

Unveiling the Nexus Between Innovation and Environmental Sustainability: The Moderating Influence of Knowledge Management Practices

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Abstract

The purpose of this study is to identify and validate the antecedents and outcomes of environmental sustainability in green manufacturing in Pakistan, by principally focusing on small and medium-sized enterprises (SMEs). This study examines the role of knowledge management processes (KMPs), specifically the knowledge acquisition, knowledge dissemination, and knowledge application, as enablers of environmental sustainability. Data were collected from 487 SMEs through an online survey and analyzed using partial least squares structural equation modeling (PLS-SEM). This study investigates the relationship between innovation, knowledge management, and environmental sustainability in the context of green manufacturing. Significant findings indicate that: (1) innovation has a significant impact on environmental sustainability and (2) knowledge management moderates the relationship between innovation and environmental sustainability. The contributions of this study to the existing literature include: (1) providing a comprehensive framework linking environmental sustainability enablers to innovation in green manufacturing sector and (2) establishing knowledge management as a mediator between innovation and environmental sustainability. The findings of this study have important implications for policymakers, managers, and researchers in understanding the dynamics of environmental sustainability in SMEs of green manufacturing in Pakistan. This study also discusses future research directions and limitations.

Keywords: Environmental Sustainability, Innovation, Knowledge Management

Introduction

Sustainable development has become one of the most important subjects of discussion in both academia and business as a result of the acknowledged current environmental concerns (Leal et al., 2024). Given that sustainable development aspires to meet the needs of every sector of society, partnerships with the widest possible range of stakeholders are expected to be necessary for the creation and dissemination of sustainability-related information (Cristofolletti; Pactwa et al., 2024). As long as these stakeholders have access to leadership and engagement opportunities, they are essential in driving organizational change (Mızrak, 2024). An academic institution has a tactical advantage when acting as the hub of knowledge for a certain area (Fehrenbach & Huisman, 2024). This is accomplished by providing pathways for interested parties to engage in initiatives aimed at

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producing and disseminating sustainability-related knowledge (Lukambagire et al., 2024; Shrestha, 2024), all with the ultimate objective of improving our understanding of the function performed by outside stakeholders. One major concern is how technology-driven enterprises will fare in the face of environmental change's uncertainties, hazards, and risks (Patil & Kulkarni). Businesses that rely heavily on technology have to deal with challenges including market fluctuations, fierce competition, unstable environments, and unrest in order to stay in operation (Kramskyi et al., 2024). Corporate sustainability is no longer just a strategic consideration because it is essential to a company's long-term survival (Florez-Jimenez et al., 2024). Corporate competitive strategies are increasingly emphasizing innovation (Dong et al., 2024; Lin, 2024). The task's ongoing difficulty is a result of a shorter product lifespan, a higher rate of new product production, fluctuating consumer wants, and a more complex domain (Alzaydi, 2024; Amajuoyi et al., 2024).

New technologies, global marketplaces, and heightened competition are some of the characteristics that define a knowledge-based economy (Ben Hassen, 2024; Liu & Chen, 2024). One of the key tools that a business may use to handle global issues is knowledge management (Jordão & Novas, 2024). To obtain a competitive edge, knowledge management has also grown in importance for researchers. Businesses are becoming more and more conscious of the fact that KM's main objective is to boost their ability to innovate (Kolehmainen, 2024). Numerous studies indicate that if businesses can successfully change their surroundings by producing new knowledge, sharing it, and implementing it into their daily operations, they will become more inventive. (Marco-Lajara et al., 2023). Businesses are under increasing pressure to balance profitability with environmental sustainability (Bataineh et al., 2024). It is true that attaining sustainability and financial success can be greatly aided by the combination of knowledge management and creative business concepts (Ortiz et al., 2024; Zientek, 2024).

The encouragement of information seeking, absorbing, and sharing has made a significant contribution to the accomplishment of organizational objectives (Chiu et al., 2024; Truong et al., 2024). KM is seen as a crucial strategic resource for businesses of all sizes (Jordão & Novas, 2024). It is important to note that information is intangible and therefore difficult to grasp, exchange, and embed throughout the various divisions of a business (Moro-Visconti, 2024). A crucial strategy for gaining a competitive edge is the efficient and consistent application of knowledge (Liu et al., 2023).

In this case, there are quantifiable advantages to effective knowledge management in terms of fostering innovation and environmental sustainability (Foster et al., 2024). Knowledge management (KM) and innovation play a critical role in fostering environmental sustainability in Pakistan's green manufacturing sector (Syed et al., 2024). Pakistan has come a long way in the last several years in adopting sustainable manufacturing methods and eco-friendly practices (Kumar et al., 2024) to reduce its environmental impact. Knowledge management (KM) is vital in this context because it facilitates the efficient exchange, dispersal, and application of critical knowledge related to environmental rules and sustainable practices (Anggraeni, 2024; Nakash & Bouhnik, 2024)

Conversely, innovation drives the development of state-of-the-art instruments and methods that can reduce waste, increase manufacturing's energy efficiency, and lower pollution (Kaur & Singhal, 2024; Osman et al., 2024). In order to accomplish long-term environmental goals and foster economic growth, Pakistan must combine economic progress with environmental stewardship (Lin & Ullah, 2024; Waheed et al., 2024). This makes it crucial to comprehend how

knowledge management (KM) and innovation interact and contribute to sustainability (Lin & Ullah, 2024).

This study's contribution is its investigation of the relationship between innovation and knowledge management and environmental appropriateness. This encouraged the researcher to start the study on the effect of Innovation on KM that help to promote environmental sustainability. According to the Resource Based View Theory, a company can become long-term competitive by determining which of its resources and competencies are valuable and uncommon (Kárpáti et al., 2024; Malhotra et al., 2024). The mediating role of organizational KM will contribute to understand the mechanism that underlie between Innovation and Environmental sustainability.

Considering what was mentioned before, in order to lead this study, the research question is:

- How Innovation influence on Organizational KM and Environmental Sustainability?

This paper is divided by the following sections: literature review, presenting the variables relations and the study hypotheses, research method, the data analyzes, and, at last, the study conclusions.

Literature Review

Over time, the importance of knowledge management in the context of sustainability has grown (Jordão & Novas, 2024; Martínez-Falcó et al., 2024). Despite its significance, little research has been done in this field, and there are several opportunities for academic study. The United Nations' Agenda 2030 in its entirety and the 17 Sustainable Development Goals in particular have given the cause of sustainable development new vigor (Oyebode, 2024). When knowledge management (KM) is applied in a sustainable setting, the company adopts a new perspective where social responsibility (Alketbi & Ahmad, 2024), environmental sustainability, and economic viability are given equal weight. Strategies for sustainable development could be layered on top of knowledge management (Ma et al., 2024). The challenges of following the environmental regulations make such a union essential. As a result, organizations need to rely more and more on their resources for producing knowledge. In the context of sustainability, knowledge management (KM) is seen as a new paradigm of development that aims to enhance adherence to the concepts of economic, environmental, and social sustainability (Barrantes-Briceño et al., 2024). Given the company's new obligations for compliance with sustainability regulations, any sustainable program becomes even more important because it has the potential to bring about long-lasting changes in the community involved, which comprises a variety of stakeholders with varying expectations. To encourage a business to function well, entrepreneurs must use greater creativity, for example, in the creation of human resources and proficient leadership (Herison et al., 2024). Enterprises utilizing state-of-the-art sustainable methods can mitigate any possible adverse consequences. High-level innovators can also maintain and grow a competitive edge (Tian et al., 2024). Therefore, in Pakistan's green manufacturing industry, knowledge management and innovation alignment might be crucial to environmental sustainability (Baquero, 2024). Nonetheless, the creation of a competitive advantage shows that the business has the means and capacity to make products that are superior to those of its competitors while also providing customers with outstanding value (Aharoni, 2024; Amaya et al., 2024).

In the rapidly expanding field of knowledge management (KM), the concept of environmental sustainability is gaining traction (Santos et al., 2024). Organizations worldwide recognize knowledge management (KM) as a critical skill, a primary source of competitive advantage, and a key factor in value development (Uto et al., 2024). However, despite the fact that knowledge management is essential, cultural barriers prevent many businesses from implementing it successfully (Truong et al., 2024). Scholars concur that knowledge management (KM) is an

interactive, integrated process that aids in a company's development, capture, organization, access, and utilization of creative resources and intellectual property in order to achieve long-term goals (Al-Husseini, 2024)

Businesses put a lot of effort into implementing creative and effective knowledge management methods in order to meet their long-term goals (Jordão & Novas, 2024). According to (Bochańczyk-Kupka, 2024) the building of contemporary economies is predicated on the application of innovative ideas derived from individual intellectual wealth, which enhances the economy's sustainability and profitability. Knowledge management (KM) aids businesses in developing the skills necessary for green innovation, which improves business performance in terms of sustainability (Shehzad et al., 2024). Knowledge management has given rise to green technologies, which have made it possible to create goods that are good for ecosystems and the environment (Alam et al., 2024). To summarize, Innovation is an essential component in achieving positive results in terms of business sustainability (Dzhunushalieva & Teuber, 2024). The foundation for a company's capacity to innovate in a sustainable manner is comprised of certain knowledge assets and abilities (Kastelli et al., 2024). Knowledge management is essential for achieving a competitive advantage and represents a significant business opportunity for businesses that are committed to environmentally responsible innovation (Arduini et al., 2024). When it comes to fostering environmental sustainability, the significance of innovation through KM cannot be understated.

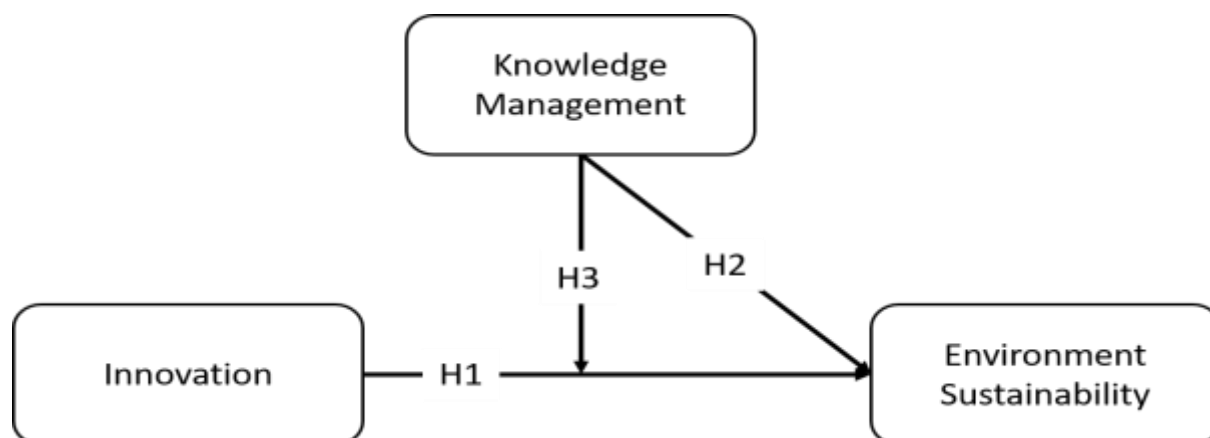
Hypothesis

H1: There is a significant and positive relation between innovation and environment sustainability

H2: There is a significant and positive relation between knowledge management and environment sustainability

H3: There is a significant and positive moderating impact of knowledge management on the relationship of innovation and environment sustainability.

Figure 1: Theoretical Framework



Research Methodology

Quantitative Data

This research utilized the quantitative data for the analysis purpose and to test the above-mentioned hypothesis. Quantitative research is deemed most appropriate to measure the given constructs and to establish the relation among them.

Descriptive Research

It is descriptive research which describes the relation among the variables and identifies the moderating impact of the moderator on the given relationship of IV on DV.

Data Collection Tool

Data were collected utilizing the questionnaire which is the most efficient way of collecting the data from a large group of people in a limited time and resources. The questionnaire was digitally distributed through Google Forms and was adopted from the previous studies.

Population and Sample

The information was gathered from Pakistan's general managers in the green manufacturing sector. This study uses proportionate stratified random sampling (SRS) as its sampling method. SRS "involves a process of stratification or segregation, followed by a random selection of subjects from each stratum (Han & Sidell, 2024). In comparison to other restricted sampling strategies, proportionate SRS is less biased and more effective than plain random sampling (Robertson & Price, 2024). Additionally, SRS creates more useful and distinct information and offers greater representation of each significant demographic component (Sekaran and Bougie, 2009).

Results

Reliability and Validity

Reliability refers to the consistency of a measure (whether the results can be reproduced under the same conditions). Validity refers to the accuracy of a measure (whether the results really do represent what they are supposed to measure). To measure reliability Cronbach's Alpha was used which shows strong reliability with value of 0.7 and above (Sekaran & Bougie, 2016). The values of all the variables is above the mentioned threshold, thus establishing the reliability of the constructs as shown in table 1:

Table 1: Cronbach's Alpha Value

Constructs	Cronbach's Alpha
ES	0.888
INNOV	0.760
KM	0.782

For validity Fornell-Larcker Criterion was used where the values of correlation of each variable with other should be less than the square root of the variance of the construct with itself. In table 2 it can be viewed that all the values satisfy the desired requirement thus establishing the discriminant validity of the collected data.

Furthermore, Heterotrait-Monotrait Ratio (HTMT) was also measured to confirm the discriminant validity. The value below 0.9 indicates the discriminant validity of the constructs (Hair, J F. et al., 2018). Table 3 shows that all the values are below the threshold of 0.9

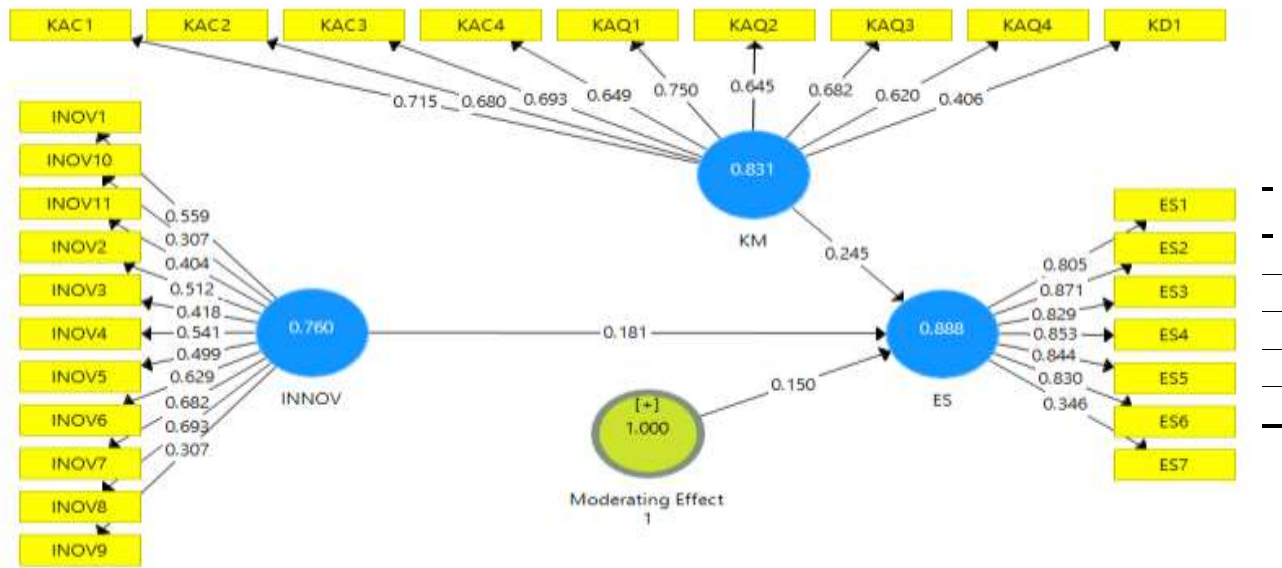
Table 3: Heterotrait-Monotrait Ratio (HTMT)

	ES	INNOV	KM
ES			
INNOV	0.192		
KM	0.280	0.256	
Moderating Effect 1	0.180	0.229	0.136

Factor Loading

According to Child, (2006) the values of factor loading should be above 0.2 and if any factor value is less than 0.2 it should be dropped. During this research two factors had value less than the threshold of 0.2 and were dropped out of the data set for analysis. Following figure shows that remaining all the factors satisfy the required values for analysis.

Figure 1: Factor loading



F square

F Square predicts the change in R Square value if the independent variable is removed from the model the value above 0.02 to is required to satisfy the F square requirement of the model. In our model all the values are above the required value of decimal zero to thus satisfying the F Square requirement of the model.

Table 4: F Square Values

	ES
ES	
INNOV	0.036
KM	0.066

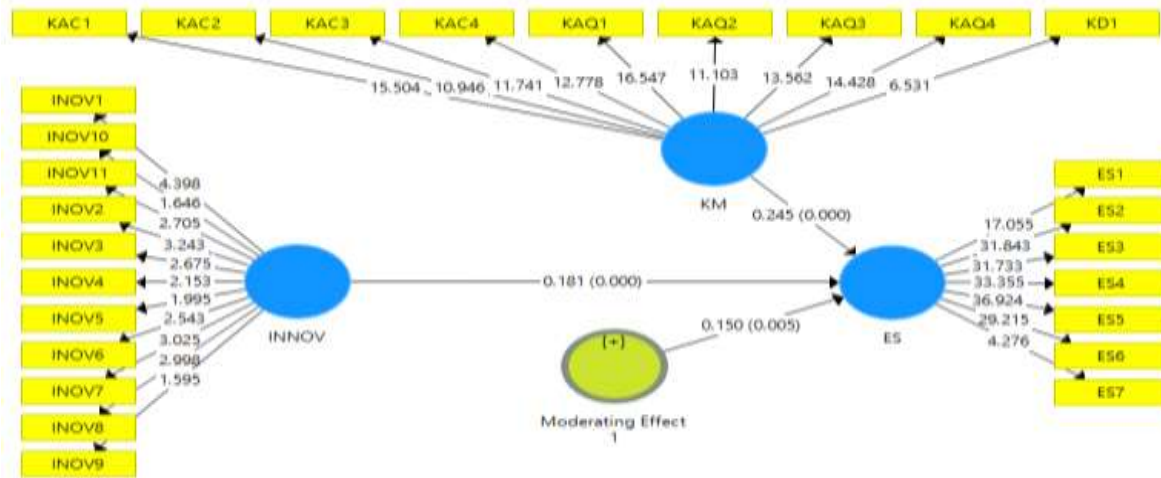
Testing of Hypothesis

PLS SEM was used to test the hypothesis and the result as shown in the following table indicates that there is a significant and positive relation between Innovation and Environment sustainability (p 0.000; 0.181). It indicates that there is a 18.1% increase in the environmental sustainability with increment of innovation, thus hypothesis 1 stating that there is a significant and positive relation between innovation and environment sustainability is accepted. Secondly, there is a significant and positive relation among the knowledge management and environment sustainability (p 0.000; 0.245) indicating that with increment of knowledge management there is 24.5% increase in the environment sustainability. Thus, hypothesis no 2 stating that there is a significant and positive relation between knowledge management and environment sustainability is accepted.

Table 5: Results of Hypothesis Testing

	Original Sample (O)	Sample Mean (M)	(STDEV)	T Statistics	P Values
INNOV -> ES	0.181	0.205	0.037	4.946	0.000
KM -> ES	0.245	0.242	0.037	6.589	0.000
Moderating Effect 1 - > ES	0.150	0.137	0.053	2.832	0.005

Furthermore, the result indicate that knowledge management moderates the relationship between innovation and environment sustainability (p 0.005; 0.15) indicating that with increase in knowledge management the relation among innovation and environment management gets strong by 15%. Thus, our hypothesis no 3 stating that there is a significant and positive moderating impact of knowledge management on the relationship of innovation and environment sustainability is accepted.

Figure 2: Factor Loading

Conclusion

The current research provides an in-depth analysis of innovation, knowledge management in terms of environmental sustainability. The results of this study correspond with the literature that innovation is an essential component in knowledge management and environmental sustainability. This discussion will expand upon the conclusions of this research in terms of their implications, limitations, and further research directions. indicates that there is a significant and positive relation between Innovation and Environment sustainability (p 0.000; 0.181). It indicates that there is a 18.1% increase in the environmental sustainability with increment of innovation, thus hypothesis 1 stating that there is a significant and positive relation between innovation and environment sustainability is accepted. Secondly, there is a significant and positive relation among the knowledge management and environment sustainability (p 0.000; 0.245) indicating that with increment of knowledge management there is 24.5% increase in the environment sustainability. Thus, hypothesis no 2 stating that there is a significant and positive relation between knowledge management and environment sustainability is accepted. This result is in line with previous studies, which have argued that the implementation of innovation can result in enhanced environmental sustainability (Usman et al., 2024). It implies that the organizations can improve their environmental sustainability through the application innovation with alignment of Knowledge management (Budur et al., 2024).

The research also emphasizes the important role of innovation as independent variable align with knowledge management positive impact on environmental sustainability, confirming that innovative practices should be promoted to encourage environmentally friendly operations. The research highlights the importance of organizations investing in knowledge generation, dissemination, and utilization to improve their ecological effectiveness. In addition, it accentuates the need for promoting innovation as a means towards increased environmental sustainability. The outcomes of the study could be useful for policy makers, scholars and practitioners in formulating strategies and policies aimed at reinforcing environmental sustainability. They can help organizations to understand where they could locate knowledge acquisition, diffusion, and utilization alongside innovation for improving their environmental sustainability.

Managerial Implications

This study, therefore has significant insights into the role of knowledge, management and innovation in environmental sustainability. The major conclusions of the study have a number of managerial implications for organizations that strive to support environmental sustainability and innovation. First, the study reveals that organizations should concentrate on knowledge dissemination and use in order to enhance environmental sustainability. This can be done by designing knowledge management strategies that allow the free flow of information and knowledge across all departmental levels.

Second, the research focuses on knowledge acquisition and diffusion as forces that foster innovation. Organizations can foster innovation by developing research and development programs that aid in the acquisition of knowledge and its dissemination. This can be done by creating alliances with learning institutions and research bodies as well as encouraging employees to pursue life-long learning initiatives.

Third, the research indicates that most important the innovation is an essential element to foster environmental sustainability. Investments in innovation activities targeting at sustainable products and services, as well as adoption of sustainable business practices contribute to the promotion of environmental sustainability among organizations. Organizations can use this finding in developing innovation strategies that promote environmental sustainability. This can be done by setting up cross-functional teams that are composed of employees from various departments and work on sustainability projects.

Last, the study has significant policy implications. The policy implications of the study findings imply that policymakers can develop policies with respect to knowledge management and innovation as a means of reaching environmental sustainability. This can be attained by giving incentives to organizations that invest in research and development activities, as well as instituting guidelines that encourage practices of sustainable business. In sum, the current paper presents significant findings on how innovation and knowledge management can influence environmental sustainability.

Limitations and Future Directions

Among the limitations of this study is the utilization of a cross-sectional design that cannot help to prove causality between the variables. For better examination on the dynamic and temporal relationship in knowledge management, innovation, and environmental sustainability, in a future study, a longitudinal research design should be used. Another weakness of the study lies in the fact that the data are self-reported and thus prone to some degree of bias. This limitation can be overcome by future research using objective measures of knowledge management, innovation, and environmental sustainability.

Moreover, the study dealt with one single industry; hence, the results are not directly applicable to other industries. Further research can be done to replicate the associations concerning knowledge management, innovation, and environmental sustainability in other industries to see if the findings will apply in other contexts. Although the current study has limitations in these aspects, a few future directions can be explored in this context. Future studies could examine the role of various knowledge management strategies and their potential toward environmental sustainability and innovation. For example, further research might examine the impact effects of knowledge generation, accumulation, and transfer toward environmental sustainability as well as innovation. Further analyses in future studies may be directed towards the influence of other types of innovation towards sustainability. For example, future research might consider questions such as

which among the following are the roles of product innovation, process innovation, and organizational innovation in the environmental sustainability of organizations? Lastly, future research may also look into the latter: the extent to which there is an influence of different environmental sustainability practices on innovation. For example, researches of the future generations may find one area of focus in sustainability of supply chain management as well as green orientation and ecological design through its impact on innovation.

Finally, future studies would find it highly intriguing to research the various contextual determinants that influence the relationships between knowledge management, innovation, and environmental sustainability. For instance, the current study may also focus on the furthering of investigations based on national culture as well as industry structure and organizational size as the determining factors governing these relationships. Overall, the present study presents useful insights into how knowledge management and innovation can help achieve environmental sustainability. Although it comes with some limitations, the findings represented possible future directions that can be advanced further to understand these relationships. By exploring the various outcomes of knowledge management strategies, innovation, and environmental sustainability practices based on a comprehensive understanding built from contextual factors, future research can elucidate ways of building efficient strategies for advancing ecological sustainability and innovation.

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