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The Nexus of Green Supplier Integration for Green Innovation in Manufacturing Firms

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Abstract

In response to the mounting emphasis on sustainability, particularly in the context of environmental impact reduction and the pursuit of eco-friendly innovations, this research delves into the relationship between green supplier integration and green innovation. The study places specific emphasis on the moderating role played by green information systems. To explore these dynamics, an online questionnaire survey was carried out within ISO 14001-certified manufacturing firms in Malaysia. A total of 275 responses were collected, and the data underwent thorough analysis via structural equation modeling using SmartPLS 4.0

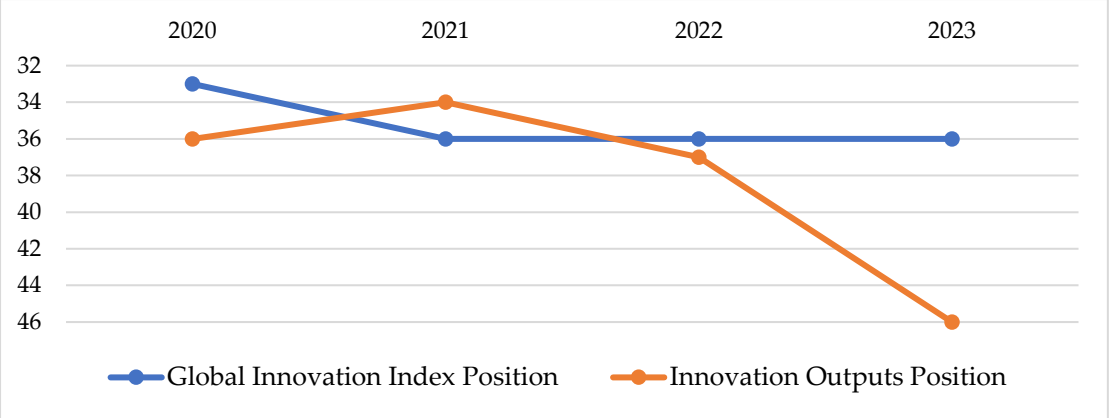
software. The findings underscore the significant influence of green supplier integration in shaping green innovation, revealing that the interaction between these two factors is modulated by the presence of green information systems. By offering this insight, the study equips manufacturing companies with valuable awareness regarding the pivotal elements that underpin green innovation practices.
Keywords: Green Supplier Integration, Green Information System, Green Innovation

Introduction

Malaysia occupies a pivotal role as a supply chain nucleus, particularly for electronics and electrical products. A multitude of multinational corporations have chosen Malaysia as a strategic base, capitalizing on its advantageous geographical location and well-established infrastructure (Yadegaridehkordi et al., 2023). The manufacturing sector, a cornerstone of technological progress and innovation, is instrumental in propelling Malaysia's global standing. Through dedicated research and development efforts, companies produce high-value goods, bolstering the nation's competitiveness and international recognition. Consequently, Malaysia's manufacturing industry stands as a linchpin of its economy, driving notable economic expansion, job generation, technological strides, and global trade facilitation. This sector remains central to Malaysia's economic evolution, steadfastly adapting to emergent trends and technologies (Ibikunle et al., 2023).

Regrettably, green innovation within Malaysia's manufacturing sector has recently displayed lackluster performance (Ogiemwonyi et al., 2023). Evaluating the extent of green innovation typically entails a tailored combination of indicators, customized to suit the study's objectives and specific context. Data sources encompass a wide spectrum, spanning industry reports, government statistics, corporate disclosures, and environmental evaluations. The Eco-Innovation Index (EII), for instance, scrutinizes industries and companies' environmental performance, weighing variables like resource efficiency, emissions mitigation, and the development of eco-friendly products (Chien, 2023). On a broader scale, the Global Innovation Index (GII) gauges worldwide innovation trends amid a landscape rife with economic uncertainties (Pham et al., 2023). Comprising approximately 80 indicators, categorized as either innovation inputs or outputs, the Global Innovation Index ranks Malaysia's economic innovation capacity. Notably, Malaysia's position in the Global Innovation Index has dipped from 33rd in 2020 to 36th in 2023, with a more pronounced decline in innovation outputs as it plummeted from 36th to 46th. Within this framework, Malaysia ranks at its lowest in infrastructure (51st), creative outputs (47th), and knowledge and technology outputs (37th). Furthermore, other innovation outputs, like global brand value, have also diminished, dwindling from 58 billion USD in 2020 to 47 billion USD in 2023 (WIPO, 2022).

Table 1
Malaysia Global Innovation Index Ranking (2020-2023)



Despite the global clarion call for sustainability and environmental stewardship, Malaysia's manufacturing sector grapples with formidable obstacles in its journey towards eco-conscious practices. This underperformance can be attributed to a dearth of collaboration between suppliers, inadequate information technology infrastructure, and a deficiency in all-encompassing environmental policies (Yusr et al., 2020). Furthermore, the absence of substantial backing and incentives for the development of green technologies, coupled with a hesitancy to invest in sustainable solutions, presents a substantial hindrance to progress. Regulatory frameworks designed to foster eco-friendly innovation often suffer from inconsistent implementation (Wungkana et al., 2023). Bridging the chasm between recognizing the significance of green innovation and executing it effectively necessitates a unified endeavor to amplify green supplier integration and harness the potential of green information systems. This pivotal stride holds the key to steering the industry toward a future characterized by sustainability and environmental conscientiousness.

Within the complex landscape of challenges and opportunities, this study revolves around a central research inquiry: "What factors drive green innovation in Malaysian manufacturing firms?" To address this question, the present research delves into the ways green supplier integration impacts and bolsters green innovation, encompassing the development of environmentally friendly products, processes, and technologies. Importantly, this relationship doesn't stand alone; the study introduces the moderating variable, green information systems, designed to facilitate the acquisition, dissemination, and utilization of environmental data within organizations. In essence, the research investigates how the presence of effective green information systems can either amplify or temper the connection between green supplier integration and green innovation. Through the pursuit of this research goal, the study aspires to furnish valuable insights and recommendations for policymakers, industry leaders, and stakeholders engaged in Malaysia's dynamic manufacturing landscape.

Literature Review and Hypotheses Development

Green supplier integration

Green supplier integration involves seamlessly incorporating environmentally sustainable practices into a company's supply chain management, fostering a positive correlation with green innovation when effectively implemented (Akhtar et al., 2023). This synergy is showcased in collaborations with eco-conscious suppliers, unleashing a wealth of expertise in sustainable technologies and practices, and igniting innovation within the organization. Likewise, environmentally committed suppliers often zero in on resource efficiency and waste reduction. Integrating these practices into the supply chain translates to

lowered resource consumption and costs, freeing up resources that can be channeled toward innovation (Lee, 2023). Furthermore, green supplier integration fosters transparency and visibility across the supply chain, granting companies a keen awareness of areas requiring eco-conscious innovation and enabling them to monitor the environmental impact of their products (C. Zhou et al., 2023). Additionally, green supplier integration serves as a catalyst for collaborative research and development initiatives, where companies and their sustainability-focused suppliers join forces to nurture eco-friendly solutions and innovations, benefiting from shared resources and knowledge (Dong et al., 2023). Furthermore, many regions have strict environmental regulations. By integrating green suppliers, a company can ensure compliance with these regulations, reducing the risk of non-compliance-related issues that could hinder innovation efforts (Awan et al., 2019). Similarly, green supplier integration aligns with increasing consumer demand for eco-friendly products, enabling organizations to improve their market position and revenue, which can then be reinvested in further green innovation (Fontoura & Coelho, 2022). To synthesize, green supplier integration fuels green innovation by granting access to expertise, fostering collaboration, amplifying resource efficiency, amplifying supply chain transparency, meeting consumer demand, and endorsing the use of sustainable materials and processes. Collectively, these benefits create an environment where the cultivation of innovative, environmentally friendly products and processes is not just welcomed but facilitated. The research postulates that as firm green supplier integration activities ascend, they will herald superior green innovation. Consequently, the first hypothesis is presented:
Hypothesis 1: Green supplier integration is positively related to green innovation.

Green Information System

The relationship between green supplier integration and green innovation undergoes significant and constructive moderation through the presence and efficacy of a green information system. This moderating influence manifests in several pivotal ways. Firstly, a green information system performs the role of a curator, aggregating environmental data from suppliers, and ensuring the organization has prompt access to pertinent environmental information. It goes a step further by enabling a comprehensive grasp of the environmental footprint across the entire supply chain (Akhtar et al., 2023). Secondly, the efficiency of a green information system lies in its capacity to facilitate the exchange of environmental data and knowledge between the organization and its suppliers. This sharing of insights nourishes a culture of collaboration and collective troubleshooting, a linchpin in fostering innovation in sustainable practices (Esfahbodi et al., 2023). Thirdly, green information systems offer invaluable feedback and reporting mechanisms, appraising the environmental performance of suppliers. Such feedback mechanisms prove instrumental in motivating suppliers to adhere to eco-friendly practices, ultimately buttressing green innovation (Xu et al., 2023). Fourthly, these systems are often equipped with analytical tools that can pinpoint patterns, trends, and openings for enhanced environmental performance. These insights are the compass guiding the development of pioneering solutions (He et al., 2023). Fifth, green information systems serve as diligent watchdogs for compliance with environmental regulations, ensuring that all parties operate squarely within legal boundaries, evading disruptions stemming from non-compliance that might impede innovation endeavors (Qu & Liu, 2022). Finally, the wealth of data and insights furnished by green information system forms the bedrock for judicious decisions regarding green supplier integration and innovation. This indispensable support empowers organizations to effectively prioritize their sustainability initiatives (Dao et al.,

2011). In essence, a green information system assumes the dual role of a regulator and an enhancer in the relationship between green supplier integration and green innovation. It lays the foundation for collaboration, transparency, and data-informed decision-making, thereby streamlining the assimilation of eco-conscious practices and propelling innovation throughout the supply chain and the organization at large. Thus, the following hypothesis was posited:

Hypothesis 2: The relationship between green supplier integration and green innovation is moderated by green information system.

Methodology

To achieve its research objectives, this study employed quantitative research methods to meticulously analyze data extracted from a cross-section of ISO14001-certified Malaysian manufacturing companies deeply entrenched in green initiatives. A quantitative approach, including a survey questionnaire, was harnessed to acilitated robust statistical analyses and hypothesis testing, thereby enabling the systematic exploration of the research objectives. Survey questionnaire also afforded a profound understanding of respondents' perceptions, attitudes, and practices, rendering it an ideal choice for investigating factors entwined with green innovation (Saunders et al., 2003).

Owners/managers were selected as the respondents for the online survey questionnaires due to their pivotal roles within the organizational framework. Their prominence lies in their decision-making authority, capacity to provide strategic insights, responsibility for performance outcomes, access to critical information, deep understanding of organizational culture, embodiment of leadership and vision, and overarching accountability for the organization's triumph (Singh & Mahmood, 2014). The inclusion of these key figures yields a comprehensive and influential perspective that bears immense value for research endeavors, informed decision-making processes, and the pursuit of organizational enhancement.

Leveraging pre-existing studies as a foundation for constructing a survey questionnaire is a pragmatic approach lauded for its efficiency in saving time, bolstering credibility, and relying on the proven efficacy of established items (Saunders et al., 2003). This method not only fosters consistency in research but also augments the quality of data collected, rendering it particularly advantageous for cross-cultural and comparative studies. Consequently, in this research, a five-item scale was adapted to measure green supplier integration (Al-Khatib, 2023). A six-item scale was adopted to measure green information system (Qu & Liu, 2022). And a five-item scale was adopted to measure green innovation (Zhou et al., 2020).

Results

Out of the surveys distributed, a total of 275 were retained for analysis, indicating a commendable effective response rate of 56.35%. The majority of respondents hailed from the food and beverage, chemical, and petroleum sub-sectors, with sole proprietorship being the less preferred form of business entity. The study also revealed that a significant portion of the participating companies had a substantial track record, having been in operation for over a decade, employing more than 75 personnel, and boasting an annual turnover exceeding fifteen million ringgits.

Measurement Model

The measurement model underwent rigorous analysis, encompassing assessments of construct validity and reliability, alongside a discriminant validity examination, conducted with SmartPLS. As depicted in Figure 1 and detailed in Table 2, all constructs exhibited robust item loadings exceeding 0.7. Furthermore, these constructs demonstrated favorable internal consistency with Cronbach's alpha values surpassing 0.7. Additionally, composite reliability scores exceeded 0.8, indicating high reliability, and the average variance extracted values exceeded 0.5, signifying strong discriminant validity.

Figure 1

Measurement model item loadings, path coefficient, and R^2 values

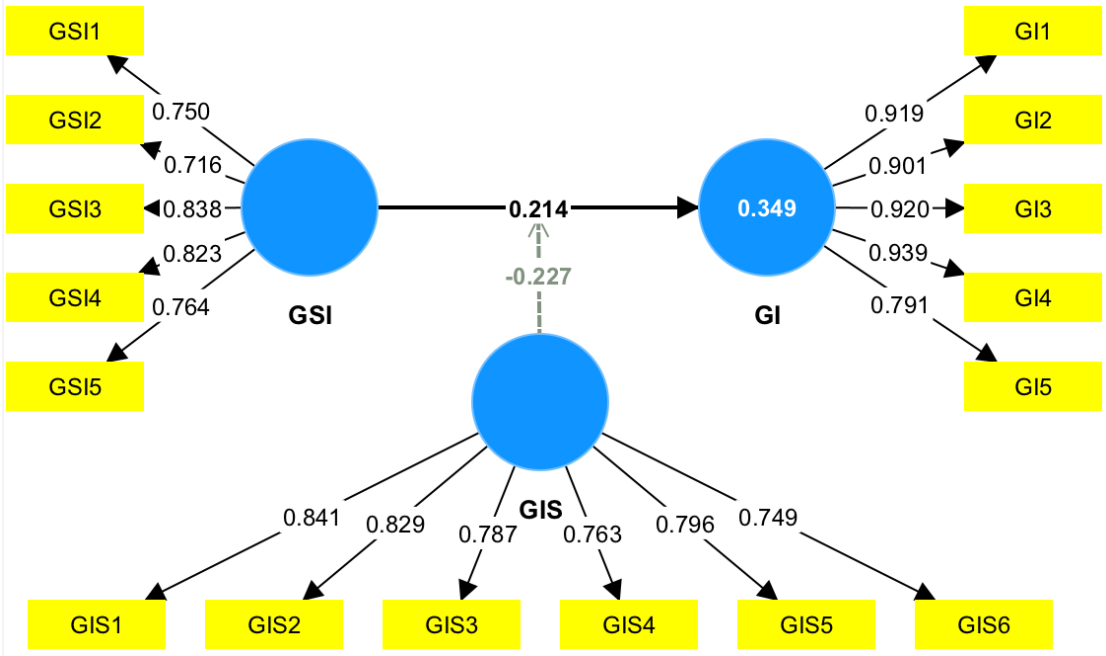


Table 2

Construct validity and reliability

Construct	Item Code	Item Loading	Cronbach Alpha (α)	CR	AVE
GI	GI1	0.919	0.937	0.953	0.802
	GI2	0.901			
	GI3	0.920			
	GI4	0.939			
	GI5	0.791			
GIS	GIS1	0.841	0.886	0.911	0.631
	GIS2	0.829			
	GIS3	0.787			
	GIS4	0.763			
	GIS5	0.796			
	GIS6	0.749			
GSI	GSI1	0.750	0.843	0.885	0.607
	GSI2	0.716			
	GSI3	0.838			
	GSI4	0.823			
	GSI5	0.764			

As illustrated in Table 3, all construct item loadings surpassed the cross-loading values, affirming the absence of any cross-loading issues. Furthermore, as presented in Table 4, the square root of the AVE by each construct exceeded the correlation with other constructs, thus satisfying the Fornell–Larcker criterion. Additionally, Table 5 indicates that the heterotrait-monotrait ratio of correlations yielded values exceeding 0.85 for all constructs. These three tests collectively demonstrated the absence of any concerns regarding discriminant validity.

Table 3
Cross loadings

	GI	GIS	GSI	GIS x GSI
GI1	0.919	0.471	0.392	-0.417
GI2	0.901	0.468	0.347	-0.428
GI3	0.92	0.434	0.373	-0.454
GI4	0.939	0.494	0.424	-0.447
GI5	0.791	0.444	0.346	-0.267
GIS1	0.358	0.841	0.354	-0.449
GIS2	0.341	0.829	0.349	-0.446
GIS3	0.318	0.787	0.331	-0.334
GIS4	0.312	0.763	0.388	-0.406
GIS5	0.559	0.796	0.637	-0.38
GIS6	0.451	0.749	0.516	-0.338
GSI1	0.219	0.394	0.75	-0.148
GSI2	0.217	0.309	0.716	-0.086
GSI3	0.336	0.466	0.838	-0.164
GSI4	0.423	0.583	0.823	-0.331
GSI5	0.36	0.398	0.764	-0.052
GIS x GSI	-0.451	-0.491	-0.217	1

Table 4
Fornell–Larcker criterion

Construct	GI	GIS	GSI
GI	0.896		
GIS	0.517	0.795	
GSI	0.422	0.572	0.779

Table 5
Heterotrait-monotrait ratio of correlations

Construct	GI	GIS	GSI	GIS x GSI
GI				
GIS	0.535			
GSI	0.446	0.596		
GIS x GSI	0.465	0.522	0.218	

Structural Model

The proposed measurement model was assessed using Smart PLS, and the research hypotheses were tested through bootstrapping. The path coefficients and the coefficient of determination are presented in Figure 1 and Table 7, respectively. Considering the direct

relationship in the structural model of this research, H_1 exhibited a path coefficient of 0.065, a t-value of 3.622, and a p-value of 0.000. Given that the p-value is less than 0.05, H_1 was substantiated. According to the results obtained from the moderation analysis, H_2 exhibited a path coefficient of 0.227, a t-value of 4.149, and a p-value of 0.000. As the p-value is less than 0.05, H_2 was corroborated.

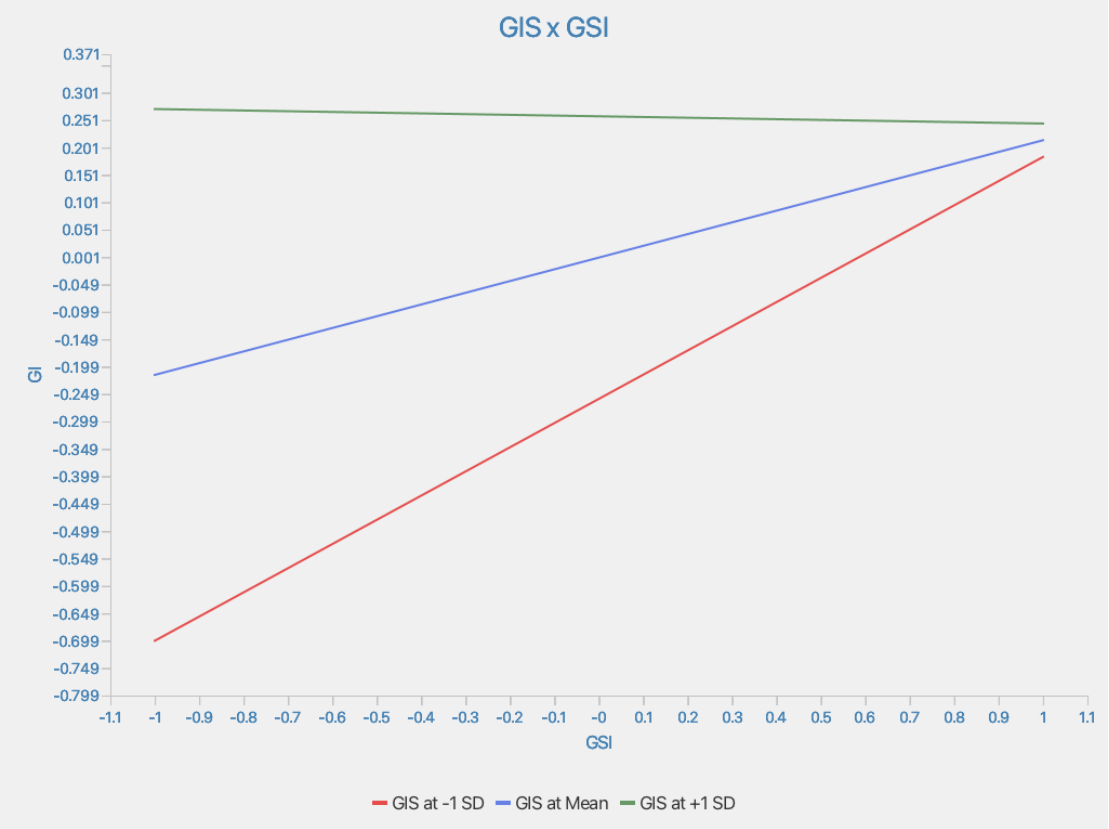
Table 7
Direct effect and moderating effect

H	Relationship	Standard Deviation (STDEV)	*t*-Statistics	*p*-Value	Decision
H_1	GSI →GI	0.071	3.622	0	supported
H_2	GSI x GIS → GI	0.055	4.149	0	supported

The coefficient of determination (R^2) results indicate that the current research model exhibits a moderate level of explanatory power for green innovation, falling within the range of 0.26 to 0.50. This suggests that the model's predictive capacity accounts for 34.9% of the variance in green innovation. However, it's worth noting that other unaccounted factors contribute to the remaining 65.1% of green innovation, underscoring the presence of additional variables that influence this outcome.

In Figure 2, the graphic representation elucidates the role of the green information system in influencing the relationship between green supplier integration and green innovation. It exemplifies an intensified interaction where both the independent variable and the moderating variable mutually enhance their impact on the dependent variable. This synergy results in an effect that surpasses a mere additive influence. In other words, this indicates that at higher levels of the green information system, the relationship between green supplier integration and green innovation becomes stronger and more pronounced. Conversely, when the green information system is at a lower level, it tends to diminish the impact of green supplier integration on green innovation.

Figure 2
Interaction plot of GIS and GSI on GI



Discussion

H_1 posited a positive correlation between green supplier integration and green innovation, a hypothesis that received support in line with previous research (Akhtar et al., 2023). Therefore, there is robust evidence indicating a positive association between green supplier integration and green innovation. This underscores the significance of investing in green supplier integration practices, particularly within the context of promoting green innovation. Based on the findings of the research and the positive correlation between green supplier integration and green innovation, it is advisable for manufacturing companies in Malaysia to invest in green supplier integration. This investment can potentially lead to improved green innovation performance. However, the decision to invest in green supplier integration should be made after a thorough analysis of the company's specific context, goals, and available resources. It's important to consider factors such as the company's current sustainability initiatives, supply chain structure, and the potential benefits and costs associated with implementing green supplier integration. Additionally, it's crucial to ensure that the integration process is aligned with the company's overall sustainability strategy and goals.

H_2 postulated that the green information system moderates the relationship between green supplier integration and green innovation, a finding that aligns with prior research (Qu & Liu, 2022). Consequently, there is substantial evidence supporting the role of the green information system as a moderator in the relationship between green supplier integration and green innovation. This underscores the importance for Malaysian manufacturing companies to enhance the efficiency of their green information systems, which, in turn, will positively impact their green innovation practices. However, the decision to invest in a green information system should be based on a comprehensive assessment of the specific needs and circumstances of each manufacturing company in Malaysia (Cheng et al., 2023). It's also

important to ensure that the implementation of such a system is well-planned and executed to maximize its effectiveness in supporting sustainability and green innovation initiatives.

Conclusion, Limitations, and Future Directions

This research has shed light on the intricate interplay between green supplier integration, expertly moderated by green information systems and its profound impact on fostering green innovation within organizations. These findings underscore the central role of supplier integration practices in propelling sustainability and innovation. Furthermore, the demonstrated moderating effect of green information systems underscores the importance of technology in elevating and optimizing green innovation processes. These insights not only enrich the comprehension of the dynamics surrounding sustainability and innovation but also offer practical guidance to businesses navigating the increasingly pivotal realm of eco-conscious practices and technology-driven innovation. As organizations grapple with the challenges of a swiftly changing world, this research provides a pathway toward a more sustainable and innovative future.

Noteworthy academic and practical contributions have been made by this research to the fields of green innovation. Academically, it enriches the understanding of the intricate relationships among green supplier integration, green information systems, and green innovation. By shedding light on the moderating role of technology in promoting sustainability efforts, the study extends existing knowledge in these domains. On a practical level, the findings offer valuable guidance to organizations seeking to enhance their eco-friendly practices and foster innovation. These insights have the potential to inform strategic decision-making, stimulate eco-conscious supply chain management, and guide businesses toward achieving their sustainability goals. In a world where environmental consciousness and innovation are paramount, this research bridges the academic-practical divide, offering a pathway toward more sustainable and innovative practices within organizations.

Last but not least, this research has limitations, notably in terms of generalizability. Findings are context-specific and must be validated in diverse industries and regions. Measurement accuracy and reliability require attention in future research. The cross-sectional design doesn't establish causality, and response bias is a concern with online surveys. Promising areas for future research include industry-specific studies, long-term investigations, and the exploration of mediating mechanisms. Comparative research, the impact of green digital learning orientation, the emerging green digitalization technologies, the cultural intelligence practices, and the role of green absorptive capability in green innovation warrant further exploration.

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