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"ECO-INNOVATION, LEARNING ORIENTATION AND COST PRECISION: A STRATEGIC APPROACH TO SUSTAINABLE PRODUCT DESIGN"

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Abstract

This study explores the impact of cost information precision, learning orientation, and performance-prove orientation on sustainable product design in the context of ecological innovation and cost efficiency. The method applied in this study is a laboratory experiment with a 2x2x2 factorial design, involving 117 accounting students as participants. The results of the ANOVA test show that each independent variable does not have a significant main effect. However, interestingly, the interaction between cost information precision and performance-prove orientation proved to be significant, indicating that precise cost information is more effective in encouraging sustainable product design when accompanied by motivation to prove performance. These findings confirm that sustainable product design does not only depend on technical factors, but also requires support from cognitive and motivational aspects. This study provides theoretical contributions and practical implications for eco-innovation strategies in facing competition in the industry.

Keywords: Sustainable Product Design, Cost Precision, Learning Orientation, Performance Prove Orientation.

INTRODUCTION

Eco-innovation represents a strategic initiative aimed at developing sustainable and environmentally friendly solutions that enable firms to maintain their competitive edge. By creating efficient products, utilizing responsible materials, and minimizing waste, these companies can satisfy the increasing consumer demand for sustainability, all while lowering costs and exploring new market opportunities (Janahi et al., 2021) In a rapidly evolving and unpredictable business landscape, innovation is crucial not only for enhancing operations and products but also for mitigating environmental impact and fostering long-term growth. (Martí et al., 2024). Analyzing eco-innovation strategies means looking beyond mere business profits. It is about how companies can create environmentally friendly solutions without neglecting human needs and long-term sustainability. Evaluating eco-innovation involves considering business beyond mere profit, ensuring that every design and production choice serves the interests of consumers, society, and the environment. Through these approaches, companies exhibit social responsibility while contributing to a more robust and sustainable future.(Janahi et al., 2021).

Previous studies indicate that environmental damage in Indonesia is a serious problem that affects people's lives. Meanwhile, Sarlin (2024) emphasizes the importance of using environmentally friendly packaging to reduce the negative effects of single-use plastics in sustainable industries. (Sarlin, 2024). This study uses an ecological innovation approach in the development of new sustainable products. This is in line with the concept of ecological innovation theory introduced by Rene Kemp and Peter Pearson in the early 2000s. In the face of challenges such as climate change, environmental degradation, and natural resource crises, innovations focused on sustainability are increasingly important in industrial and agricultural development strategies. One rapidly developing theoretical approach is eco-innovation by Kemp and Pearso (2007), which is a type of innovation that not only improves economic performance but also significantly reduces negative impacts on the environment (Marín-Vinuesa et al., 2020). This concept was first developed systematically, defining eco-innovation as the process of developing or implementing new products, services, processes, or managerial methods for an organization, with the primary goal of reducing environmental risks and improving resource efficiency (Kuncoro, 2017). This approach is an important foundation in the design of sustainable production and management systems, as it encompasses technological, social, and institutional dimensions (Karakter et al., 2017).

Rennings (2000) introduced the concept of "double externality," which indicates that eco-innovation faces two types of externalities: knowledge externalities (as with innovation in general) and environmental externalities, which often require policy intervention for the adoption of these innovations (Rogge et al., 2017). According to Carrillo-Hermosilla et al. (2010) classifying eco-innovation into four main categories: Product Innovation, Process Innovation, Organizational Innovation, Systemic Innovation. Each reflects a different approach to reducing a company's ecological footprint (Nurhayati & Purnomo, 2017). This study examines environmentally friendly innovation and cost efficiency, two important aspects of sustainable product design strategies that are increasingly relevant in the face of competition in the global industry (Arifa K et al., 2021). Environmentally friendly innovation, or green innovation, refers to companies' efforts to develop products, processes, or technologies that minimize negative impacts on the environment. This includes the use of more environmentally friendly raw materials, reducing carbon emissions in the production process, and creating products that can be recycled or reused (Wen & Harris, 2020). Meanwhile, cost efficiency encompasses various strategies to reduce expenses, ranging from energy and water conservation, utilization of waste as a new resource, to optimization of logistics and manufacturing processes (Hery Suprapto, 2016). When these two approaches are integrated into product design, the result is not only improved environmental sustainability, but also strengthened corporate competitiveness through cost reduction and enhanced brand image.

Sustainable packaging is now a crucial component of corporate sustainability strategies, as it not only protects products but also reflects a company's environmental values and contributes to reducing its ecological impact. (Dewi et al., 2023). According to a journal written by Sarlin, there are several areas that have not been fully explored and could be opportunities for future research (Sarlin, 2024). First, although this journal provides comprehensive review results, integrated quantitative measurements of the effectiveness of various types of environmentally friendly packaging, such as PLA, PHA, and recycled paper, are still very minimal. This makes it difficult to conduct objective and systematic comparisons of environmental impacts across various industrial sectors.

This study itself makes a significant contribution by integrating two approaches that are often considered contradictory, namely environmentally friendly innovation and cost efficiency (Rohmah, 2019). Most previous studies have focused on one aspect, either from the perspective of environmental sustainability without considering the economic impact, or conversely, emphasizing cost efficiency without regard to ecological aspects (Wisnubroto et al., 2023). This study offers a new perspective by showing that product design that takes environmental aspects into account can serve as a strategy to reduce production costs and increase competitiveness amid increasingly fierce industrial competition. In addition, another novelty lies in its strategic approach, whereby sustainable design is not only viewed as an additional element in corporate social responsibility policies, but as an integral part of competitive advantage that is integrated into business strategy (Suardhika, 2012).

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

In the context of new product development, especially eco-design-based products, cost precision plays a very important role (Ramadhani et al. 2024). This information enables designers and company managers to assess long-term cost efficiency. Management control theory emphasizes the importance of collecting and using accurate and relevant cost data to improve decision-making within organizations (Alfaried et al. 2023). Research shows that consumers who have access to comprehensive cost precision tend to prefer environmentally friendly products, because they can assess the financial benefits offered by these products (Nurul Fitria 2024). Research also shows that applying Life Cycle Assessment (LCA) in product design can optimize production costs and reduce environmental impact (Muhammad and Syahrullah 2022). Furthermore, it shows that organizations that implement appropriate cost-based performance measurement systems can achieve competitive advantage through a sustainable approach (Melsi Febrianti 2025). Prior studies, including Booker et al. (2007) and Jatiningsih and Sholihin (2015), show that more precise cost information improves decision quality in new product development. When managers clearly understand the cost implications of design choices, they can better evaluate trade-offs and allocate resources efficiently. Therefore, cost precision is likely to influence sustainable product design, where accurate cost insights are crucial for balancing environmental and economic goals.

H_1: Cost Precision Affects Sustainable Product Design.

Learning orientation encourages product designers to continuously seek new knowledge, adopt environmentally friendly technologies, and understand sustainability trends and regulations (Gumulya 2023). Designers with a high learning orientation tend to be open to change, reflective about past experiences, and proactive in developing innovative and environmentally conscious design solutions. With a spirit of continuous learning, they are better able to integrate green design principles, such as the use of recycled materials, energy efficiency, and longer product life cycles. Therefore, learning orientation is a key factor that influences the extent to which a designer is able to create products that are not only functional and aesthetic, but also environmentally responsible (Gumulya 2023).

H_2: Learning Orientation of Product Designers Affects Sustainable Product Design.

Designers who are highly motivated to prove their abilities and performance will be more driven to create innovative and high-value works, including in terms of sustainability (Yudha, Hasanah, and Arnani 2025). Designers with this orientation tend to want to demonstrate their competence through recognized achievements, one of which is by applying environmentally friendly design principles that are now increasingly valued globally. In an effort to prove their performance, they will be more open to new technologies, green material selection, and design strategies that have a positive impact on the environment. Thus, the drive to prove themselves not only improves design quality, but also encourages the adoption of more sustainable design practices.

H_3: Performance-Prove Orientation of Product Designers Affects Sustainable Product Design.

METHOD

Participant

The method used in this research to obtain data was the experimental method. There were 117 students from Undergraduate Accounting Study Program, who participated in the study. Using students as participants is appropriate when the experimental scenario does not require professional judgment or experience and can be easily understood by non-experts. In this study, the task was designed to be simple and clear, and the manipulation check confirmed that participants correctly understood the scenario and the intended manipulation, ensuring the validity of using students in the experiment.

Measurement of Variables

The dependent variable, namely sustainable product design, was evaluated through the use of environmentally friendly materials, energy efficiency, waste reduction, and the application of life cycle principles. The independent variables included cost precision (specific cost which measured by exact rupiah-amount information, and relative cost which measured by comparison of cost between materials type), learning orientation, and performance-prove orientation evidence. Learning orientation reflects a person's focus on developing competence, gaining new skills, and mastering tasks, measured using items from Vandewalle's (1997) Goal Orientation Scale. Performance-prove orientation captures individuals' desire to demonstrate their competence and gain favorable judgments from others.

Research Model

This study used a 2x2x2 factorial experimental method that tested three main independent variables, namely:

1. Cost Precision (Specific vs Relative)
2. Learning Orientation (High vs Low)
3. Performance-Prove Orientation (High vs Low)

Experimental design provides researchers with the opportunity to test hypotheses through clearly defined steps before conducting the experiment (Nanda Pratama et al., 2024). The method is the most effective way to test cause-and-effect hypotheses and ensure internal validity. Factorial design allows for the testing of multiple hypotheses simultaneously, without the need to conduct separate experiments for each hypothesis (Hinkelmann, 2012). The basic statistical methods used to test hypotheses is analysis of variance (Nurjanah & Jatiningsih, 2023).
Table 1 explains each combination of variables, produces eight experimental cells consisting of grouping participants into specific treatments.

Table 1. Experimental Design

Cost Information	Learning Orientation : High		Learning Orientation : Low	
	Performance Prove : High	Performance Prove : Low	Performance Prove : High	Performance Prove : Low
Specific	Cell 1	Cell 3	Cell 5	Cell 7
Relative	Cell 2	Cell 4	Cell 6	Cell 8

The combination of three variables was grouped into cells as follows:

Cell 1: Specific cost information, high learning orientation, and high performance prove
Cell 2: Relative cost information, high learning orientation, and high performance prove
Cell 3: Specific cost information, high learning orientation, and low performance prove
Cell 4: Relative cost information, high learning orientation, and low performance prove
Cell 5: Specific cost information, low learning orientation, and high performance prove
Cell 6: Relative cost information, low learning orientation, and high performance prove
Cell 7: Specific cost information, low learning orientation, and low performance prove
Cell 8: Relative cost information, low learning orientation, and low performance prove
Through this design, researchers can test the main effects of each variable and the interaction effects between variable combinations on product design outcomes that reflect innovative value and cost efficiency. This approach also allows for richer and more in-depth analysis.

RESULTS AND DISCUSSION

Descriptive Statistics

The instruments were randomly assigned to participants. The purpose of this method was to ensure that the results truly reflected the objective effects of the treatment and were not influenced by other variables. This approach supported the increased internal validity of the study. In addition, a series of questions were asked to test participants' understanding of the experimental treatment (manipulation) given. These questions aimed to ensure that participants were aware of whether they received cost information in specific or relative terms, and understood that the choice of materials affected the extent to which the resulting design was environmentally friendly. Based on the manipulation test results, 117 participants were deemed eligible for analysis, indicating that all participants (100%) successfully understood and passed this verification process.

Table 2. Descriptive Statistics

Cost Precision	LearnOr	PerfProve	Mean	Std.Deviation	N
Specific	Learning Orientation Low	PerfProve Low	4,2500	1,25831	4
		PerfProve High	5,5000	1,60357	8
		Total	5,0833	1,56428	12
	Learning Orientation High	PerfProve Low	3,3333	1,52753	3
		PerfProve High	4,6000	1,25678	40
		Total	4,5116	1,29784	43
	Total	PerfProve Low	3,8571	1,34519	7
		PerfProve High	4,7500	1,34481	48
		Total	4,6364	1,36577	55
Relative	Learning Orientation Low	PerfProve Low	4,6667	2,30940	3
		PerfProve High	4,4444	1,33333	9
		Total	4,5000	1,50756	12
	Learning Orientation High	PerfProve Low	5,2500	1,38873	8
		PerfProve High	4,7143	1,15369	42
		Total	4,8000	1,19523	50
	Total	PerfProve Low	5,0909	1,57826	11
		PerfProve High	4,6667	1,17757	51
		Total	4,7419	1,25366	62
Total	Low	PerfProve Low	4,4286	1,61835	7
		PerfProve High	4,9412	1,51948	17
		Total	4,7917	1,53167	24
	High	PerfProve Low	4,7273	1,61808	11
		PerfProve High	4,6585	1,19897	82
		Total	4,6667	1,24528	93
	Total	Low	4,6111	1,57700	18
		High	4,7071	1,25562	99
		Total	4,6923	1,30292	117

The descriptive statistics in table 2 above showed resulting mean of sustainable product design in each experimental groups. It can be acknowledged that between cost precision usage, specific cost revealed more sustainable design (4,6364) compared to relative cost (4,7419). Lower mean of dependent variable reflects more sustainable product design due to lower plastic component used which was not environmentally friendly. Between product designer's learning orientation level, high learning orientation revealed more sustainable design (4,6667) compared to low learning orientation (4,7917). Further, between product designer's performance-prove orientation, low performance-prove orientation revealed more sustainable design compared to high performance-prove orientation. Meanwhile, it can be acknowledged that in case of high performance-prove designers, it would be more suitable using specific cost precision since it would produce more sustainable design compared to relative cost precision. Whereas for low learning orientation designers, more sustainable design would be produced when using relative cost compared to specific one

Hypothesis Test

Hypothesis testing was conducted using ANOVA (Analysis of Variance) at a significance level of 0.05. Table 3 showed result of homogeneity test as the prerequisite condition for performing ANOVA. From table 3 it could be observed that the p-value was 0,595 (>0,05) indicating variances across the experimental groups are statistically equal. This means the assumption of homogeneity of variances is met, suggesting that the groups have similar variability. Therefore, the data meet the prerequisite conditions for conducting ANOVA, and the comparison of group means can proceed reliably

Table 3. Homogeneity

F	df1	df2	Sig.
0,793	7	109	0,595

Based on the ANOVA analysis shown in Table 4, it can be seen that the CostPrec variable has an F value of 0.875 with a p-value of 0.352 (>0.05), which indicates that this variable does not have a significant effect on the dependent variable. In addition, the LearnOr variable also shows an F value of 0.419 with a p-value of 0.519 (>0.05), and the PerfProve variable has an F value of 1.397 and a p-value of 0.240 (>0.05), indicating that neither has a significant individual effect. For the interaction between variables, the combination of CostPrec*LearnOr produced an F value of 3.218 with a p-value of 0.076, which is close to the significance threshold but still >0.05, so it is not significant. On the other hand, the interaction between CostPrec*PerfProve produced an F value of 4.842 with a p-value of 0.030 (<0.05), indicating a significant effect from the interaction between cost information precision and performance-prove orientation on the dependent variable. Conversely, the interaction between LearnOr*PerfProve with an F value of 0.040 and a p-value of 0.842 and the interaction between the three variables CostPrec*LearnOr*PerfProve with an F value of 0.049 and a p-value of 0.825 were not significant because the p-value was greater than 0.05. Thus, it can be concluded that, in general, the variables CostPrec, LearnOr, and PerfProve do not have a significant main effect on the dependent variable. However, the interaction between CostPrec and PerfProve proved to be significant, indicating that the effect of cost information precision on sustainable design is depending on the level of performance-prove orientation of the designers.

Discussion

The results of this study provide interesting insights into the relationship between cost information precision, learning orientation, and performance-prove orientation on sustainable product design. the results of the analysis of variance (ANOVA) show that the direct influence of each independent variable (CostPrec, LearnOr, and PerfProve) on sustainable design is not significant. This finding confirms that efforts to create environmentally friendly designs are not the result of a single factor, but rather a combination of several interacting variables. Specifically, the CostPrec variable was not proven to be significant when tested as the main effect, indicating that the existence of accurate cost information alone is not sufficient to encourage the creation of environmentally friendly designs. This is in line with research (Kuncoro, 2017) and (Nurjanah & Jatiningsih, 2023) emphasizing that cost information systems only function as supporting instruments in decision making, but their effectiveness is greatly influenced by human factors and organizational culture. Similarly, the variables LearnOri and PerfProve individually do not show a significant effect. Although literature such as Gumulya (2023) dan Yudha et al. (2025) emphasizing the importance of learning orientation and performance motivation in enhancing design creativity, this study shows that both factors require the right context in order to make a real contribution to sustainable design.

Interestingly, the interaction between CostPrec and PerfProve proved to be significant with an F value of 4.842 and a p-value of 0.030. This shows that the accuracy of new cost information really does have an impact on environmentally friendly design when combined with designers' motivation level to prove performance. These findings support the eco-innovation theory introduced by (Nurfalah A., 2025) that the success of environmentally friendly innovation requires integration between technical aspects (such as cost information) and motivational and social aspects (such as the drive to achieve). Designers who are highly performance-oriented will use cost information as a tool to demonstrate their abilities, resulting in more environmentally friendly designs.

Table 4. Anova Result

Factors	Mean Square	F-Stat	p-value
COSTPREC	1,461	0,875	0,352
LEARNOR	0,700	0,419	0,519
PERFPROVE	2,332	1,397	0,240
COSTPREC *LEARNOR	5,373	3,218	0,076*
COSTPREC *PERFPROVE	8,083	4,842	0,030**
LEARNOR*PERFPROVE	0,066	0,040	0,842
COSTPREC *LEARNOR* PERFPROVE	0,082	0,049	0,825

Overall, the results of this study make an important contribution to the eco-innovation literature by showing that environmentally friendly design cannot be supported solely by technical factors such as cost information, but also requires motivational and cognitive support. For managerial practice, the implication of these findings is that companies need not only to provide accurate cost information systems, but also to create a strong learning culture and reward mechanisms that encourage a healthy performance orientation. In this way, designers and workers can be motivated to make optimal use of cost information and produce sustainable product innovations. Thus, this study not only reinforces the theoretical concept of eco-innovation, but also offers practical insights for the industrial world in facing global sustainability challenges.

CONCLUSION

This study analyzes the impact of cost precision, learning orientation, and performance-prove orientation on sustainable product design in the context of ecological innovation and cost efficiency. The results show that ANOVA result revealed no significant main effect of CostPrec, LearnOr, or PerfProve individually. However, the interaction between CostPrec and PerfProve proved significant, indicating that cost information precision is more meaningful when accompanied by motivation to prove performance. Thus, it can be concluded that technical factors alone are not sufficient; rather, they must be combined with cognitive and motivational factors to encourage the creation of sustainable eco-design. This study has limitations in the use of student participants, so the results cannot be generalized broadly in an industrial context. Therefore, further research is recommended to involve industry practitioners with diverse backgrounds and add other variables such as organizational culture, technological support, and environmental regulations that can affect the success of eco-innovation. From a practical standpoint, companies need to not only develop precise cost information systems, but also foster a culture of continuous learning and a healthy performance reward system. These efforts are expected to motivate designers and employees to produce environmentally friendly innovations that not only increase competitiveness, but also meet global sustainability demands.

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