a more comprehensive understanding.

H2c Higher levels of conscientiousness of higher education students positively influence their innovative digital attitude.

H3c Higher levels of conscientiousness of higher education students positively influence their digital entrepreneurial intention.

H4c Higher levels of conscientiousness of higher education students positively influence their digital entrepreneurial intention when mediated by their innovative digital attitude.

Openness

The trait of openness to experience is associated with individuals who are creative, receptive to new ideas, inquisitive, intelligent, and adaptable (McCrae & Costa, 1985). People with elevated levels of openness are often characterized by greater acceptance and inclusivity, welcoming a variety of experiences and perspectives (Kvasova, 2015). A person's openness can enhance their digital self-confidence and their inclination towards engaging in practical and realistic digital activities (Maran et al., 2022). In the context of the swiftly evolving technological landscape, particularly within the realm of digital entrepreneurship, individuals may derive advantages from showcasing elevated levels of openness to experience and a propensity to embrace novel stimuli in order to achieve success (Bandera & Passerini, 2020). Therefore, openness to experience contributes to cultivating an innovative digital attitude and strengthening digital entrepreneurial intention through its facilitation of adaptability, creativity, and exploration of new digital opportunities. Nevertheless, a negative correlation has been observed between entrepreneurs' openness and the long-term survival of ventures (Ciavarella et al., 2004), emphasizing the need to further investigate openness in digital entrepreneurship contexts.

H2d Higher levels of openness to experience of higher education students positively influence their innovative digital attitude.

H3d Higher levels of openness to experience of higher education students positively influence their digital entrepreneurial intention.

H4d Higher levels of openness to experience of higher education students positively influence their digital entrepreneurial intention when mediated by their innovative digital attitude.

Neuroticism

Neuroticism, often associated with adverse emotions like anxiety, nervousness, and sadness (McCrae & Costa, 1985), exposes a deficit in emotional stability vital for making crucial decisions in daily business operations (Bandera & Passerini, 2020). Individuals exhibiting high levels of neuroticism tend to be apprehensive about change and feel anxious when required to adjust their behavior to new situations (Maran et al., 2022). Therefore, increased levels of neuroticism might correlate with adverse behaviors and experiences in online environments (Roberts et al., 2023). Additionally, neuroticism's potential to weaken entrepreneurs' resilience and adeptness in navigating challenges and criticism contrasts with the positive relation

academics found between emotional stability (opposite of neuroticism) and entrepreneurial intention (Bandera & Passerini, 2020). Consequently, high neuroticism undermines innovative digital intention and digital entrepreneurship intention by impeding effective navigation of challenges and criticism. Still, neuroticism, particularly in the context of vulnerable narcissism, influences entrepreneurial intention, and entrepreneurial education programs play a significant role as a moderating factor in this indirect relationship (Lee et al., 2023), hence, additional clarification is warranted.

H2e Higher levels of neuroticism of higher education students negatively influence their innovative digital attitude.

H3e Higher levels of neuroticism of higher education students negatively influence their digital entrepreneurial intention.

H4e Higher levels of neuroticism of higher education students negatively influence their digital entrepreneurial intention when mediated by their innovative digital attitude.

Moderate effects of digital entrepreneurial education in the association between innovative digital attitude and digital entrepreneurial intention

The shift from traditional to digital entrepreneurship education involves adapting curriculum to instruct students in founding new businesses, identifying entrepreneurial opportunities, and launching digital enterprises (Nowiński et al., 2019; Ratten & Usmanij, 2021). Digital entrepreneurship education offers insights into establishing businesses on digital platforms and provides a contemporary view of the digital entrepreneurial lifestyle (Clinkard, 2018). This education nurtures entrepreneurial intentions by imparting crucial knowledge (Karyaningsih et al., 2020). Research indicates that such education equips students with the necessary knowledge and mindset for innovation and risk-taking in business (Karyaningsih et al., 2020; Wardana et al., 2020), thereby serving as a significant supporter of entrepreneurial intentions (Hasan et al., 2017). Well-designed digital entrepreneurship education notably influences the intentions and the entrepreneurial success of students (Jena, 2020), boosting viability, boldness, and endurance prospects (Ho et al., 2018; Jena, 2020), and effectively stimulating digital entrepreneurial intentions (Ahmed et al., 2020; Bischoff et al., 2018). Despite the support provided by existing research for these reasonings, the interplay between digital entrepreneurship education and the relationship between innovative digital attitude and digital entrepreneurial intention remains insufficiently investigated within the higher education context.

H5 The association between the innovative digital attitude and the digital entrepreneurial intention of higher education students is more intense when they have a higher digital entrepreneurial education.

Figure 1 shows the research model.

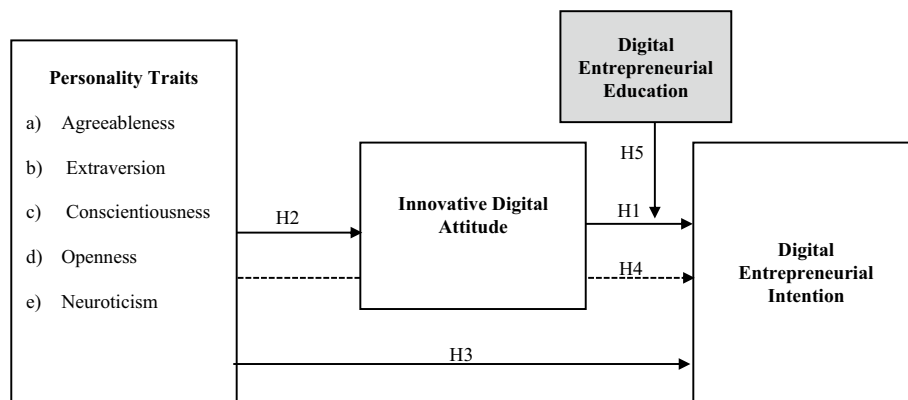


Fig. 1 Research model. Direct effects (→) and mediating effects (→)

Methods

Data and measurements

Between September and November 2023, authors published a link on their social networks and email contacts to an online questionnaire used to obtain the sample for this study. 417 responses were considered valid and cumulatively fulfilled two conditions: first, being over 18 years of age and residing in Portugal, and second, being a university student in Portugal. The sample was collected using a non-probabilistic convenience sampling technique, and as such, participants were selected without statistical criteria about the target population (Portuguese higher education students residing in Portugal). As such, the sample is not representative of this target of the Portuguese population. Informed consent was also obtained from all participants, and the questionnaire was anonymous. A pre-test was also carried out with 12 participants to assess their understanding of the questionnaire questions and the average response time. Participants reported no problems understanding and the average response time was 5 min.

The questionnaire was composed of four sections (details in Appendix A.). The first section refers to Big-Five personality traits with 15 items, whose scale was adapted from Costa and McCrae (1992). The choice of this scale was due to the following reasons: (i) this scale has a solid and consensual empirical basis; (ii) includes only 15 items (three items for each personality trait), and as such, the questions are quick to answer and it has been proven to be a valid and reliable alternative, especially in a research context with limited time, such as this questionnaire; (iii) this scale has been successfully tested in adults; (iv) broad applicability in different contexts and cultures and (v) strong predictive capacity for behaviors and results in different contexts (McCrae, 2009). Second, digital entrepreneurial education with five items was adapted from Wibowo et al. (2023). The third section referred to innovative digital attitude with four items adapted from Sobaih and Elshaer (2022). The fourth section referred to digital entrepreneurial intention with eight items adapted from Wibowo et al. (2023). All items were measured on a five-point Likert scale, ranging from 1—completely disagree to 5—completely agree.

Data analysis

The data analysis of this study was carried out in five stages. In the first stage, statistical analysis was used to carry out a sociodemographic characterization of the participants and describe the means and standard deviation of the items that measure the constructs, using SPSS (V. 29) software. The second stage consisted of factor analysis, with exploratory factor analysis (EFA) being carried out to divide the items into different factors and evaluate their commonalities, and confirmatory factor analysis (CFA) to assess the confirmatory factor load and the reflective nature of the research model. In the third stage, using the Smart PLS software (V. 4.0), the partial least square (PLS) method was applied to the research model. This method combines factor analysis with linear regression estimation. It has been increasingly used in studies with a similar theme, such as Wibowo et al. (2023); Mohammed et al. (2023); Lungu and Georgescu (2024). In the fourth stage, the model was evaluated in terms of convergence and reliability according to the measures suggested by Sarstedt et al. (2022): Cronbach alpha ($C\alpha > 0.70$), composite reliability ($CR > 0.70$) and average variance extracted ($AVE > 0.50$). According to Benitez et al. (2020), the discriminant validity was evaluated using the heterotrait–monotrait (HTMT) ratio, whose reference value was below 0.85. In the last stage, the relationships established in the research model were estimated, and a bootstrap analysis was carried out in Smart PLS (V. 4.0).

Results

Sociodemographic characterization of participants

The sample comprises 417 students residing in Portugal who attend higher education. The majority of participants are women (59%). The minimum age of participants is 18, and the maximum is 28, with the average age being 21.4 years. 87.3% are undergraduate students, the remainder being master's and doctoral students.

Items and constructs

Table 1 contains the statistical analysis of the items that measure the constructs shown in Fig. 1. On average, conscientiousness was the personality trait that generated the most significant agreement ($M = 3.71$), and the one that generated the most minor agreement was neuroticism ($M = 2.92$). Furthermore, participants revealed, on average, high agreement with the items of innovative digital attitude ($M = 3.75$) but lower average agreement with the items of digital entrepreneurial education ($M = 2.97$) and digital entrepreneurial intention ($M = 2.85$).

Exploratory factor analysis and confirmatory factor analysis

The results of the factor analysis are included in Appendix B. The implementation of EFA divided the items into eight factors corresponding to the constructs included in the research model, with high communalities (> 0.70). The accumulated variance of the eight factors is 66.74%, with none individually representing more than 50% of the total variance. The CFA results demonstrate that all items have high confirmatory

Table 1 Statistical description of items and constructs

	Mean	Standard deviation
Personality traits		
Agreeableness	3,02	1,131
Agre_1	3,94	0,937
Agre_2	2,49	1,205
Agre_3	2,64	1,252
Extraversion	3,56	0,944
Ext_1	3,08	1,029
Ext_2	3,89	0,863
Ext_3	3,71	0,941
Conscientiousness	3,71	0,907
CONS_1	3,61	0,916
CONS_2	3,67	0,91
CONS_3	3,84	0,896
Openness	3,25	1,039
Open_1	3,68	0,946
Open_2	3,27	1,027
Open_3	2,80	1,143
Neuroticism	2,92	1,161
Neur_1	2,69	1,202
Neur_2	3,02	1,207
Neur_3	3,05	1,073
Digital entrepreneurial education (DEE)	2,97	1,046
DEE1	3,00	1,018
DEE2	2,94	1,074
DEE3	2,98	1,052
DEE4	2,99	1,036
DEE5	2,92	1,049
Innovative digital attitude (ATT)	3,75	0,981
ATT_1	3,83	0,982
ATT_2	3,76	0,9
ATT_3	3,52	1,072
ATT_4	3,88	0,97
Digital entrepreneurial intention (DEI)	2,85	1,045
DEI1	3,27	1,202
DEI2	3,59	1,204
DEI3	3,32	1,241
DEI5	3,73	1,124
DEI6	3,07	1,231
DEI7	2,94	1,146
DEI8	2,90	1,214

factor loadings (> 0.70). Thus, no item was eliminated and the reflective nature of the model was confirmed.

Assessment of the model

After applying the PLS method to the research model, the obtained model was evaluated in terms of convergence, reliability, and discriminant validity (Table 2). According to the

Table 2 Model measurement evaluation

	Ca	CR	AVE	HTMT criterion								
				Agre	Ext	Cons	Open	Neur	DEE	ATT	DEI	
Agreeableness (Agre)	0.767	0.769	0.511									
Extraversion (Ext)	0.722	0.844	0.645	0.591								
Conscientiousness (Cons)	0.809	0.887	0.724	0.405	0.728							
Openness (Open)	0.709	0.797	0.590	0.803	0.783	0.728						
Neuroticism (Neur)	0.760	0.756	0.595	0.753	0.422	0.272	0.737					
Digital entrepreneurial education (DEE)	0.916	0.937	0.750	0.328	0.269	0.209	0.515	0.483				
Innovative digital attitude (ATT)	0.797	0.870	0.629	0.481	0.387	0.568	0.692	0.370	0.173			
Digital entrepreneurial intention (DEI)	0.916	0.933	0.666	0.357	0.643	0.305	0.685	0.307	0.296	0.342		

reference values suggested by Sarstedt et al. (2022), the model is convergent and reliable since the values obtained for the Cronbach alpha ($C\alpha > 0.70$), Composite Reliability ($CR > 0.70$), and AVE ($AVE > 0.50$) coefficients are higher than the reference values. The model also presents discriminant validity according to the heterotrait–monotrait (HTMT) ratio results since the values obtained are lower than the reference value (0.85).

The good fit of the model was also evaluated according to the measures suggested by Sarstedt et al. (2022): Chi-square ($p = 0.093$), goodness-of-fit (0.97; reference > 0.90), the comparative fit index (0.98; reference value > 0.90) and standard root mean square residual (0.069; reference value < 0.08). As the values obtained for these measurements comply with the reference values, we can conclude that the model presents a good fit. The possibility of collinearity problems was also assessed using the variance inflation factor (VIF). The item that presents the highest VIF is DEI3 (2.953) and as such, there are no collinearity problems. Finally, the significance and relevance of path coefficients were evaluated using the R-square (R^2) and the predictive relevance of the estimated model using the Stone–Geisser measure (Q^2). According to Cohen (2013) criterion, the dependent variable digital entrepreneurial intention presents a “moderate effect” ($R^2 = 0.248$) and the dependent variable innovative digital attitude a “substantial effect” ($R^2 = 0.353$). Finally, the model presents predictive relevance (digital entrepreneurial intention— $Q^2 = 0.161$ and innovative digital attitude— $Q^2 = 0.210$, respectively), given that the coefficients obtained are greater than zero.

Estimation of the relationship between constructs

Table 3 shows the estimation of direct and mediating relationships between constructs formulated in the research model.

Table 3 Direct and mediating effects between constructs

Effects on endogenous variable	Path (β)	t Value (bootstrap)	P-value	Confidence interval		Hypothesis support
				2.5%	97.5%	
H1: ATT → DEI	0.103	1.548	0.002	0.040	0.218	Yes
H2a: <i>Agre</i> → ATT	0.254	4.215	0.000	0.149	0.381	Yes
H2b: <i>Ext</i> → ATT	0.158	2.567	0.011	0.039	0.273	Yes
H2c: <i>Cons</i> → ATT	0.204	4.093	0.000	0.110	0.306	Yes
H2d: <i>Open</i> → ATT	0.126	2.648	0.008	0.033	0.219	Yes
H2e: <i>Neur</i> → ATT	−0.033	0.700	0.004	−0.058	0.127	Yes
H3a: <i>Agre</i> → DEI	−0.026	0.394	0.694	−0.153	0.102	No
H3b: <i>Ext</i> → DEI	−0.008	0.112	0.911	−0.149	0.125	No
H3c: <i>Cons</i> → DEI	0.029	0.431	0.667	−0.109	0.157	No
H3d: <i>Open</i> → DEI	0.340	5.850	0.435	0.225	0.450	No
H3e: <i>Neur</i> → DEI	0.036	0.587	0.557	−0.077	0.163	No
H4a: <i>Agre</i> → ATT → DEI	0.126	1.459	0.005	−0.011	0.062	Yes
H4b: <i>Ext</i> → ATT → DEI	0.116	1.234	0.001	−0.005	0.044	Yes
H4c: <i>Cons</i> → ATT → DEI	0.121	1.410	0.001	−0.008	0.050	Yes
H4d: <i>Open</i> → ATT → DEI	0.113	1.202	0.002	−0.004	0.038	Yes
H4e: <i>Neur</i> → ATT → DEI	−0.003	0.574	0.003	−0.006	0.016	Yes

Agre agreeableness, *Ext* extraversion, *Cons* conscientiousness, *Open* openness, *Neur* neuroticism, *ATT* innovative digital attitude (ATT), *DEI* digital entrepreneurial intention (DEI)

The results demonstrate that innovative digital attitude positively influences the digital entrepreneurial intention of higher education students in Portugal ($\beta=0.103$), confirming H1. There is a statistically significant influence of personality traits on innovative digital attitude but not on digital entrepreneurial intention. This way, hypotheses H2a to H2e are confirmed, but hypotheses H3a to H3e are rejected. However, the intensity of the influence of personality traits on innovative digital attitudes is not uniform. First, the personality traits agreeableness, extraversion, conscientiousness, and openness to experience positively influence innovative digital attitudes, unlike neuroticism, which negatively influences. Second, agreeableness is the personality trait that most influence innovative digital attitude ($\beta=0.254$), followed by conscientiousness ($\beta=0.204$), extraversion ($\beta=0.158$), and finally, openness to experience ($\beta=0.126$). Neuroticism has a residual negative influence on innovative digital attitude ($\beta=-0.033$).

However, when the relationship between personality traits and digital entrepreneurial intention is mediated by innovative digital attitude, this relationship becomes statistically significant, confirming hypotheses H4a to H4e. Also, agreeableness is the personality trait that most influence digital entrepreneurial intention when mediated by innovative digital attitude ($\beta=0.126$), followed by conscientiousness ($\beta=0.121$), extraversion ($\beta=0.116$), and finally, openness to experience ($\beta=0.113$).

Table 4 shows the results of the moderating effect of digital entrepreneurial education on the relationship between innovative digital attitude and digital entrepreneurial intention. The results reveal that the association between innovative digital attitude and digital entrepreneurial intention is more intense the higher the digital entrepreneurial education of Portuguese higher education students ($\beta=0.163$). Thus, hypothesis H5 is confirmed.

Discussion and implications

In an effort to address the lack of comprehensive models that integrate personality traits, innovative digital attitude, and digital entrepreneurial intention among higher education students, this study has yielded numerous valuable insights into how the Big-Five personality traits of higher education students influence their innovative digital attitude and digital entrepreneurial intentions. Additionally, it advances the understanding of how the digital entrepreneurial education moderates the relationship between innovative digital attitude and digital entrepreneurial intention.

The results reveal that innovative digital attitude positively influences the digital entrepreneurial intention of higher education students in Portugal. Alkhalailah et al. (2023) highlight that students who have a positive perspective on digital innovation are

Table 4 Moderating effect

Main effect	Hypothesized moderating effect	Results
<i>Digital entrepreneurial education (DEE) as moderator</i>		
Innovative digital attitude (ATT) → Digital entrepreneurial intention (DEI)	H5: The association between the digital and innovative attitude and the digital entrepreneurial intention of higher education students is more intense when they have a higher digital entrepreneurial education	$\beta=0.163$ $t=1.539$ $\rho=0.001$

more likely to engage in digital entrepreneurship, a conclusion that supports this study findings. This relationship may be influenced by factors such as openness to change, a proactive mindset, confidence in technology, creativity, resilience in the face of failure, networking opportunities, and alignment with market trends, all of which deserve further exploration. This study research findings further demonstrate that personality traits exert a statistically significant influence on innovative digital attitude, whereas no statistically significant influence was observed on digital entrepreneurial intention. This suggests that while individual traits play a role in shaping attitudes towards digital innovation, other factors may predominantly influence intentions towards digital entrepreneurship. Nevertheless, the impact of personality traits on innovative digital attitude exhibits variability. Specifically, traits such as agreeableness, extraversion, conscientiousness, and openness to experience are observed to exert a positive influence on innovative digital attitude, whereas neuroticism is found to have a negative effect. Agreeableness exhibited the highest influence on innovative digital attitude. This finding underscores the significant role that agreeableness plays in shaping the online behavior of young individuals (Malo-Cerrato et al., 2023). The role of conscientiousness, as the second strongest, is also prominently highlighted, translating to and reinforcing its significant influence on online behavior (McCreless et al., 2017; Tseng et al., 2021). Under-scoring the crucial impact that conscientiousness has on shaping and guiding how young individuals engage with digital platforms. The results related to extraversion also provide robust support for its connection to digital innovation. Supporting its substantial role in fostering and advancing innovative endeavors within digital contexts (Malo-Cerrato et al., 2023). Similarly, the same applies to openness to experience. The observed negative influence of neuroticism is consistent with anticipated outcomes. As heightened levels of neuroticism typically correlate with unfavorable online behaviors and experiences, such as anxiety induced by social media use (Roberts et al., 2023). Additionally, neuroticism is linked to personal distress stemming from ineffective problem-solving (Clark & Ro, 2014), which may hamper their ability to engage in positive or proactive digital activities, ultimately limiting their participation in innovative digital pursuits. Consequently, neurotic individuals may be less inclined to explore or adopt new digital practices due to apprehensions about potential failure or negative social feedback.

Initially, no statistically significant influence of personality traits on digital entrepreneurial intention was evident. Digital entrepreneurship introduces unique challenges that differ from those in traditional entrepreneurship (Berman et al., 2024), particularly regarding the need to adapt to rapid technological changes and navigate competition in digital markets. As a result, situational factors like access to technology and current market trends may play a more significant role in shaping entrepreneurial intentions than stable personality traits. External factors such as market demand, availability of financial resources, and technical support can overshadow personality traits by either creating opportunities or imposing limitations. Furthermore, the skills essential for digital entrepreneurship are typically acquired through education and experience rather than being inherently linked to one's personality. However, upon considering the mediating role of innovative digital attitude, the relationship between personality traits and digital entrepreneurial intention attained statistical significance. This change can be understood in the context that, intention in psychology refers to a person's planned actions based on

achievable desires (Gibbs, 1999), shaped by their attitudes towards behavior, perceived control over behavior, and subjective norms (Sobaih & Elshaer, 2022). Thus, it is understood that innovative digital attitude enhances the positive influence of personality traits, as there is a significant link between students' attitudes and digital entrepreneurship (Younis et al., 2020). This is because intentions are regarded as comprehensive constructs that encapsulate motivational determinants influencing behavior, thereby serving as proxies for individuals' readiness to allocate effort towards specific actions (Munir et al., 2012). These findings underscore the importance of cultivating students' digital attitudes to foster digital entrepreneurship. By fostering a conducive digital mindset, educational institutions and stakeholders can effectively equip students to navigate and capitalize on opportunities within the digital economy. This strategy not only augments students' entrepreneurial aspirations, but also develops the requisite skills and mentality essential for achieving success in digital entrepreneurship.

This rationale is reinforced by the findings, which indicate that the relationship between digital innovative attitude and the digital entrepreneurial intention of higher education students is more pronounced when they receive higher digital entrepreneurial education, highlighting the essential role of education in fostering digital entrepreneurship. Furthermore, education in digital entrepreneurship have been shown to enhance comprehensive understanding and proficiency in digital entrepreneurial practices (Briel et al., 2021; Nambisan, 2017). Moreover, it contributes significantly to imparting knowledge and fostering approaches that influence ground-breaking activities and risk-taking behaviors in professional contexts (Karyaningsih, 2020; Wardana et al., 2020). Consequently, this targeted education enhances students' confidence and capability to initiate and manage digital ventures, thereby increasing their likelihood of entrepreneurial intention and success in the digital economy.

Theoretical implications

This study makes a significant contribution to academia by emphasizing several key points that warrant scientific inquiry. Firstly, it underscores the crucial importance of examining the relationship between personality traits, their influence on personal attitudes, and digital entrepreneurial intentions, especially given the accelerating influence of digitalization on societal dynamics. Highlighting the fact that digitalization itself promotes entrepreneurship (Dabbous et al., 2023). Secondly, the study emphasizes the importance of investigating other variables that might have a stronger influence on intentions towards digital entrepreneurship. Thirdly, it underscores the critical importance of exploring the dynamics of innovative digital attitudes, essential for developing effective educational and training programs aimed at fostering entrepreneurial skills in digital environments. Fourthly, it emphasizes the ongoing need to investigate the field of digital entrepreneurship. Lastly, given the extensive scope of digital innovation and digital entrepreneurship, there is a compelling rationale to extend the study's findings to other scientific disciplines (Nambisan, 2017). This cross-disciplinary approach has the potential to enhance comprehension of how personality traits and digital attitudes impact behavior across diverse contexts, thereby contributing to expanded theoretical frameworks and practical applications across multiple fields.

Practical implications

Numerous valuable implications are presented in the study. First, more efforts are needed to shape the personal traits of graduates (Sobaih & Elshaer, 2022), to enhance their adaptability, innovation, employability, entrepreneurial potential, interpersonal skills, mental well-being, and alignment with evolving industry demands. Second, comprehensive digital entrepreneurship education initiatives aimed at enhancing students' skills and mindsets should be developed and strengthened (Wibowo et al., 2023). To enhance digital entrepreneurship education, institutions should integrate it into various curricula, allowing diverse student engagement. They should provide hands-on learning through workshops and collaborations with local startups, establish mentorship programs connecting students with entrepreneurs, and offer online resources like e-learning modules on digital marketing and data analytics. Additionally, promoting innovation through hackathons and competitions, implementing robust assessment frameworks, collaborating with industry partners for relevant insights and internships, and utilizing diverse teaching methods will cater to different learning styles. Third, there is a need to cultivate students' innovative behavior and encourage risk-taking in professional contexts. Encouraging students to innovate and take risks in their education prepares them to drive future progress and adapt to dynamic professional environments. Fourth, support programs that empower students to effectively initiate and manage digital ventures, enhancing their potential for success in the digital economy, must be created. And, lastly, to understand shifts in students' behavior post-educational programs, it would be useful to consider entrepreneurial learning outcomes in the dimensions of emotional, mental, and competency-based results (Ratten & Usmanij, 2021; Saptono et al., 2021).

Conclusion

This study explores the influence of higher education students' personality traits on innovative digital attitude and digital entrepreneurial intention. Furthermore, it explores the moderating role of digital entrepreneurial education in the association between innovative digital attitude and digital entrepreneurial intention.

The study started with formulating two important research questions: (RQ1) What is the influence of higher education students' personality traits on innovative digital attitudes? And (RQ2) How do higher education students' personality traits influence digital entrepreneurial intention?. Thus, the results reveal that (i) innovative digital attitude positively influences the digital entrepreneurial intention of higher education students in Portugal; (ii) the Big-Five personality traits directly influence the innovative digital attitude but not the digital entrepreneurial intention of higher education students; (iii) however, this relationship becomes significant when the relationship between personality traits and digital entrepreneurial intention is mediated by innovative digital attitude; (iv) agreeableness is the personality trait that most influences innovative digital attitude and digital entrepreneurial intention when mediated by innovative digital attitude; and (v) the higher the level of digital entrepreneurial education, the more intense the association between innovative digital attitude and digital entrepreneurial intention.

Based on the results, we formulate important theoretical and practical implications. At a theoretical level, this study highlights the important role of individual personality

traits as influencers of digital entrepreneurial attitudes and intentions, allowing a deeper understanding of the antecedents of digital entrepreneurial intentions. In practical terms, it is demonstrated that, given the importance of personality traits in digital entrepreneurial attitude and intention, policymakers must invest in education for digital entrepreneurship, working according to students' personality traits to equip them with the skills and mindsets necessary to start a digital entrepreneurial activity, but also to enable them to manage digital ventures successfully.

This study has some limitations. First, despite the large number of participants, the sample is non-probabilistic, collected for convenience, and is not representative of the population residing in Portugal who attend Portuguese higher education. Therefore, it is recommended that a representative sample of the target audience be collected in future studies to generalize the results. Second, no information was collected about higher education students' study area. It would be interesting to analyze the differences between natural sciences, social sciences, and humanities students regarding personality traits, innovative digital attitudes, and digital entrepreneurial intention and how the relationships between these constructs change. Third, personality traits were considered as antecedents of innovative digital attitude. Future studies may use other variables such as digital entrepreneurial education, digital entrepreneurial knowledge, and digital entrepreneurial alertness. It would also be interesting to use gender, age, and the education area attended in higher education as moderate variables in the relationship between innovative digital attitude and digital entrepreneurial intention.

Appendix

A. Questionnaire available at: https://drive.google.com/file/d/1GNNGpW_1_sGY_Lg_UMBI93uG4rlScgZD/view?usp=sharing

B. EFA and CFA results.

	Confirmatory factor loads	1	2	3	4	5	6	7	8	Commonalities
Personality traits										
Agreeableness										
Agre_1	0.915	0.774								0.795
Agre_2	0.989	0.793								0.786
Agre_3	0.947	0.785								0.785
Extraversion										
Ext_1	0.702		0.703							0.760
Ext_2	0.827		0.774							0.710
Ext_3	0.871		0.741							0.702
Conscientiousness										
CONS_1	0.857			0.795						0.743
CONS_2	0.852			0.794						0.729
CONS_3	0.843			0.797						0.788
Openness										
Open_1	0.874				0.742					0.731
Open_2	0.819				0.747					0.730
Open_3	0.884				0.781					0.851
Neuroticism										

	Confirmatory factor loads	1	2	3	4	5	6	7	8	Commonalities
Neur_1	0.812					0.719				0.789
Neur_2	0.581					0.799				0.797
Neur_3	0.766					0.756				0.836
Digital entrepreneurial education (DEE)										
DEE1	0.788						0.722			0.898
DEE2	0.881						0.842			0.786
DEE3	0.894						0.859			0.797
DEE4	0.890						0.875			0.801
DEE5	0.870						0.858			0.783
Innovative digital attitude (ATT)										
ATT_1	0.833							0.817		0.781
ATT_2	0.855							0.807		0.735
ATT_3	0.712							0.563		0.780
ATT_4	0.848							0.803		0.742
Digital entrepreneurial intention (DEI)										
DEI1	0.828								0.780	0.713
DEI2	0.782								0.744	0.725
DEI3	0.854								0.833	0.748
DEI5	0.761								0.724	0.764
DEI6	0.869								0.858	0.775
DEI7	0.778								0.762	0.761
DEI8	0.835								0.804	0.721

Abbreviations

Agre	Agreeableness
Ext	Extraversion
Cons	Conscientiousness
Open	Openness
Neur	Neuroticism
DEE	Digital entrepreneurial education
ATT	Innovative digital attitude
DEI	Digital entrepreneurial intention
DEI	Digital entrepreneurial intention

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Author contribution

JL and SG conceived the core idea of the manuscript and conducted empirical studies, analyzed the data, and drafted the manuscript. EN helped with the literature review and discussion. All authors have read and approved the manuscript.

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Data availability

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Declarations

Ethics approval and consent to participate

Written consent was obtained from all the participants involved in the study. This is an original work of authors.

Competing interests

The authors declare no potential competing interest.

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