Experimental Perspective on the Role of Cost Information in Eco-Friendly Product Design: Do Individual Characteristics Matter?

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Abstract
This research employs a controlled experimental approach to investigate how cost information precision, designer learning orientation, and designer gender jointly influence eco-friendly new product development (NPD). Prior studies highlight that while cost data and individual characteristics such as learning orientation and gender can affect new product performance, their effects on environmentally friendly design remain under-explored. Through an experiment with 117 undergraduate accounting students acting as proxies for product designers, this study systematically examines interaction between variables in a simulated NPD environment. Participants were randomly assigned to either precise (specific) or imprecise (relative) cost information conditions, with classifications based on learning orientation and gender, enabling a controlled analysis of each factor's impact on eco-friendly design choice. The 2x2x2 ANOVA results indicate significant interaction effects, specifically between cost precision and learning orientation, where high-learning-oriented individuals exhibited a greater tendency toward eco-friendly design when provided with specific cost information. A further significant interaction between cost precision and gender revealed that female participants integrated more eco-friendly consideration under specific cost conditions. These findings underscore the effectiveness of experimental methods in isolating and examining the combined effects of cost data precision and individual characteristics, providing actionable insights into strategies that organizations can adopt to foster eco-friendly innovation in product design. This study validates the experimental approach as a powerful tool for advancing knowledge of the role individual characteristics play in sustainable NPD practices.

Article History:

Keywords:
Eco-Friendly Design,
Cost Information,
Learning Orientation,
Experimental Method

1. Introduction

In recent years, the urgency of sustainable development has intensified, placing eco-friendly practices at the forefront of product innovation. As environmental concerns increasingly drive consumer demand and regulatory mandates, organizations are under pressure to integrate eco-friendly features into their new product development (NPD) processes (Fatma and Haleem, 2023; Doshi and Noble, 2023; Le Mouellic *et al*., 2023). However, the successful implementation of green design principles depends on multiple factors, including cost-related constraints, individual designer characteristics, and organizational priorities. Specifically, cost precision (Booker *et al*., 2007; Zhang et al., 2023; Nurjanah and Jatiningsih, 2023), designer's learning orientation (Espinoza *et al*., 2023), and gender (Jatiningsih and Zafirah, 2023; Wardani and Jatiningsih, 2024) have emerged as influential factors that may shape the extent and effectiveness of eco-friendly new product development .

In the field of sustainable product development, understanding the drivers of eco-friendly new product design (NPD) is critical for organizations aiming to reduce environmental impact while meeting market demands. While cost management practices, particularly cost precision, are widely acknowledged for their influence on design decisions (Dekker & Smidt, 2003; Elghaish *et al*., 2020), there is a growing need to explore how these practices interact with individual characteristics of designers, such as learning orientation and gender, to impact sustainable innovation. Existing literature has largely focused on separate effects of organizational factors and designer attributes in NPD; however, limited research examines their potential interaction and the cumulative impact on environmentally-conscious design choices while a synergistic approach is currently needed (Zhang *et al*., 2023). Investigating the joint effect is crucial for developing organizational strategies that support eco-friendly product innovation.

Experimental research provides a unique approach for studying these interactions by enabling controlled manipulation of key variables, thus overcoming limitations present in observational or correlational studies. Observational studies, though valuable, can be constrained by extraneous variables that complicate the analysis of cost management practices and designer characteristics on eco-friendly NPD outcomes (Christensen, Johnson, & Turner, 2015). Using an experimental approach allows researchers to isolate and systematically explore the effects of cost precision and individual designer characteristics, thereby providing stronger causal insights into how these factors drive sustainable innovation. Specifically, this study utilizes a 2x2x2 factorial experimental design to test how cost precision (specific vs. relative) interacts with learning orientation (high vs. low) and gender (male vs. female) in shaping eco-friendly design choices.

Furthermore, this study addresses the practical challenges of experimental research in organizational behavior by utilizing undergraduate accounting students as surrogates for product designers. This approach has precedent in experimental design research, where surrogate samples allow researchers to generalize findings when direct access to industry professionals may be limited (Hughes & Gibson, 1991). Accounting students, who are familiar with cost-related decision-making, provide an accessible yet relevant sample for studying how financial data influences design choices.

The findings of this study will contribute to the understanding of eco-friendly NPD by revealing how cost precision and designer characteristics interact to impact environmentally-focused design decisions. This paper proceeds with a discussion on cost precision, learning orientation, and gender in sustainable design, followed by hypotheses, methods, results, and implications for theory and practice. By leveraging an experimental approach, this research offers insights into the combined effects of cost management practices and designer attributes on eco-friendly product innovation, with important implications for fostering sustainability in NPD strategies.

Literature Review and Hypothesis Development

Cost Precision and Eco-Friendly NPD

Drawn from agency theory (Jensen and Meckling, 1976), there will be conflict arise due to information asymmetry, when there are the parties who have access to private information that management cannot directly observe, and leads to decisions that do not align with the organization's goals (Jensen & Meckling, 1976). When pursuing eco-friendly design, uncertainty about costs—such as the trade-offs between sustainable materials and financial performance—can deter new product designers from prioritizing environmental objectives, especially if they perceive sustainability efforts as risky or costly.

Studies have shown that precise cost estimations reduce uncertainty and financial risk, allowing designers to experiment with eco-friendly materials and processes without financial ambiguity (Dekker & Smidt, 2003; Elghaish *et al*., 2020). Cost precision, or the degree of accuracy in cost information for estimating product development costs (Booker *et al*., 2007), plays a critical role in decision-making for eco-friendly designs. Precise cost information can reduce financial uncertainty, allowing designers to explore environmentally friendly materials and processes with a clearer understanding of the financial impact (Le Mouellic *et al*., 2023; Jatiningsih and Zafirah, 2023; Jatiningsih and Rahma, 2023). However,

a lack of cost precision may lead to risk aversion, deterring the incorporation of green elements that might increase initial production costs. From this argument, hypothesis 1 is proposed as follows:

H1: Designers provided with precise cost information will incorporate more eco-friendly features in NPD than those with imprecise cost information.

Designer's Learning Orientation and Eco-Friendly NPD

Learning orientation theory posits that individuals with a strong focus on learning are motivated to acquire and apply new knowledge, driving exploratory behavior and openness to innovation (Sinkula, Baker, & Noordewier, 1997). In the context of eco-friendly NPD, designers with high learning orientation are more likely to engage with new sustainable practices, view environmental challenges as opportunities, and integrate eco-friendly features into their designs. They may also be more resilient to the uncertainties that eco-friendly features often entail.

Designer's learning orientation—the extent to which an individual is motivated to acquire and apply new knowledge—can significantly impact their approach to eco-friendly product development. Designers with a strong learning orientation are more likely to seek innovative solutions, embrace new environmental technologies, and remain adaptable to evolving sustainability standards (Calantone et al., 2002). Conversely, those with a low learning orientation may exhibit reluctance toward unfamiliar eco-friendly practices, viewing them as disruptive to established routines. While Calantone et al. (2002) found that learning-oriented organizations and individuals are more inclined toward innovation, Pujari (2006) suggests that such orientation is critical in advancing eco-innovation capabilities in product design. From this argument, hypothesis 2 is proposed as follows:

H2: Designers with a high learning orientation will incorporate more eco-friendly features in NPD than those with a low learning orientation.

Effect of Designer's Gender on Eco-Friendly NPD

Based on social role theory, gender roles and societal expectations shape attitudes and behaviors, with women often socialized to adopt more communal, care-oriented values, including environmental stewardship (Eagly & Wood, 2012). In the context of eco-friendly design, this theory suggests that female designers might prioritize sustainable features as part of their broader alignment with environmental and social responsibility.

Gender may also play a role in the design decision-making process, with research indicating that gender differences could influence attitudes toward environmental sustainability. Studies suggest that women are generally more attuned to environmental concerns and may, therefore, exhibit a stronger inclination toward green design compared to men. Research suggests that women generally have a stronger inclination toward environmental sustainability, which may translate into more eco-friendly design choices (Zelezny et al., 2000; Wardani and Jatiningsih, 2024). In this case, Zelezny et al. (2000) observed that women display stronger pro-environmental attitudes than men, which can influence decision-making in design. Similarly, Davidson and Freudenburg (1996) reported that women are more likely to view environmental issues as important, indicating a potential gender effect in eco-friendly product development (Aziza and Jatiningsih, 2024; Wardani and Jatiningsih, 2024). From this argument, hypothesis 3 is proposed as follows:

H3: Female designers will incorporate more eco-friendly features in NPD than male designers.

Interaction Effect of Cost Precision and Learning Orientation on Eco-Friendly NPD

A designer's learning orientation which defined as their drive to gain and apply new insights plays a crucial role in their approach to environmentally conscious product innovation. Those with a high learning orientation are more inclined to explore creative solutions, adopt emerging green technologies, and adjust to changing sustainability demands. This adaptability supports their ability to address ecological challenges effectively (Calantone et al., 2002).

Grounded in agency theory (Jensen and Meckling, 1976) and learning orientation concept (Sinkula, Baker, & Noordewier, 1997), cost precision (Le Mouellic *et al*., 2023; Jatiningsih and Zafirah, 2023; Jatiningsih and Rahma, 2023) is more influential among those with a high learning orientation. High learning-oriented designers are likely to respond more positively to precise cost information by

taking creative approaches to eco-friendly solutions, as they are more willing to explore sustainable alternatives (Hult et al., 2004). From this argument, hypothesis 4 is proposed as follows:

H4: The effect of cost precision on eco-friendly NPD will be greater among designers with a high learning orientation than among those with a low learning orientation.

Interaction Effect of Gender and Learning Orientation on Eco-Friendly NPD

Intersectionality theory posits that overlapping social identities (e.g., gender, learning orientation) can interact to produce unique experiences and behaviors (Crenshaw, 1989). In eco-friendly NPD, gender and learning orientation may intersect to affect designers' attitudes and decisions. For instance, female designers with a high learning orientation might approach eco-friendly design differently than their male counterparts, potentially making more innovative eco-friendly choices when precise cost information is available.

Thereby, gender differences in environmental concern (Aziza and Jatiningsih, 2024; Wardani and Jatiningsih, 2024) combined with a strong learning orientation (Pujari, 2006) may result in increased eco-friendly design choices among female designers (Davidson & Freudenburg, 1996; Zelezny et al., 2000). From this argument, hypothesis 5 is proposed as follows:

H5: Female designers with a high learning orientation will incorporate more eco-friendly features in NPD than male designers with a high learning orientation

Three-Way Interaction of Cost Precision, Learning Orientation, and Gender on Eco-Friendly NPD

Sheding light on intersectionality theory which suggests the existence of overlapping factors and will interact in ways that shape distinct behaviors (Crenshaw, 1989), cost precision, learning orientation and gender may have an interaction effect as well. In the context of eco-friendly new product development (NPD), these intersecting factors could influence designers' perspectives and decision-making processes, potentially shaping their approach to sustainability initiatives.

The combined influence of gender (Aziza and Jatiningsih, 2024; Wardani and Jatiningsih, 2024), high learning orientation (Pujari, 2006), and precise cost information (Le Mouellic *et al*., 2023; Jatiningsih and Zafirah, 2023; Jatiningsih and Rahma, 2023) may create an optimal environment for eco-friendly NPD, as all factors support environmental innovation (Pujari, 2006; Chen & Chang, 2013). Studies suggest that women with high environmental awareness (Zelezny et al., 2000) and high learning orientation may respond most positively to enabling conditions like cost precision, aligning with their pro-environmental motivations (Davidson & Freudenburg, 1996; Hult et al., 2004). From this argument, hypothesis 6 is proposed as follows:

H6: The highest level of eco-friendly features in NPD will be observed in female designers with high learning orientation and precise cost information.

2. Method

2.1. Experimental Approach

The experimental method is particularly well-suited for investigating the effects of cost precision, designer's learning orientation, and designer's gender on eco-friendly new product development (NPD) because it allows for controlled manipulation of independent variables and direct observation of their effects on design decisions. This experimental approach setup enables a robust analysis of the individual and combined effects of cost precision, learning orientation, and gender on eco-friendly NPD, testing the formulated hypotheses in a controlled manner, with the following details:

a. Control over Independent Variables

Experimental methods allow researchers to control variables directly, which is essential for isolating the effects of specific factors namely cost precision (specific and relative), learning orientation (high and low), and gender (male and female). In this syudy, specific cost is measured by varying material cost in the experiment ranging in Indonesian rupiah value whereas relative cost is measured by

comparison of materials with one cost of material can be higher or lower compared to the other (Booker *et al.*, 2007). Learning orientation measure which is split into high and low level, is drawn from Brett and Vande Walle (1999) which assessed participants with one dimension in goal orientation consist of challenging assignments, new skill and knowledge, difficult task, developed ability and high level talent. Gender is categorized from participants data which is allocated into male and female students.

By using a 2x2x2 factorial design, the study can systematically vary each independent variable and examine their individual and combined effects on eco-friendly NPD outcomes. Controlled manipulation is critical in understanding causation, as it helps distinguish whether cost precision, learning orientation, and gender indeed cause variations in eco-friendly design choices, rather than other external factors (Campbell & Stanley, 1963).

Figure 1. Experimental Matrix

		Learning Orientation			
		High		Low	
		Male	Female	Male	Female
Cost Precision	Specific	Cell 1	Cell 2	Cell 3	Cell 4
	Relative	Cell 5	Cell 6	Cell 7	Cell 8

Further, experimental control allows researchers to simulate conditions like precise vs. imprecise cost information and to prime or measure learning orientation, thus reducing confounding variables that might otherwise obscure relationships between these factors and eco-friendly design outcomes (Christensen, Johnson, & Turner, 2015).

b. Causality and Hypothesis Testing

The experimental method is ideal for testing causal relationships, which is central to the study's objective of understanding how the interaction of cost precision, learning orientation, and gender influences eco-friendly NPD. According to Shadish, Cook, and Campbell (2002), experimental methods are the gold standard for establishing causality due to their reliance on manipulation and control. By randomly assigning participants to different experimental conditions, the study minimizes biases, ensuring that any differences in eco-friendly design outcomes can be attributed to the manipulated variables rather than external influences.

This focus on causality is crucial because it moves beyond simple associations, providing insights into how specific factors can drive sustainable innovation in product design. For instance, the experiment can directly assess whether designers given precise cost information are more inclined to integrate eco-friendly features than those with imprecise cost data, thus confirming or refuting Hypothesis 1.

c. Measurement of Interaction Effects

The experimental approach is also particularly suitable for testing interaction effects, which are central to this study's hypotheses. In a 2x2x2 factorial design, the study can evaluate not only the main effects of cost precision, learning orientation, and gender but also the interactions between them, such as whether cost precision has a greater effect on eco-friendly NPD among designers with high learning orientation (H4) or whether female designers with a high learning orientation respond differently to cost precision compared to male designers (H5). Interaction effects are more complex to measure in observational studies due to uncontrolled extraneous variables, making experiments a more robust choice for understanding these multifaceted relationships (Montgomery, 2017).

Factorial experiments, in particular, are suited for these multi-variable interactions because they allow for the examination of different combinations of variables in one comprehensive design. This setup enables more nuanced insights into how learning orientation and gender, for example, might influence eco-friendly decisions differently when cost precision is manipulated (Maxwell & Delaney, 2004).

d. Random Assignment and Reduction of Bias

By randomly assigning participants to different levels of cost precision and measuring learning orientation and gender, the experimental method reduces selection bias and improves internal validity. Randomization helps balance known and unknown factors across conditions, allowing for more generalizable results regarding the influence of cost precision, learning orientation, and gender on eco-friendly NPD. According to Cohen, Manion, and Morrison (2011), random assignment is essential in experimental research because it controls for confounding variables and increases the reliability of causal inferences.

Random assignment is particularly relevant for this study as it ensures that differences in eco-friendly design choices are not due to individual differences in experience, background, or external organizational factors. This feature is key in making the study's findings applicable to broader populations of designers, beyond the specific sample used.

e. Ecological Validity and Practical Implications

While experiments often face criticism for lacking ecological validity, carefully designed experiments with realistic NPD tasks can closely simulate real-world conditions, making findings applicable to actual product design scenarios. In this study, participants would complete a realistic NPD task, such as designing a sustainable consumer product, with experimental conditions that mimic decision-making scenarios they might encounter in their professional roles. By creating a realistic yet controlled environment, the experiment can provide practical insights into how design teams might optimize their processes to enhance eco-friendly NPD (Bordens & Abbott, 2018).

Experimental tasks related to NPD also allow for measurable and comparable outcomes, which is essential for evaluating eco-friendly features across conditions. These tasks enable researchers to directly observe and quantify eco-friendly decisions, enhancing the study's applicability and relevance for organizations seeking to understand how different factors influence sustainable design (Rosenthal & Rosnow, 2008).

Experimental Task and Procedure

The task performed by participants in the experiment is designing a new product in the form of doll house using Lego like blocks in a hypothetical company. Detail steps of the task is as follows:

1. Assign participants randomly to cost precision conditions and measure or prime their learning orientation.
2. Provide a simulation of NPD task where participants make decisions on materials, manufacturing processes, and design features under different cost precision conditions.
3. Analyze designs of the new product based on the total cost and the extent of eco-friendly features included. Degree of eco-friendly features is measured from total plastic ingredients of the blocks which construct the doll house.

3. Results and Discussion

3.1 Results

The analysis was conducted using a 2x2x2 ANOVA to examine the effects of cost precision (InfoBiaya), gender, and learning orientation (LearnOr) on eco-friendly new product development (NPD) among undergraduate accounting students. The primary focus was on both the main effects of each variable and their interactions.

Before running the ANOVA, homogeneity test should be performed. Based on the results of the homogeneity test in table 1, a significant value of $0.444 \geq 0.05$ is obtained. Meaning, it can be concluded that the variants of the data groups in this study are the same or homogeneous. This means that the variance of the data groups in this study is not significantly different.

Table 1
Homogeneity Test Result
Levene's Test of Equality of Error Variances

F	df1	df2	Sig.
0.988	7	109	0.444

1. Main Effects

Result of ANOVA can be seen in table 2. Based on ANOVA result, main effect of the independent variable which is hypothesized in H1, H2 and H3 can be concluded as follows:

Cost Precision (InfoBiaya): The main effect of cost precision on eco-friendly NPD was not statistically significant (F = 3.193, p = 0.077). This suggests that the level of precision in cost information alone did not significantly influence the inclusion of eco-friendly features in the designs.

Gender: Similarly, gender did not have a statistically significant effect on eco-friendly NPD (F = 0.197, p = 0.658). This result indicates that male and female participants did not differ significantly in their propensity to incorporate eco-friendly features when cost precision was not considered in interaction.

Learning Orientation (LearnOr): The main effect of learning orientation was also non-significant (F = 0.041, p = 0.840), suggesting that the designers' learning orientation alone did not independently influence eco-friendly NPD.

Table 2
ANOVA Result

Dependent Variable: EcoFriendly

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	18.613[a]	7	2.659	1.625	.136
Intercept	1129.593	1	1129.593	690.513	.000
InfoBiaya	5.224	1	5.224	3.193	.077
Gender	.322	1	.322	.197	.658
LearnOr	.067	1	.067	.041	.840
InfoBiaya * Gender	11.994	1	11.994	7.332	.008
InfoBiaya * LearnOr	8.474	1	8.474	5.180	.025
Gender * LearnOr	1.092	1	1.092	.668	.416
InfoBiaya * Gender * LearnOr	4.376	1	4.376	2.675	.105
Error	178.310	109	1.636		
Total	2773.000	117			
Corrected Total	196.923	116			

R Squared = .095 (Adjusted R Squared = .036)

2. Interaction Effects

The interaction effects provide more nuanced insights into how cost precision, gender, and learning orientation influence eco-friendly NPD when considered together. Table 2 also revealed the conclusion for each hypotheses concerning interaction effect as follows:

Cost Precision * Gender Interaction (InfoBiaya * Gender): There was a significant interaction effect between cost precision and gender on eco-friendly NPD (F = 7.332, p = 0.008). This finding indicates that cost precision influenced eco-friendly NPD differently for male and female designers. Specifically, the presence of precise cost information appears to encourage female designers more than male designers to incorporate eco-friendly features in their designs, supporting Hypothesis 5 (H5). This aligns with social role theory, which suggests that women may be more responsive to environmental considerations, especially when provided with clear financial information, as it reduces perceived risk and supports their natural pro-environmental inclinations (Zelezny, Chua, & Aldrich, 2000).

Figure 2. Graphical Plot of Interaction between Cost Precision and Gender

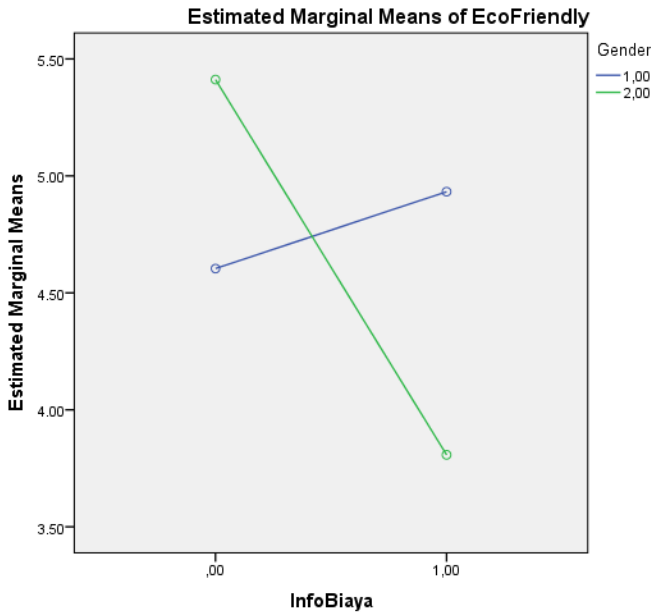
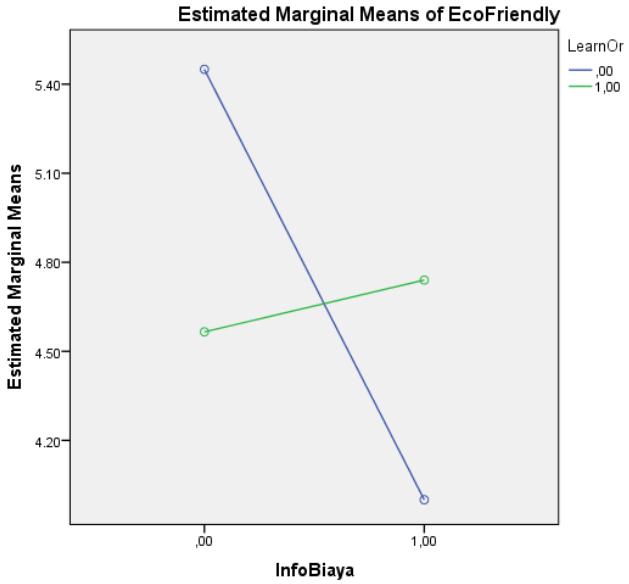


Figure 2 shows that the more precise cost information (1.00) compared to less precise one (0.00) resulting a more eco-friendly design mean (lower score revealed better eco-friendly feature due to lower plastic ingredients) for female designer (2.00, green line).

Cost Precision * Learning Orientation Interaction (InfoBiaya * LearnOr): The interaction between cost precision and learning orientation was also statistically significant (F = 5.180, p = 0.025). This suggests that designers with high learning orientation were more responsive to precise cost information, leading to greater inclusion of eco-friendly features in their designs. This finding supports Hypothesis 4 (H4), which posited that the impact of cost precision on eco-friendly NPD would be stronger among designers with high learning orientation. This result is consistent with agency theory, which posits that precise information empowers designers with high learning orientation to make sustainable choices without the perceived risk associated with imprecise cost estimates (Calantone et al., 2002).

From figure 3 it can be seen that the more precise cost information (1.00) compared to less precise one (0.00) resulting a more eco-friendly design mean (lower score revealed better eco-friendly feature due to lower plastic ingredients) for high learning orientation (0.00, blue line).

Figure 3. Graphical Plot of Interaction between Cost Precision and Learning Orientation



Gender * Learning Orientation Interaction (Gender * LearnOr): The interaction between gender and learning orientation was not significant (F = 0.668, p = 0.416). This result suggests that gender and learning orientation did not jointly influence eco-friendly NPD in a significant way when cost precision was not considered. Therefore, Hypothesis 3, which anticipated an effect of gender alone, was not supported by this interaction.

Three-Way Interaction (InfoBiaya * Gender * LearnOr): The three-way interaction between cost precision, gender, and learning orientation was not statistically significant (F = 2.675, p = 0.105). This result suggests that the combined effects of cost precision, gender, and learning orientation on eco-friendly NPD were not significant enough to warrant a three-way interaction effect. Therefore, Hypothesis 6, which anticipated the strongest eco-friendly NPD choices among female designers with high learning orientation and precise cost information, was not supported.

3.2 Discussion

The findings of this study underscore the importance of interaction effects in understanding the drivers of eco-friendly NPD. While individual main effects of cost precision, gender, and learning orientation were not significant on their own, the interactions between cost precision with gender and learning orientation revealed significant insights. The significant interaction between cost precision and gender aligns with previous research suggesting that women are generally more environmentally conscious, especially when financial uncertainties are minimized (Eagly & Wood, 2012). This implies that organizations aiming to promote eco-friendly NPD could benefit from providing designers, particularly female designers, with precise cost information to facilitate sustainable decision-making.

The interaction between cost precision and learning orientation further suggests that designers with high learning orientation benefit from cost precision in eco-friendly design decisions. This finding highlights the importance of fostering a learning-oriented culture within design teams, as such individuals are more inclined to leverage cost information to explore sustainable options (Sinkula, Baker, & Noordewier, 1997). Organizations that wish to enhance eco-friendly NPD outcomes may therefore benefit from providing precise cost information alongside encouraging a high learning orientation among their designers.

Overall, while the study did not support all hypothesized effects, the findings illustrate the nuanced interplay between cost precision, designer characteristics, and eco-friendly NPD. These results

contribute to the literature by demonstrating how cost management practices can interact with individual designer characteristics to promote sustainable innovation. Future research could explore these interactions further, perhaps by including a broader sample of professional designers or by examining additional individual characteristics, such as risk tolerance, that may further influence eco-friendly design choices.

4. Conclusion

This study explored the effects of cost precision, designer's learning orientation, and designer's gender on eco-friendly new product development (NPD), providing insight into how financial data precision and individual characteristics interact to influence sustainable design choices. Using an experimental approach with undergraduate accounting students as proxies for product designers, we found significant interaction effects between cost precision and gender, as well as between cost precision and learning orientation. Specifically, cost precision had a greater positive effect on eco-friendly design choices among female designers and those with a high learning orientation. These findings underscore the importance of understanding how cost management practices and individual designer traits combine to support or hinder sustainability in product innovation. Overall, this research highlights the role of precise cost information in enabling designers, especially those predisposed to environmental responsiveness, to pursue sustainable design choices more confidently.

The experimental method is highly suitable for investigating the effects of cost precision, learning orientation, and gender on eco-friendly NPD due to its capacity to control and manipulate variables, test causal relationships, and analyze interaction effects. By designing a realistic NPD task within a controlled experimental framework, this approach provides a robust platform for understanding how specific factors influence eco-friendly design decisions. Experimental findings from this study will be valuable for companies and design teams seeking to foster sustainable innovation, with implications for refining NPD practices based on cost management, designer characteristics, and demographic factors.

Research Limitations

This study has several limitations that should be considered when interpreting the results. First, the use of undergraduate accounting students as surrogates for professional product designers may limit the generalizability of the findings. While accounting students are familiar with cost-related decision-making, they may not fully represent the complexities faced by experienced product designers in real-world settings. Second, the experimental design, though effective for isolating effects, may not capture the broader organizational and industry contexts that can also impact eco-friendly NPD decisions. Third, the study focused on gender, cost precision, and learning orientation but did not account for other potential influences such as risk tolerance, environmental attitudes, or team dynamics, which could affect eco-friendly NPD.

Although the experimental method provides strong causal inferences, it may face limitations such as artificiality and limited external validity. To address these concerns, the study can use a sample of professional designers, ensuring the findings reflect real-world applications. Additionally, while laboratory settings may not fully replicate organizational constraints, the experiment can simulate realistic budget limitations, deadlines, and other situational factors, enhancing the ecological validity of the findings.

Moreover, because gender and learning orientation are more intrinsic characteristics, priming or measuring these variables carefully is essential to avoid confounding effects and ensure reliable results. Cross-validation with other methods, such as field studies or longitudinal analysis, could further validate findings and enhance their generalizability to other settings (Creswell & Creswell, 2017).

Avenue for Future Research

Future research could address these limitations by conducting similar studies with professional designers to enhance the generalizability of the findings. Additionally, future work could expand on these findings by incorporating other individual characteristics, such as risk tolerance and environmental values, which may interact with cost precision to shape sustainable design decisions. Exploring the role of team dynamics, particularly in collaborative design environments, could also offer valuable insights,

as eco-friendly NPD often requires input from multiple stakeholders. Furthermore, longitudinal studies could examine how learning orientation and responsiveness to cost precision evolve with experience, providing a more nuanced understanding of the factors that foster sustainability in product development over time. These avenues offer promising directions for future research into how financial, individual, and organizational factors converge to drive eco-friendly innovation.

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