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Sustainable Entrepreneurial Education and Entrepreneurial Intention in the Generative AI Era

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Abstract

Sustainability-oriented entrepreneurship education is gaining traction, but few studies examine the mechanisms by which learning experiences translate into intentions to create socially and environmentally responsible businesses. Based on Human Capital Theory and the Theory of Planned Behaviour, this research investigates the mediating effect of sustainable opportunity recognition and green creativity sequentially and the moderating effect of Generative AI Literacy for Learning. Partial least squares structural equation modeling (PLS-SEM) was used to analyse the survey responses of 407 students from public and private universities in Punjab, Pakistan. The findings showed a positive correlation between educational exposure and opportunity identification, which is linked to creative idea generation and, in turn, higher entrepreneurial intentions. The indirect (sequential) relationship is significant. Moreover, GenAI literacy strengthens both the education–intention and creativity–intention relationships, suggesting that technological competence complements sustainability-focused learning. These findings complement the existing explanations of entrepreneurial intention by adding an extension of the cognitive and creative process to a technology-related boundary condition. The study also underscores the importance of integrating sustainability problems, opportunities, innovative problem-solving, and responsible leveraging of generative AI into the curriculum, especially for higher education institutions, which are crucial for nurturing entrepreneurial aspirations in today's learning landscape.

Introduction

The integration of economic, environmental, and social value creation has been determined as a strategic approach to addressing global issues such as climate change, resource scarcity, and social inequality in the field of sustainable entrepreneurship (Rosário & Figueiredo, 2024; Abbas & Bulut, 2024). Sustainable entrepreneurship is not only about traditional entrepreneurship, but it is a matter of innovative business solutions that have a long-term social, environmental and economic impact (Maaßen et al., 2026; Onofrei et al., 2026). Thus, universities are becoming more and more called upon to train entrepreneurs who have the knowledge and skills to recognise and capitalise on sustainability opportunities (Leal Filho et al., 2025). Hence, entrepreneurship education is no longer just about entrepreneurship but also about equipping students with entrepreneurial skills for sustainability, following the Sustainable Development Goals (SDGs) (Planck et al., 2024; Suguna et al., 2024).

This shift has resulted in focus on Sustainable entrepreneurship education (SEE) being a major research and policy issue. The existing studies show that educational activities can positively affect students' entrepreneurial skills, attitudes, and intentions (Duan et al., 2025; Kaabnezhadian et al., 2025; Otache et al., 2024). The empirical evidence of the relationship between sustainable entrepreneurship education and sustainable entrepreneurial intention, however, is not conclusive. Many studies have examined the direct link or have adopted traditional psychological frameworks, including the concept of entrepreneurial self-efficacy and the Theory of Planned Behavior (TPB) (Valencia-Arías et al., 2025; Seong et al., 2025). While these variables have been important in entrepreneurship studies, they offer

very little insight into the thinking and innovation that inspire the students to materialize the knowledge about sustainability in their entrepreneurial aspirations.

Over the past few years, research on entrepreneurship has focused on the importance of entrepreneurs identifying business opportunities that arise from the concept of sustainability. In the latest research on entrepreneurship, one of the fundamental skills required for future entrepreneurs is the recognition of sustainability-related business opportunities. Opportunity recognition aids in discerning the unfulfilled environmental and social demands, subsequently converting these recognized wants into innovative concepts that may be utilized to create entrepreneurial solutions. The role of opportunity recognition as an intermediate factor in the process of becoming a green and sustainable entrepreneur has been paid less attention in the literature, despite its growing significance in the field of green and sustainable entrepreneurship intentions, particularly in higher education.

Aside from identifying opportunities, it's essential that individuals can think about new sustainable solutions, too. This ability is embodied in ‘green creativity'—the ability to produce novel and useful concepts, which can be used for the benefit of the environment. Although the field of organizational and innovation management has already explored the issue of green creativity in great detail, the topic of its application in entrepreneurship education has not yet been explored to the same extent. Specifically, there is little empirical evidence to answer the question of whether students who have been introduced to sustainable opportunities are more likely to subsequently develop green creative ideas to support their intentions to establish sustainable businesses. Viewing opportunity recognition and green innovation as cognitive and sequential processes might furnish a more complete account of the influence of sustainable entrepreneurship education on entrepreneurial intention.

The role of generative AI (GenAI) in shaping entrepreneurial learning and opportunity creation is being transformed in the meantime. Students can leverage generative AI tools to gain insight into market data, ideate business concepts, explore sustainability issues, and creatively adjust solutions compared to learning done traditionally. However, entrepreneurship researchers have argued for the use of AI in entrepreneurship education to help students get ready for the future of business. In most of the previous studies, however, the immediate educational effects of AI or the effect on entrepreneurial self-efficacy have been investigated, but the context and conditions under which Generative AI Literacy for Learning supports students' green creative potential to become sustainable entrepreneurship intention have not received much attention.

This study fills in three significant gaps in the literature. First, it expands on SE research and takes into consideration how sustainable entrepreneurship education affects SEI via a serial cognitive route that involves green innovation and sustainable opportunity perception. Second, it presents Generative AI Literacy for Learning as a boundary condition to reinforce the linkage between green creativity and sustainable entrepreneurial intention, highlighting the increasing significance of entrepreneurial learning with AI. Third, this paper addresses recent calls in the literature for a more integrated model to explain

sustainable entrepreneurial behaviour in higher education by combining sustainability education, opportunity recognition, creativity, and AI literacy into a single model.

Consequently, this research aims to investigate the mediating function of sustainable opportunity recognition and green creativity in the relationship between sustainable entrepreneurship education and students' sustainable entrepreneurial intentions, while also exploring the moderating influence of Generative AI Literacy for Learning on this relationship. The findings will theoretically advance the field of sustainable entrepreneurship education beyond the traditional intention models, and practically inform universities and policy-makers in the field with evidence-based guidance in designing AI-enabled sustainability-oriented entrepreneurship education curricula for the development of the next generation of sustainable entrepreneurs.

Literature Review

Theoretical Underpinning

The Human Capital Theory (HCT) (Becker, 1964) and the Theory of Planned Behaviour (TPB) (Ajzen, 1991) underpin this study. These corresponding theories explain the development of students' capacity through sustainable entrepreneurship education and how this capacity is related to sustainable entrepreneurial intention. The Human Capital Theory states that education is an investment that can improve a person's capacity to see possibilities and come up with creative solutions (Becker, 1964; Marvel et al., 2016). Thus, the knowledge and skills of sustainability and entrepreneurship education are combined to form entrepreneurial human capital. Investing in education promotes Sustainable Opportunity Recognition, as students become more aware of environmental and social issues as investment opportunities. Furthermore, the learning gained helps students to design new and Green solutions for business challenges. Similarly, Generative AI Literacy for Learning is considered a contemporary version of digital human capital to enhance students' learning and evaluation capability, and to apply AI-based knowledge skills in entrepreneurial learning (Ng et al., 2021). The two theories are used to explain the entrepreneurial capabilities and influence of entrepreneurial capabilities on Sustainable Entrepreneurial Intention (SEI). The influence of entrepreneurial capabilities on Sustainable Entrepreneurial Intention (SEI) is explained by the Theory of Planned Behavior, while HCT explains entrepreneurial capabilities development. The Theory of Planned Behavior posits that entrepreneurial intention arises from an individual's assessments of entrepreneurial actions and their assessed competencies to engage in such behaviors (Ajzen, 1991). Sustainable entrepreneurship can increase students' entrepreneurial intentions if they become aware of sustainable opportunities and create green creative solutions (Liñán & Chen, 2009; Schlaegel & Koenig, 2014). Therefore, the ability to develop the capability development process as served by HCT, and to develop entrepreneurial intention that will be retained as served by TPB, provides theoretical explanations that can be used as a theoretical foundation for the proposed research model.

Sustainable Entrepreneurial Education and Sustainable Entrepreneurial Intention

Sustainable Entrepreneurial Education (SEE) is foundational to building individuals' knowledge, skills, attitudes and competencies to pursue sustainable entrepreneurial activities. Drawing on human capital theory, education serves as a mechanism for enhancing entrepreneurial capabilities by providing learners with sustainability-oriented knowledge, opportunity recognition skills, and problem-solving abilities. In addition to raising understanding of environmental and social issues, sustainable entrepreneurship education boosts people's self-esteem and drive to pursue sustainable endeavours. Previous research suggests that educational experiences focused on sustainability encourage entrepreneurial mindsets by improving perceived feasibility, self-efficacy, and commitment toward sustainable entrepreneurship. Students are more likely to recognise and capitalise on sustainable opportunities through exposure to sustainable business models, ethics, and innovative business practices. Therefore, the greater sustainable entrepreneurial education presented by individuals is expected to lead to more sustainable entrepreneurial venture intentions. Based on this, it is hypothesized that:

H1

Sustainable Entrepreneurial Education positively influences Sustainable Entrepreneurial Intention.

Sustainable Entrepreneurship Education and Sustainable Opportunity Recognition

Sustainable entrepreneurship education (SEE) is a process that helps students develop knowledge, skills, competencies and a sustainability mindset to recognize opportunities which create economic, environmental and social value. In SEE, experiential learning, systems thinking and sustainability problem solving are core principles, and students are taught to identify unmet societal and environmental needs as business opportunities, rather than simply traditional entrepreneurship education. As per Human Capital Theory (HCT), education contributes to the development of knowledge and cognitive power and thus better endows individuals with the ability to detect and assess entrepreneurial opportunities (Becker, 1964; Marvel et al., 2016). Students have the opportunity to develop a sustainability perspective that enables them to approach issues of sustainability not just as social and environmental issues, but also as entrepreneurial challenges, through sustainability-related knowledge and entrepreneurial skills. Empirical evidence indicates that entrepreneurial education fosters entrepreneurial knowledge, critical thinking and problem-solving skills that contribute to the opportunity recognition process (Nabi et al., 2017). Similarly, sustainability-focused education strengthens sustainability innovation skills and sustainable opportunity recognition (Planck et al., 2024). Thus, SEE increases students’ likelihood of recognizing sustainable entrepreneurial opportunities. Therefore, it is hypothesized that:

H2

Sustainable Entrepreneurship Education positively influences Sustainable Opportunity Recognition.

Sustainable Opportunity Recognition and Green Creativity

Sustainable opportunity recognition (SOR) refers to an individual's ability to identify entrepreneurial opportunities that address environmental, social, and economic problems. It is a key cognitive ability for recognizing unmet sustainability needs and transforming them into innovative business ideas (Shane & Venkataraman, 2000). According to Human Capital Theory (HCT), accumulated knowledge, experience, and learning enhance cognitive capacities, enabling individuals to identify opportunities and generate creative solutions that create value (Becker, 1964; Marvel et al., 2016). Sustainable opportunities, therefore, provide a foundation for developing innovative and environmentally conscious entrepreneurial ideas. Green creativity reflects the ability to develop novel and useful ideas that contribute to environmental sustainability (Chen & Chang, 2013). Sustainability-related opportunities may be useful in stimulating creative thinking, in that they provide a way to explore alternative approaches to complex environmental and social issues (Tang et al., 2012). Sustainability-oriented education further helps students transform recognized opportunities into green entrepreneurial ideas (Ploum et al., 2018). So, a stronger SOR is expected to enhance green creativity. Therefore, it is hypothesized that:

H3

Sustainable Opportunity Recognition positively influences Green Creativity.

Green Creativity and Sustainable Entrepreneurial Intention

Green creativity refers to the generation of novel and useful ideas that contribute to environmental sustainability by addressing ecological challenges through innovative products, services, or processes (Chen & Chang, 2013). From a sustainable entrepreneurship perspective, green creativity allows people to convert knowledge and opportunities surrounding sustainability into viable entrepreneurial solutions. Creative people are more likely to be creative in generating new business ideas that generate economic, social and environment benefits, which makes the creation of sustainable ventures more attractive. The relationship can be explained using a suitable theory, which is the Theory of Planned Behavior (TPB). TPB assumes that positive evaluations of behaviour and perceived ability to perform it increase the likelihood of the development of behavioural intentions (Ajzen, 1991). Higher levels of green creativity translate to the students being more capable of developing creative innovations for sustainable business, and this increases their perception of the desirability and feasibility of creating a sustainable business. Thus, green creativity is anticipated to enhance the sustainable entrepreneurial intention. Previous research indicated that creativity is positively related to entrepreneurial intention, as creative people tend to have higher capacity to develop new business ideas and be able to perceive entrepreneurial opportunities (Biraglia & Kadile, 2017; Chen & Chang, 2013). Thus, the students' intention

to sustainable entrepreneurship is expected to be high for those who show higher levels of green creativity. Therefore, it is hypothesized that:

H4

Green Creativity positively influences Sustainable Entrepreneurial Intention.

Sequential Mediation of Sustainable Opportunity Recognition and Green Creativity

Sustainable Entrepreneurial Education (SEE) equips learners with the knowledge, competencies, and sustainability-oriented mindset needed to identify opportunities addressing environmental and social challenges (Ploum et al., 2018; Lackéus, 2020). However, opportunity recognition alone may not generate entrepreneurial intentions unless opportunities are transformed into innovative and environmentally responsible ideas. Green Creativity (GC) facilitates this transformation by enabling individuals to develop novel solutions to sustainability challenges (Amabile, 1996; Chen & Chang, 2013). Opportunity recognition can stimulate creativity by encouraging new approaches to sustainability-related problems (Ardichvili et al., 2003; Shane & Venkataraman, 2000). Green creativity further strengthens confidence in developing sustainable business solutions, thereby enhancing Sustainable Entrepreneurial Intention (SEI) (Chen & Chang, 2013; Hu et al., 2018). Therefore, it is hypothesized that GC will mediate the relationship between SOR and SEI. Similarly, there is a possibility that SEE can indirectly affect GC through SOR. SOR and GC are sequential processes that are complementary to each other, in line with literature on entrepreneurship suggesting that opportunity identification and creative idea generation are complementary processes (Baron, 2006; Krueger, 2009).For the above reasons, the following hypotheses are proposed:

H5a

Green Creativity (GC) mediates the positive relationship between Sustainable Opportunity Recognition (SOR) and Sustainable Entrepreneurial Intention (SEI).

H5b

Sustainable Opportunity Recognition (SOR) and Green Creativity (GC) sequentially mediate the positive relationship between Sustainable Entrepreneurial Education (SEE) and Sustainable Entrepreneurial Intention (SEI).

H5c

Sustainable Opportunity Recognition (SOR) mediates the positive relationship between Sustainable Entrepreneurial Education (SEE) and Green Creativity (GC).

The Moderating Role of Generative AI Literacy for Learning (GAIL)

GAIL can bolster the impact of Sustainable Entrepreneurial Education (SEE) by enabling learners to adeptly use AI-based tools for acquiring knowledge, generating ideas, and making decisions sustainably. According to the human capital theory and the technological acceptance perspective, people with higher levels of AI literacy will be better able to absorb information, think creatively, and assess opportunities, making it easier for them to apply their academic knowledge to entrepreneurial endeavors. Even though sustainable entrepreneurial education equips people with the knowledge and motivation to build sustainable ventures, generative AI literacy empowers them to apply the knowledge, innovate and adapt to the problems. Therefore, it is expected that learners who are more educated in AI literacy will benefit more from sustainable entrepreneurial education and have higher sustainable entrepreneurial intentions. Therefore, this study proposes that GAIL positively moderates the relationship between SEE and SEI.

H6

Generative AI Literacy for Learning significantly moderates the relationship between Sustainable Entrepreneurial Education and Sustainable Entrepreneurial Intention.

Sustainable Entrepreneurial Education (SEE) equips learners with the knowledge, competencies, and sustainability-oriented mindset needed to identify opportunities addressing environmental and social challenges (Ploum et al., 2018; Lackéus, 2020). However, opportunity recognition alone may not generate entrepreneurial intentions unless opportunities are transformed into innovative and environmentally responsible ideas. Green Creativity (GC) facilitates this transformation by enabling individuals to develop novel solutions to sustainability challenges (Amabile, 1996; Chen & Chang, 2013). Opportunity recognition can stimulate creativity by encouraging new approaches to sustainability-related problems (Ardichvili et al., 2003; Shane & Venkataraman, 2000). Green creativity further strengthens confidence in developing sustainable business solutions, thereby enhancing Sustainable Entrepreneurial Intention (SEI) (Chen & Chang, 2013; Hu et al., 2018). Thus, GC is expected to mediate the relationship between SOR and SEI. Similarly, SEE may indirectly influence GC through SOR. Together, SOR and GC represent a sequential mechanism through which SEE can enhance SEI, consistent with entrepreneurship literature emphasizing opportunity identification and creative idea generation as complementary processes (Baron, 2006; Krueger, 2009). Therefore, the following hypothesis is proposed:

H7

Generative AI Literacy for Learning positively moderates the relationship between Green Creativity and Sustainable Entrepreneurial Intention, such that the relationship is stronger when students possess higher levels of Generative AI Literacy for Learning.

Research Framework

Methodology

Demography

Table 1
Demographic Profile

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	218	53.6
	Female	189	46.4
Age (Years)	18–20	76	18.7
	21–23	214	52.6
	24–26	96	23.6
	Above 26	21	5.2
Academic Level	Undergraduate	223	54.8
	Master's	132	32.4
	PhD	52	12.8
Field of Study	Social Sciences	84	20.6
	Engineering & Technology	97	23.8
	Natural Sciences	46	11.3
	Business & Management	148	36.4
	Other	32	7.9
Type of University	Public	261	64.1
	Private	146	35.9
Completed Entrepreneurship Course	Yes	248	60.9
	No	159	39.1

Demographic Profile of Respondents

Table 1 shows the demography of the Higher Education Institutions (HEIs) students (N = 407). The sample included 218 males (53.6%) and 189 females (46.4%). Most respondents were aged 21–23 years (52.6%), followed by 24–26 years (23.6%), 18–20 years (18.7%), and over 26 years (5.2%). The majority of the undergraduate students (54.8%) were followed by master's students (32.4%) and doctoral students (12.8%). The fields of participation were varied with the largest number (36.4%) coming from business and management, followed by engineering and technology (23.8%), social sciences (20.6%),

natural sciences (11.3%), and other (7.9%). The majority of the respondents enrolled in public universities (64.1%), and 35.9% were enrolled in private universities. Further, 60.9% had attended at least one entrepreneurship-related course before. In general, the sample was relatively diversified in terms of gender, age, academic level, discipline and institution, and could represent a good sample for the study of sustainable entrepreneurship among university students.

3.1 Research Design, Population, Unit of Analysis

In this study, researchers adopted a quantitative and cross-sectional research design to examine the relationship between Sustainable Entrepreneurship Education, Sustainable Opportunity Recognition, Green Creativity, Generative AI Literacy for Learning, and Sustainable Entrepreneurial Intention of the University students of Punjab, Pakistan. A quantitative approach was considered appropriate because it enables the evaluation of the hypothesized relationships in the current empirical study by statistical data analysis and testing the hypothesis by applying structural equation modeling analysis. Higher Education Institutions (HEIs) enrolled students in public and private universities all over the province of Punjab were targeted. Universities are significant in building entrepreneurial knowledge, awareness and innovation capacities in formal entrepreneurial education. The unit of analysis was the individual student because they are the first beneficiaries of sustainable entrepreneurship education and the final decision-makers regarding future entrepreneurial careers.

Sampling Technique

This study used a purposive sampling technique and was conducted in three phases. In the first stage, HEIs that teach entrepreneurship courses were identified, both public and private. The second stage involved purposive sampling of students with knowledge about entrepreneurship, sustainability, innovation, or business education. In the chosen institutions, the respondents were approached depending on their accessibility and willingness to participate. The process enabled the study to reach subjects that were relevant to the research situation and responses from various academic disciplines and types of institutions. Such a method is frequently used in higher education and entrepreneurship research where the number of population members is too large to achieve a complete sampling frame, and members of the population must have relevant knowledge to give informed evaluations (Etikan et al., 2016).

Sample size

The a priori power analysis was carried out using the G*Power 3.1.9.7 software. With the most complex endogenous construct, the minimum sample size required was 119, which corresponds to a medium effect size ($f^2 = 0.15$), a significance level of 0.05, and a statistical power of 0.95. The final sample comprised valid answers which met or exceeded the required number of answers (150), which was considered adequate for testing the measurement model, structural relationships, serial mediation and the moderation effects using PLS-SEM.

3.3 Data Collection Procedure

The study protocol was approved by the Institutional Review Board of the University of Gujrat under the approval number UOG/ORIC/2026/274. The research was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki, particularly respect for persons, beneficence, and justice. The research was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki, particularly respect for persons, beneficence, and justice. Informed consent was obtained from all participants before their participation in the study. Structured self-administered questionnaires were used to collect the data from the students of public and private higher education institutes of Punjab, Pakistan. To ensure content and face validity, the questionnaire was pretested with academic experts prior to the main survey. They suggested some minor adjustments, which were made. Later, the completed questionnaire was distributed to the students, first by mail (Google Forms) and later in person to maximise the number of respondents and diversify the sample. All participation was voluntary, and the respondents were informed of the academic objective of the study. Their responses were assured that they would be confidential, anonymous and for research purposes only. Common method bias was kept to a minimum by asking participants to provide sincere responses to the items and by not gathering any personally identifiable information. The data collection took place in March-April 2026, and 440 questionnaires were distributed. Following screening for missing data, missing responses, and response inconsistencies, 407 questionnaires were usable for further analysis, using SmartPLS 4.

Measurement of constructs

All constructs included in this study were measured using previously validated instruments adopted from established studies to ensure content validity and measurement reliability. The questionnaire contained five latent constructs: Sustainable Entrepreneurship Education (SEE), Sustainable Opportunity Recognition (SOR), Green Creativity (GC), Generative AI Literacy for Learning (GAIL), and Sustainable Entrepreneurial Intention (SEI). The five-point Likert scales, ranging from 1 = strongly disagree to 5 = strongly agree, were used to measure the responses, as this scale is more sensitive to responses and is recommended in behavioural and entrepreneurship research (Hair et al., 2022). The measurement scales of Sustainable Entrepreneurship Education were adopted from Turker and Selcuk 2009 and Agu 2021 which were used to measure students' perceptions of sustainable entrepreneurial education. The validated scale developed by Kuckertz et al. (2017) to measure the ability to recognise entrepreneurial opportunities was used to assess Sustainable Opportunity Recognition. The items from Barczak et al. (2010) and Rego et al. (2007) that measured respondents' capacity to generate creative and eco-friendly ideas were used to assess green creativity. The assessment of Generative AI Literacy for Learning was conducted by employing the GenAI-LLs developed by Gümüş and Kara (2025) with the purpose of measuring students' effective and responsible use of generative AI in learning. Lastly, Sustainable Entrepreneurial Intention was assessed on the scale suggested by Yasir et al. (2021), which quantifies students' intentions to start businesses that add economic, social, and environmental value. Some minor changes at the contextual level were made for clarity, to enhance the measure's fit with the aims of the current study, and to ensure the original conceptual meaning of each measure.

Common Method Bias

Full collinearity variance inflation factor (VIF) was used to check for common method bias. Kock (2015) stated that VIF values less than 3.3 do not present any threat to the validity of results due to common method bias. The recommended value for the variance inflation factor is below 5; in the present study, it ranges from 1.000 to 1.330. Thus, the findings indicate that there was not a big issue of common method bias in this study.

Table 2
Variance Inflation Factor

Constructs	VIF
GAIL -> SEI	1.034
GAIL x GC -> SEI	1.303
GAIL x SEE -> SEI	1.330
GC -> SEI	1.228
SEE -> SEI	1.250
SEE -> SOR	1.000
SOR -> GC	1.000

Results

Measurement Model

The measurement model (Fig. 2) was first evaluated to confirm the reliability and validity of the constructs.

Table 2: **Outer Model Evaluation**

The results of the measurement model assessment (Table 3) show that the constructs of the study have satisfactory reliability and convergent validity. All the factor loadings are greater than 0.70, which is considered the minimum acceptable figure for indicator reliability (Fornell & Larcker, 1981; Hairet al., 2019).

Table 3
Indicator Loading

Construct	Items	Values	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Generative AI literacy for Learning	**GAIL1**	0.814	0.938	0.949	0.947	0.667
	GAIL2	0.792				
	GAIL3	0.863				
	GAIL4	0.816				
	GAIL5	0.847				
	GAIL6	0.789				
	GAIL7	0.818				
	GAIL8	0.807				
	GAIL9	0.801				
Green Creativity	**GC1**	0.857	0.921	0.923	0.938	0.718
	GC2	0.851				
	GC3	0.889				
	GC4	0.822				
	GC5	0.820				
	GC6	0.842				
Sustainable Entrepreneurial Education	**SEE1**	0.848	0.913	0.913	0.932	0.696
	SEE2	0.847				
	SEE3	0.847				
	SEE4	0.818				
	SEE5	0.841				
	SEE6	0.803				
Sustainable Entrepreneurial Intention	**SEI1**	0.840	0.915	0.917	0.934	0.703
	SEI2	0.837				
	SEI3	0.876				
	SEI4	0.791				

Construct	Items	Values	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
	SEI5	0.830				
	SEI6	0.856				
Sustainable Opportunity Recognition	**SOR1**	0.874	0.907	0.910	0.931	0.730
	SOR2	0.851				
	SOR3	0.891				
	SOR4	0.805				
	SOR5	0.850				
	GAIL x GC	1.000				
	GAIL x SEE	1.000				

The internal consistency is high, with values of Cronbach's alpha ranging from 0.907 to 0.938 and composite reliability (rho_a and rho_c) for all constructs higher than 0.90. Additionally, the Average Variance Extracted (AVE) values range from 0.667 to 0.730, which is above the minimum accepted threshold of 0.50, thus satisfying the convergent validity test. Specifically, Generative AI Literacy for Learning (GAIL) has high reliability (α = 0.938; rho_c = 0.947) and an AVE of 0.667. Green Creativity (GC) has good reliability (α = 0.921; rho_c = 0.938) and an AVE = 0.718. The internal consistency of Sustainable Entrepreneurial Education (SEE) is satisfactory, with an alpha of 0.913, a rho_c of 0.932, and an AVE value of 0.696. In the same way, Sustainable Entrepreneurial Intention (SEI) and Sustainable Opportunity Recognition (SOR) demonstrate excellent reliability and validity, since the AVE values are 0.703 and 0.730, respectively. The findings in general support that all measurement constructs have high reliability and acceptable convergent validity, so it is suitable for further structural model analysis.

Discriminant Validity

Construct validity is established by discriminant validity, which ascertains that constructs are conceptually differentiated and authentically dissimilar. In this study, the HTMT ratio is applied, given its high criterion in PLS-SEM. A value less than 0.85 (or 0.90 for less stringent conditions) represents good discriminant validity and low conceptual similarity between constructs (Henseler et al., 2015; Hair et al., 2019; Hair et al., 2022).

Table 4
Heterotrait–Monotrait (HTMT) Ratio

GAIL	GAIL	GC	SEE	SEI	SOR	GAIL x GC	GAIL x SEE
GC	0.099						
SEE	0.148	0.461					
SEI	0.206	0.612	0.430				
SOR	0.141	0.629	0.638	0.473			
GAIL x GC	0.029	0.057	0.035	0.381	0.042		
GAIL x SEE	0.122	0.027	0.105	0.337	0.052	0.477	

The Heterotrait–Monotrait (HTMT) ratio (Table 4) results confirm discriminant validity among all constructs. Each concept is empirically different from the others since all HTMT values are below the suggested cutoff of 0.85. The highest HTMT value is observed between SEE and SOR (0.638), followed by GC and SOR (0.629) and GC and SEI (0.612), which remain well below the acceptable limit. The interaction constructs (GAIL × GC and GAIL × SEE) also show low HTMT values, confirming their distinctiveness. Overall, the findings establish adequate discriminant validity and support the suitability of the measurement model for further structural analysis (Hair et al., 2022; Henseler et al., 2015).

Structural Model

The structural model (Fig. 3) was subsequently assessed to examine the hypothesised relationships among the constructs.

Path Coefficient

Path coefficients indicate the magnitude of relationships between constructs in the structural model, representing the impact of one variable on the other (Hair et al., 2019). There is relevance, based on the t-value and p-value, which indicates whether the hypothesised relationships are statistically supported or not (Hair et al., 2019).

Table 5
Path Coefficient Results

Hypothesis	Paths	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values	Result
H1	**SEE -> SEI**	0.206	0.205	0.039	5.290	0.000	Supported
H2	**SEE -> SOR**	0.581	0.582	0.031	18.780	0.000	Supported
H3	**SOR -> GC**	0.578	0.578	0.035	16.681	0.000	Supported
H4	**GC -> SEI**	0.446	0.447	0.037	12.173	0.000	Supported
H6	**GAIL x SEE -> SEI**	0.253	0.252	0.040	6.386	0.000	Supported
H7	**GAIL x GC -> SEI**	0.222	0.222	0.041	5.484	0.000	Supported

The results of the specific indirect effects can be seen in Table 5. As the results of the mediation analysis test, all indirect effects (H5a – H5c) are supported. The results show that SOR mediates the relationship between GC and SEI ($\beta = 0.258$, $t = 9.654$, $p < 0.001$). Moreover, SEE indirectly influences SEI through sequential mediation by SOR and GC ($\beta = 0.150$, $t = 8.167$, $p < 0.001$). Furthermore, SEE significantly influences GC through SOR mediation ($\beta = 0.336$, $t = 11.172$, $p < 0.001$). The overall findings are consistent with the significance of the mediating role of SOR and GC in understanding how sustainable entrepreneurial education influences sustainable entrepreneurial intention.

Specific Indirect Effect

The specific indirect effects were examined to assess mediation and moderation relationships within the model (Hair et al., 2019).

Table 6
Specific Indirect Effect

Hypothesis	Path	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values	Result
H5a	**SOR -> GC -> SEI**	0.258	0.258	0.027	9.654	0.000	Supported
H5b	**SEE -> SOR -> GC -> SEI**	0.150	0.151	0.018	8.167	0.000	Supported
H5c	**SEE -> SOR -> GC**	0.336	0.337	0.030	11.172	0.000	Supported

The results of the specific indirect effects can be seen in Table 6. The mediation analysis results confirm that all proposed indirect effects (H5a–H5c) are supported. The results show that SOR mediates the relationship between GC and SEI ($\beta = 0.258$, $t = 9.654$, $p < 0.001$). Additionally, SEE has a significant indirect effect on SEI through the sequential mediation of SOR and GC ($\beta = 0.150$, $t = 8.167$, $p < 0.001$). Furthermore, SEE significantly influences GC through SOR mediation ($\beta = 0.336$, $t = 11.172$, $p < 0.001$). Overall, the findings confirm the important mediating roles of SOR and GC in explaining how sustainable entrepreneurial education enhances sustainable entrepreneurial intention.

Total Effect

The total effects are important because they include the direct effect of one construct on another and the indirect effect(s) mediated by other constructs, which provides a complete picture of the relationships in the model (Hair et al., 2019). They are needed to understand the true nature of impact and to avoid underestimation of relationships through mediators (Hair et al., 2019).

Table 7
Total Effect

Paths	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
GAIL -> SEI	0.162	0.166	0.040	4.028	0.000
GAIL x GC -> SEI	0.222	0.222	0.041	5.484	0.000
GAIL x SEE -> SEI	0.253	0.252	0.040	6.386	0.000
GC -> SEI	0.446	0.447	0.037	12.173	0.000
SEE -> GC	0.336	0.337	0.030	11.172	0.000
SEE -> SEI	0.355	0.356	0.038	9.271	0.000
SEE -> SOR	0.581	0.582	0.031	18.780	0.000
SOR -> GC	0.578	0.578	0.035	16.681	0.000
SOR -> SEI	0.258	0.258	0.027	9.654	0.000

The total effect results (Table 7) demonstrate that all hypothesised relationships are positive and statistically significant ($p < 0.001$). Sustainable Entrepreneurial Education (SEE) shows a strong positive effect on Sustainable Opportunity Recognition (SOR) ($\beta = 0.581$, $t = 18.780$) and Green Creativity (GC) ($\beta = 0.336$, $t = 11.172$), while SOR significantly enhances GC ($\beta = 0.578$, $t = 16.681$) and SEI ($\beta = 0.258$, $t = 9.654$). Green Creativity also positively influences Sustainable Entrepreneurial Intention ($\beta = 0.446$, $t = 12.173$). Moreover, Generative AI Literacy (GAIL) has a significant positive effect on SEI ($\beta = 0.162$, $t = 4.028$), and its interaction effects with GC ($\beta = 0.222$, $t = 5.484$) and SEE ($\beta = 0.253$, $t = 6.386$) significantly strengthen SEI. Overall, the findings confirm the substantial contribution of SEE, SOR, GC, and GAIL in explaining sustainable entrepreneurial intention.

Slope Analysis

The slope analysis is important because it identifies the changes in the relationship between the independent and dependent variables across different levels of a moderator (Aiken, 1991). The direction of the interaction effect is significant as well as the strength of the interaction effect; whether the relationship is stronger or weaker under other conditions, needs to be visualised and understood (Hair et al., 2019).

Figure 4 illustrates the moderating effect of Generative AI Literacy for Learning (GAIL) on the relationship between Green Creativity (GC) and Sustainable Entrepreneurial Intention (SEI). The interaction plot shows that the relationship between GC and SEI is positive at all levels of GAIL. However, the slope becomes increasingly steep as GAIL increases, with the strongest positive relationship observed at + 1

SD of GAIL and the weakest relationship at − 1 SD of GAIL. This indicates that higher Generative AI literacy strengthens the positive effect of Green Creativity on Sustainable Entrepreneurial Intention, confirming the proposed moderating role of GAIL.

The moderating role of Generative AI Literacy for Learning (GAIL) between Sustainable Entrepreneurial Education (SEE) and Sustainable Entrepreneurial Intention (SEI) is depicted in the diagram shown in Fig. 5. The interaction plot indicates that the effect of SEE on SEI differs at the various levels of GAIL. The relationship is strongly positive at higher levels of GAIL (+ 1 SD) and is indicated by the steepest slope. At the mean level of GAIL, SEE shows a positive correlation with SEI, but at lower levels of GAIL (− 1 SD), this correlation is slightly negative and weaker. The results of this study revealed that the positive relationship between Sustainable Entrepreneurial Education and Sustainable Entrepreneurial Intention was enhanced by increasing the level of Generative AI literacy, which is in line with the moderating role of the variable GAIL.

R-Square

R^2 indicates how good the structural model is, or how much of the variance in the dependent variables is explained by the independent variables (Hair et al., 2019). The stronger the R^2, the better the model is at predicting. Hair et al. (2019) claimed that R^2 of 0.25, 0.50, and 0.75 are weak, moderate, and strong, respectively.

Table 8
R-Square

GC	R-square	R-square adjusted
	0.334	**0.332**
SEI	0.527	0.521
SOR	0.338	0.336

As can be seen from the results of the R-squared (Table 8), the model explains a lot of the variation in the endogenous constructs. The model accounts for 33.4% of the variance in Green Creativity (GC), 52.7% of the variance in Sustainable Entrepreneurial Intention (SEI), and 33.8% of the variance in Sustainable Opportunity Recognition (SOR). The adjusted R-square values (0.332, 0.521, and 0.336) are very close to the initial values, making the model stable and having strong predictive explanatory ability. The results indicate that the structural model has medium predictive power, as the average value is 0.46.

Table 9
F Square

GAIL	GAIL	GC	SEE	SEI	SOR	GAIL x GC	GAIL x SEE
				0.054			
GC				0.343			
SEE				0.071	0.510		
SEI							
SOR		0.501					
GAIL x GC				0.079			
GAIL x SEE				0.103			

The effect size (f^2) results (Table 9) show that the effect of each exogenous construct on the endogenous variables is relative to the other constructs. Based on the recommended thresholds, Green Creativity (GC) has a moderate effect size ($f^2 = 0.343$); Sustainable Opportunity Recognition (SOR) has a large effect size ($f^2 = 0.501$). Sustainable Entrepreneurial Education (SEE) has a small effect on GAIL ($f^2 = 0.071$) and a large effect on SOR ($f^2 = 0.510$). The interaction effects between GAIL and GC ($f^2 = 0.079$) and between GAIL and SEE ($f^2 = 0.103$) suggest small effects. In general, the results indicate that SOR and SEE were the most significant variables in the structural model, while the moderating variables of GAIL accounted for some additional, lesser amount of the explanation.

Table 10
Q Square

GC	Q^2predict	RMSE	MAE
	0.169	**0.915**	**0.772**
SEI	0.303	0.838	0.697
SOR	0.332	0.821	0.675

The results of the Q^2predict (Table 10) show that the model has high predictive relevance for all endogenous constructs. All three Q^2predict values (Green Creativity (GC = 0.169), Sustainable Entrepreneurial Intention (SEI = 0.303), and Sustainable Opportunity Recognition (SOR = 0.332)) have values above zero, which are indicative of meaningful out-of-sample predictive power. The RMSE and MAE values also show good accuracy of the prediction. On a global scale, the model has a moderate predictive power to explain the GC, SEI, and SOR.

Model Fit

The model fit indices indicate how well the proposed model corresponds with the observed data (Hair et al., 2019). Fit indicators that are generally reported are SRMR, d_ULS, d_G, Chi-square, and NFI. Hair et al.

(2019) state that a value of SRMR below 0.08 can be considered an acceptable model fit, and an NFI value around 1 can be regarded as a better-fitting model.

Table 11
Model Fit

SRMR	Saturated model	Estimated model
	0.035	**0.043**
d_ULS	0.657	0.976
d_G	0.248	0.245
Chi-square	579.248	561.370
NFI	0.938	0.940

Model fit assessment (Table 11) shows that the fit between the proposed model and the observed data is good. Model fit is acceptable as the SRMR value of the saturated model (0.035) is below the recommended value of 0.08, as is that of the estimated model (0.043). The NFI values (0.938 and 0.940) also suggest a high fit value, which is higher than the recommended value of 0.90. Overall, the result shows that the structural model has satisfactory goodness of fit and is able to represent the data well.

5. Discussion

This study aims to examine the connections between Sustainable Entrepreneurship Education (SEE), Sustainable Opportunity Recognition (SOR), Green Creativity (GC), Generative AI Literacy for Learning (GAIL), and Sustainable Entrepreneurial Intention (SEI). The results are aligned with all the hypotheses put forward, as it is concluded that the development of sustainable entrepreneurial intention is a sequential process, where, in the first step, the opportunity recognition and green creativity of students are positively affected by sustainable entrepreneurial intention; and in the second step, AI literacy is found to increase the effect of green creativity on entrepreneurial intention. This study contributes to the body of knowledge by combining the educational, cognitive, and creative approaches together with the technological approaches in one package. The results revealed that there is a positive effect of Sustainable Entrepreneurship Education on Sustainable Opportunity Recognition, indicating that the inclusion of sustainability education can pave the way for entrepreneurial opportunities to address environmental and social problems. This result aligns with the Human Capital Theory, which holds that education should increase the capacity of an individual (Becker, 1964) and with previous findings that education influences the capacity to see opportunities (Nabi et al., 2017; Ploum et al., 2018). The results of the study also indicate that Sustainable Opportunity Recognition is a positive influence on Green Creativity. Students who are aware and are able to identify opportunities related to sustainability are likely to be able to come up with innovative and sustainable ideas. This finding is in line with a previous study, which showed that opportunity recognition can positively influence creativity through innovation, problem-solving, and exploring opportunities (Shane & Venkataraman, 2000; Tang et al., 2012). There

was a significant positive relationship between Green Creativity and Sustainable Entrepreneurial Intention, which is in accordance with the Theory of Planned Behaviour. Entrepreneurial intentions (Ajzen, 1991) are increased by students' ability to create innovative green solutions, making sustainable entrepreneurship more feasible and desirable in their eyes. This result also corroborates the previous studies, which have emphasised the role of creativity in entrepreneurial intention (Biraglia & Kadile, 2017; Chen & Chang, 2013). The other big finding is that Generative AI Literacy for Learning had a significant moderating effect. As AI literacy becomes more prevalent among students, they can more readily transform their green creative concepts into entrepreneurial intentions and use AI tools to gain insights into the market, generate business concepts, and assess sustainable opportunities. The discovery is important in highlighting the significance of AI literacy in digital human capital alongside entrepreneurial skills (Ng et al., 2021; Gümüş & Kara, 2025). Furthermore, mediation analysis shows that Sustainable Opportunity Recognition stands between Sustainable Entrepreneurship Education and Green Creativity, as well as between Sustainable Entrepreneurial Intention and Green Creativity. Furthermore, it was found that Sustainable Entrepreneurship Education has a sequential mediating effect between itself and Sustainable Entrepreneurial Intention, which is the mediating effect of Sustainable Opportunity Recognition and Green Creativity. The findings suggest that the students' intentions are influenced by entrepreneurship education; first, it enhances students' ability to identify sustainability opportunities, and second, it enhances their ability to build green creative skills. In general, the results validate the complementary association of the Human Capital Theory and the Theory of Planned Behaviour. The education-AI literacy relationship is captured by Human Capital Theory, and the entrepreneurial capabilities-entrepreneurial intention relationship is captured by the Theory of Planned Behaviour. The overall results show that sustainable education, opportunity recognition, green creativity, and AI literacy in university education are a promising approach to increasing students' sustainable entrepreneurial intention.

7. Theoretical Implications

This study is an exploratory effort to combine both Human Capital Theory (HCT) and Theory of Planned Behaviour (TPB) into one framework that explains the relationship between Sustainable Entrepreneurship Education (SEE) and Sustainable Entrepreneurial Intention (SEI) in the literature of sustainable entrepreneurship. In contrast to previous studies that focused primarily on direct relationships, the present study demonstrates that Sustainable Opportunity Recognition (SOR) and Green Creativity (GC) are mediated sequentially, and hence can be used to provide deeper insight into underlying cognitive mechanisms. In addition, the study extends the existing knowledge of entrepreneurship by introducing the concept of Generative AI Literacy for Learning (GAIL) as a mediator. This concept highlights the role of AI-related competencies in shaping sustainable entrepreneurial practices.

8. Practical Implications

The findings are applicable to universities, teachers, and policymakers in their efforts to promote sustainable entrepreneurship. Higher education institutions should incorporate entrepreneurship education that includes sustainability components and activities supporting opportunity recognition, green creativity, and responsible AI usage into the curriculum. Experiential learning, innovation projects, business simulations, and entrepreneurial training with the support of AI can complement students' abilities to identify sustainability issues and develop innovative business solutions. Through these programs, graduates can be better prepared to start their own sustainable enterprise and to contribute to sustainable economic, social, and environmental development in the longer term.

Conclusion

The present study examined the mediation effect of Sustainable Entrepreneurial Intention (SEI) through Sustainable Opportunity Recognition (SOR) and Green Creativity (GC), and the moderation effect of Generative AI Literacy for Learning (GAIL) in the relationship between SEE and SEI. Based on Human Capital Theory and the Theory of Planned Behaviour, the results indicate that sustainable entrepreneurship education can stimulate entrepreneurial intention, as well as opportunity recognition skills and green creativity of students. In addition, the application of Generative AI in entrepreneurship education has a positive impact on sustainable entrepreneurial intention, which further demonstrates the significance of the application of Generative AI in entrepreneurship education. The present study contributes to the literature on sustainable entrepreneurship through a multi-instrument approach that validates an integrated framework for sustainable entrepreneurship that integrates the concepts of sustainable education, opportunity recognition, creativity, and AI literacy. The results indicate that universities should make sustainability-related learning, creative problem-solving, and AI skills an integral part of entrepreneurship education in order to equip students with the skills they need to create innovative and sustainable ventures. This can foster the next generation of entrepreneurs who can create economic, environmental, and social value.

9. Limitations

This study has some limitations, which are mentioned here. First, because of the cross-sectional type of research study being used, causal relations between the variables in the study cannot be drawn. More evidence for the development of entrepreneurial intention over time might be obtained by the use of continuous and longitudinal designs. Secondly, the findings could not be generalised to other regions, countries, and/or educational settings because the data were drawn from students studying at the university in Punjab, Pakistan. Thirdly, the selected antecedents of sustainable entrepreneurial intention were studied, so other factors such as institutional support, entrepreneurial ecosystem, environmental values and digital competencies can also play an important role in the entrepreneurial intention of students and can be further examined in the future.

10. Future Research Directions

Future studies should use longitudinal or experimental studies to confirm the causal relationships found in this study. The generalizability of the proposed model would be improved by comparative studies in other countries, learning systems, and cultural contexts. Other traits like entrepreneurial self-efficacy, institutional support, sustainability orientation, or digital innovation capacities can further enrich the framework. Furthermore, other constructs related to AI, such as AI adoption, AI readiness, or AI competency, could be investigated in further research to better understand the process of developing AI in sustainable entrepreneurship education and entrepreneurial intention.

Declarations

Ethical Approval

The study protocol was approved by the Institutional Review Board of the University of Gujrat under the approval number UOG/ORIC/2026/274. The research was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki, particularly respect for persons, beneficence, and justice.

Consent to participate

Informed consent was obtained from all participants before their participation in the study.

Consent for publication

Not applicable

Competing interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Author Contribution

Saqib Farid Sheikh: Conceptualization, methodology, and original draft preparation.Dr. Mohamad Zulkifli Bin Abdul Rahim: Supervision, critical review, and intellectual guidance.Dr. Hamid Mahmood: Literature review, validation, and manuscript revision.Muhammad Mohsin: Data analysis, interpretation, and manuscript preparation.Dr. Muhammad Aftab: Investigation, critical review, and editing.Lilian Anthonysamy (Corresponding Author): Manuscript review, editing, coordination, and correspondence.

Data Availability

Data will be available when required by the Journal.

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Figures

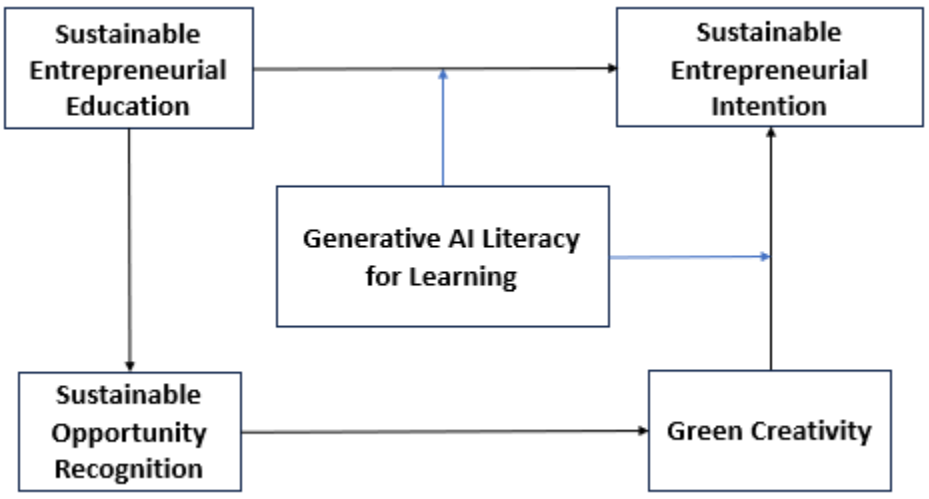


Figure 1

Research Framework

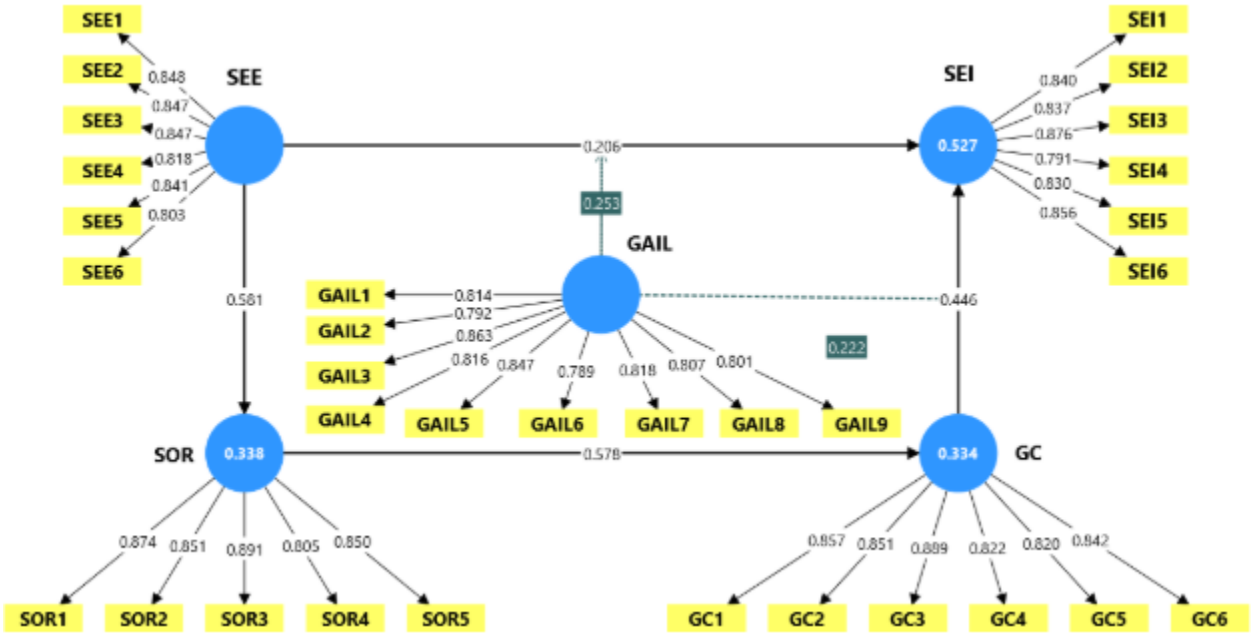


Figure 2

Measurement Model

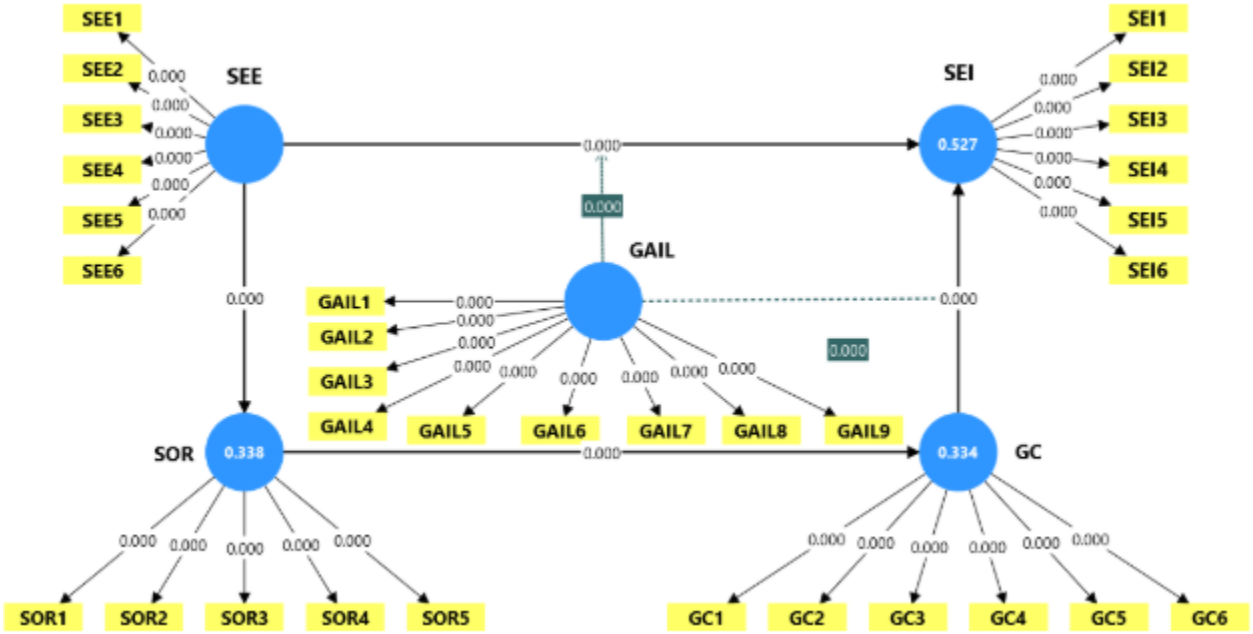


Figure 3

Structural Model

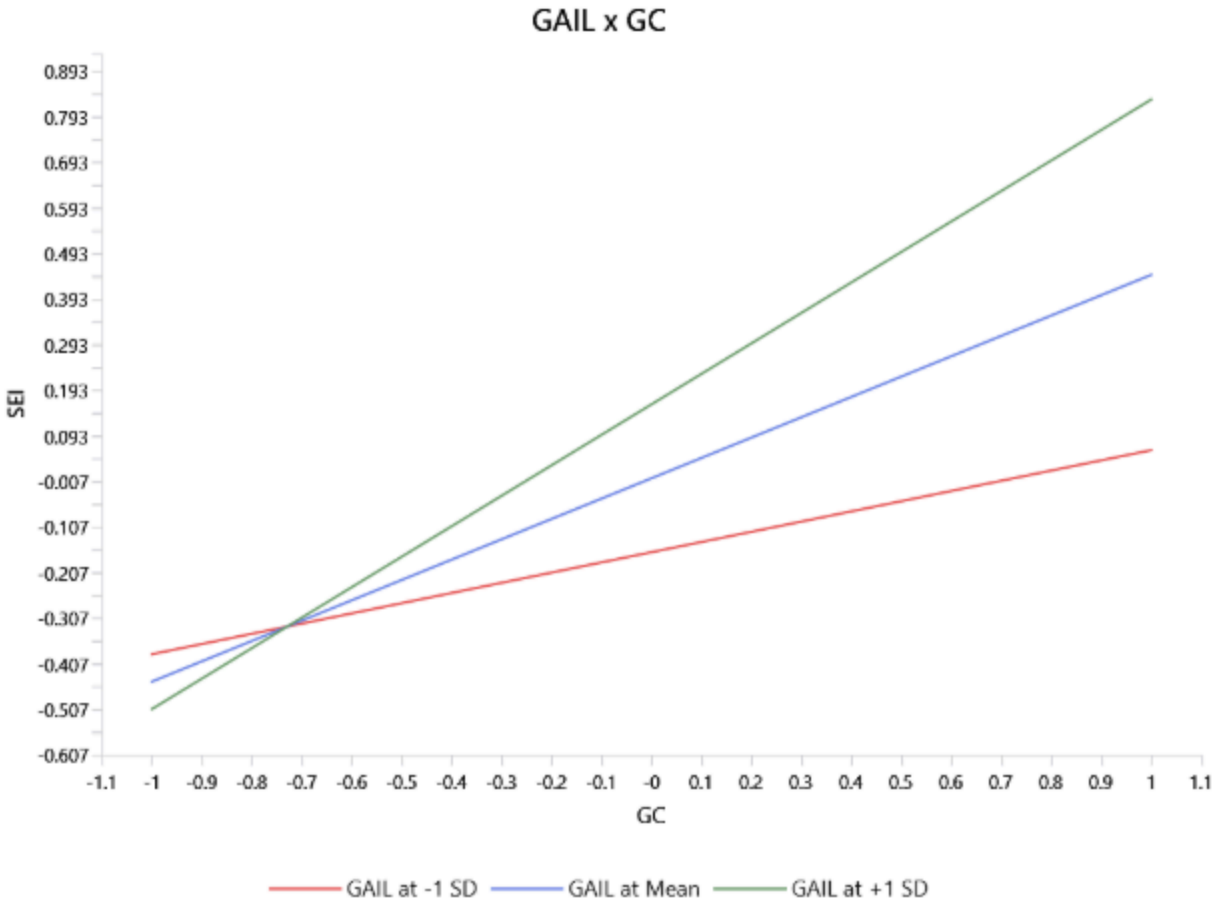


Figure 4

The Author's work using SmartPLS

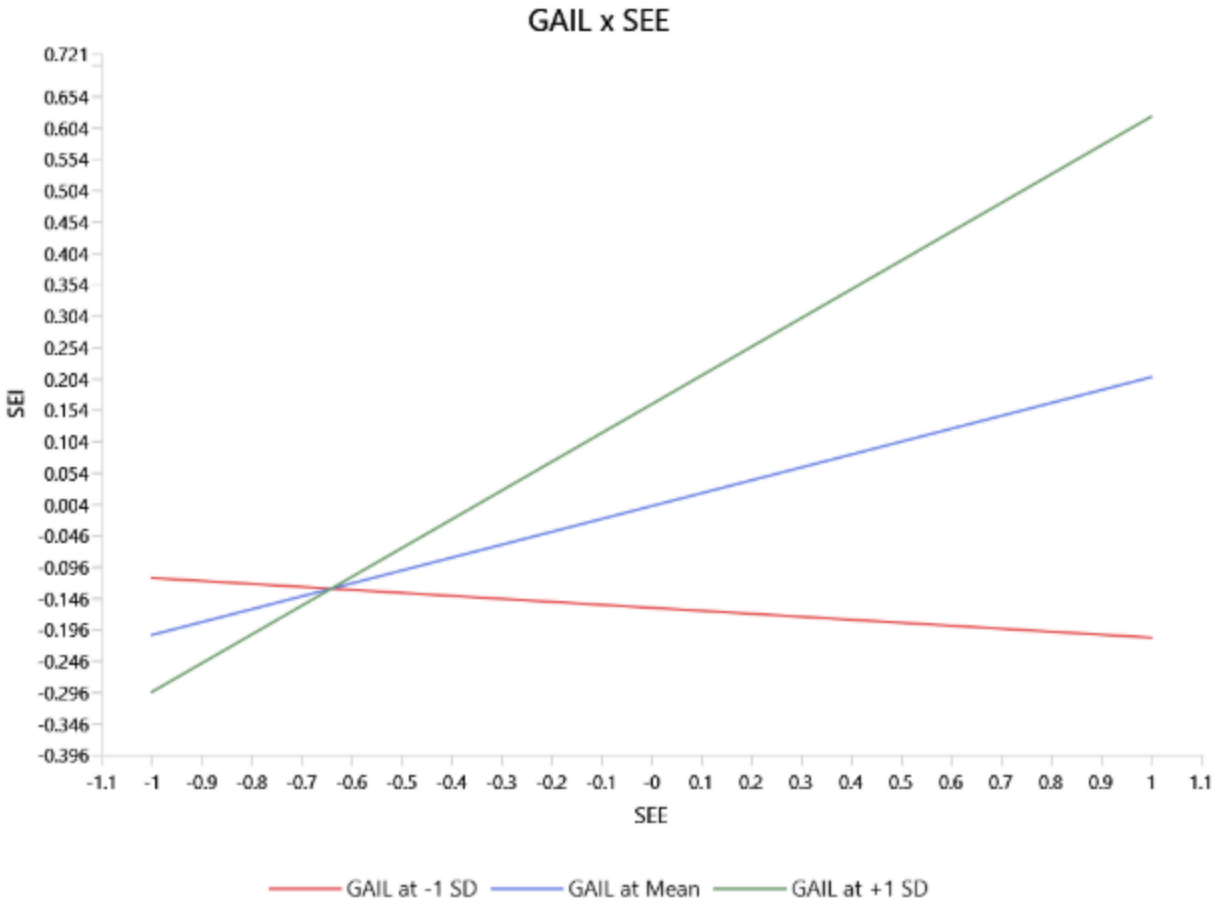


Figure 5

The Author's work using SmartPLS