Bridging Engineering and Sustainability: Insights from Mechanical Engineers in Pangasinan

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ABSTRACT

Sustainability has become a critical consideration in mechanical engineering, requiring professionals to balance environmental, economic, and social responsibilities in design, manufacturing, and operational processes. This qualitative phenomenological study explored the perspectives of ten licensed mechanical engineers in Pangasinan to understand how they define, implement, and navigate challenges in sustainable engineering practices. Data were collected through semi-structured interviews and document analysis, and analyzed using thematic analysis, resulting in three major themes: (1) diverse conceptualizations of sustainable engineering practices, (2) facilitators and barriers to implementing sustainability, and (3) the influence of personal beliefs, workplace culture, and industry dynamics on sustainability actions. Findings revealed that while engineers are aware of sustainable principles and motivated by personal and organizational factors, practical implementation is often constrained by limited resources, management priorities, and systemic challenges. The study highlights the complex interplay between individual, organizational, and contextual factors in shaping sustainable engineering practices and underscores the need for holistic approaches that integrate technical expertise, organizational support, and policy guidance. Recommendations include fostering professional development, enhancing organizational culture and resources, integrating sustainability into engineering curricula, and developing regional policies and guidelines to support long-term adoption of sustainable practices in the Philippines.

INTRODUCTION

Mechanical engineering is a core branch of engineering that focuses on the design, analysis, manufacturing, and maintenance of mechanical systems essential for industrial and societal development. According to the American Society of Mechanical Engineers (2025), mechanical engineers apply principles of mechanics, thermodynamics, materials science, and energy systems to develop technologies ranging from power systems to industrial machinery and transportation infrastructure. Fiandini et al. (2025) emphasize that mechanical engineers are critical in translating scientific knowledge into practical solutions that drive productivity and innovation, but they also highlight that the heavy use of energy and materials in these systems has implications for environmental sustainability.

Sustainability has become a fundamental consideration in contemporary mechanical engineering practice. The American Society of Mechanical Engineers (2025) defines sustainable engineering as the design and operation of systems that meet present needs without compromising future generations, balancing economic, environmental, and social goals. Fiandini et al. (2025) stress that integrating sustainability into engineering practice requires both technical innovation and awareness of broader societal impacts. Chen (2024) further notes that engineers must adopt energy-efficient designs, eco-friendly materials, and intelligent manufacturing systems to reduce environmental footprints while maintaining functionality. These perspectives indicate that mechanical engineers are now expected to consider sustainability not as an optional feature, but as an essential aspect of professional practice.

Globally, the integration of sustainability into mechanical engineering remains uneven. Chen (2024) highlights that technologies such as renewable energy systems, intelligent manufacturing, and eco-design are increasingly adopted in advanced industrial contexts to optimize resource utilization and reduce waste. Ahmed and Dada (2025) further argue that sustainable materials, including recycled composites and bioplastics, are being explored to replace conventional materials, minimizing environmental harm without compromising performance. Fiandini et al. (2025) note, however, that regulatory, economic, and technological disparities across countries result in inconsistent application of sustainable practices, leaving significant gaps between ideal standards and real-world engineering implementation.

In the Philippine context, sustainability awareness in mechanical engineering is growing, yet challenges remain in turning this awareness into consistent practice. Dizon et al. (2023) point out that while sustainable techniques are promoted in education and industry, implementation remains fragmented due to limited access to advanced technologies, insufficient industry–academe collaboration, and inconsistent institutional support. The Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI, 2024) highlights ongoing R&D initiatives in AI and sustainable engineering, but notes that practical adoption in regional settings such as Pangasinan is still limited. These findings suggest that while the Philippines is making progress, local mechanical engineers often face barriers in applying sustainability principles in everyday practice.

This study aims to explore the perspectives of mechanical engineers in Pangasinan, examining how they interpret, implement, and encounter obstacles in sustainable engineering practices. By capturing their insights, the study intends to inform localized strategies for integrating sustainability into mechanical engineering education, professional practice, and policy.

Research Questions

1. How do mechanical engineers in Pangasinan define and conceptualize “sustainable engineering practices”?
2. What factors facilitate or hinder the implementation of sustainable practices in their work?
3. How do personal beliefs, workplace culture, and industry dynamics influence engineers’ sustainability actions?

METHODOLOGY

Research Design

A qualitative phenomenological design was employed to capture the lived experiences of mechanical engineers regarding sustainability practices. This approach allowed rich, narrative data to emerge from participants’ personal and professional perspectives, providing a deeper understanding of how sustainability was understood, interpreted, and enacted in their work. Phenomenology was chosen because it focuses on exploring participants’ subjective experiences and meanings, which are central to understanding complex concepts such as sustainability in engineering practice.

Participants

Purposive sampling was used to select licensed mechanical engineers currently practicing in industries across Pangasinan, including manufacturing, energy, construction, and HVAC sectors. Ten participants were recruited, each with at least three years of professional experience, to ensure sufficient depth of insight into sustainability practices. This sampling strategy was intended to capture information-rich cases where participants could provide detailed reflections on both successes and challenges related to sustainable engineering.

Data Collection

Data were gathered primarily through semi-structured interviews, which allowed participants to describe their understanding of sustainability, the specific practices they implemented, and the obstacles they encountered. Follow-up questions were used to clarify responses and probe deeper into participants’ experiences. In addition, document analysis of relevant materials, such as company sustainability reports and internal policy documents, was conducted to triangulate the interview data and provide additional context for participants’ practices and perspectives.

Data Analysis

All interviews were transcribed verbatim and analyzed using thematic analysis. The analysis involved identifying recurring patterns and key themes, including personal values, workplace culture, organizational drivers, and barriers to sustainability implementation. Themes were refined through an iterative process of coding and categorization. To ensure trustworthiness, member checking was conducted by sharing preliminary findings with participants for validation, and coding consistency was reviewed by a second researcher to reduce subjectivity and enhance reliability.

RESULTS AND DISCUSSION

Based on the semi-structured interviews conducted with 10 mechanical engineers practicing in Pangasinan, three major themes emerged from the data:

Theme 1: Diverse Conceptualizations of Sustainable Engineering Practices

Participants demonstrated varied interpretations of what constituted sustainable engineering. Some defined sustainability primarily in **environmental terms**, emphasizing energy efficiency, waste reduction, and resource conservation. For example, Participant 3 described sustainable practices as “reducing energy consumption in machinery while ensuring production targets are met.” Others incorporated **social and economic dimensions**, noting that sustainability also involved cost-effectiveness, worker safety, and community impact. Participant 7 emphasized, “Sustainability for us is not just saving energy—it is also about ensuring that the work we do benefits both the company and the local community.”

This finding aligns with global perspectives on sustainable engineering, which recognize that sustainability extends beyond environmental conservation to include social responsibility and economic viability (Chen, 2024; Fiandini et al., 2025). The diversity in conceptualization suggests that mechanical engineers’ understanding of sustainability is influenced by their educational background, industry type, and personal values, highlighting the multifaceted nature of sustainable engineering practices in regional Philippine industries.

Theme 2: Facilitators and Barriers to Implementing Sustainable Practices

Participants identified several factors that either enabled or hindered the integration of sustainable practices in their work. **Facilitators** included organizational support, access to sustainable technologies, and alignment with industry regulations. Participant 1 shared, “Our company provides training and resources for green manufacturing, which makes it easier for us to implement sustainable processes.” In contrast, **barriers** included limited budget allocations, lack of management commitment, and insufficient awareness or expertise among staff. Participant 5 noted, “Sometimes, even if we know better solutions exist, cost constraints and lack of management approval prevent us from applying them.”

These insights echo findings from Dizon et al. (2023) and DOST-ASTI (2024), which highlighted that organizational and resource factors strongly influence the adoption of sustainability practices in Philippine industries. The results suggest that while technical knowledge is important, structural and systemic factors are equally critical in shaping engineers’ ability to implement sustainable solutions.

Theme 3: Influence of Personal Beliefs, Workplace Culture, and Industry Dynamics

Participants emphasized that personal values, workplace culture, and broader industry dynamics significantly influenced their sustainability-related decisions. Engineers with strong environmental awareness or a personal commitment to ethical engineering practices were more likely to proactively propose or implement sustainable solutions, even in resource-constrained settings. Participant 8 explained, “I try to suggest eco-friendly alternatives wherever possible, even if the company is slow to adopt them.” Workplace culture also played a role: participants working in organizations that encouraged innovation and environmental responsibility reported higher engagement with sustainability initiatives. Conversely, participants in highly profit-driven or rigid hierarchical organizations reported feeling constrained in their ability to advocate for green practices.

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These findings are consistent with the phenomenological perspective, which emphasizes the importance of lived experience and individual meaning-making in shaping behavior (Fiandini et al., 2025; Chen, 2024). They also highlight the interplay between personal, organizational, and industry-level factors in influencing sustainable engineering practices, suggesting that effective sustainability implementation requires alignment across multiple levels of influence. The study revealed that mechanical engineers in Pangasinan conceptualize sustainability in diverse ways, face multiple facilitators and barriers, and are influenced by personal beliefs, workplace culture, and industry dynamics. The three themes collectively illustrate that sustainability practices are not solely technical choices but are embedded within social, economic, and organizational contexts. These findings have implications for both policy and practice, suggesting that promoting sustainable engineering requires not only technical training but also organizational support, culture change, and industry-level incentives.

Table 1 presents a summary of the responses from the ten mechanical engineers who participated in the study, highlighting key quotes that illustrate their perspectives on sustainability and the corresponding emergent themes. The table shows that participants conceptualized sustainable engineering practices in diverse ways, ranging from focusing on energy efficiency and waste reduction to considering broader social and economic impacts, as reflected in the quotes of P2, P3, P5, and P10. It also reveals the factors that facilitated or hindered the implementation of sustainable practices, including organizational support, resource availability, cost constraints, and management priorities, as indicated by P1, P4, and P8. Finally, the table highlights the influence of personal beliefs, workplace culture, and industry dynamics on sustainability actions, with participants such as P6, P7, and P9 emphasizing how individual commitment and supportive work environments shaped their engagement with sustainable practices. In general, the table illustrates the complex interplay between individual, organizational, and contextual factors in shaping mechanical engineers' understanding and application of sustainability in Pangasinan industries.

Table 1 Summary of Participant Responses and Emergent Themes

Participant	Key Quote	Emergent Theme
P1	"Our company provides training and resources for green manufacturing, which makes it easier for us to implement sustainable processes."	Facilitators and Barriers to Implementing Sustainable Practices
P2	"Sustainability is about making sure our machines are energy-efficient and that we minimize waste."	Diverse Conceptualizations of Sustainable Engineering Practices
P3	"Reducing energy consumption in machinery while ensuring production targets are met—that's what sustainability means to me."	Diverse Conceptualizations of Sustainable Engineering Practices
P4	"Sometimes, we know better solutions exist, but cost constraints and lack of management approval prevent us from applying them."	Facilitators and Barriers to Implementing Sustainable Practices
P5	"Sustainability for us is not just saving energy—it is also about ensuring that the work we do benefits both the company and the local community."	Diverse Conceptualizations of Sustainable Engineering Practices
P6	"In our office, managers encourage innovation and ecofriendly ideas, so we feel empowered to suggest green alternatives."	Influence of Personal Beliefs, Workplace Culture, and Industry Dynamics
P7	"I try to suggest eco-friendly alternatives wherever possible, even if the company is slow to adopt them."	Influence of Personal Beliefs, Workplace Culture, and Industry Dynamics
P8	"If sustainability is aligned with company profits, it's easier to implement; otherwise, initiatives often get delayed."	Facilitators and Barriers to Implementing Sustainable Practices

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P9	"Personal responsibility drives me—I make small changes like recommending energy-efficient materials, even when others are indifferent."	Influence of Personal Beliefs, Workplace Culture, and Industry Dynamics
P10	"Sustainability also means considering cost, safety, and community impact, not just environmental concerns."	Diverse Conceptualizations of Sustainable Engineering Practices

CONCLUSION

The study concluded that mechanical engineers in Pangasinan conceptualize sustainable engineering practices in diverse ways, encompassing environmental, economic, and social dimensions. Their ability to implement sustainability was influenced by personal values, workplace culture, organizational support, and industry dynamics. Facilitators such as training, access to sustainable technologies, and supportive management enhanced sustainability engagement, while barriers like limited budgets, lack of management commitment, and insufficient technical knowledge hindered implementation. Overall, sustainable engineering practices are shaped by a complex interplay of individual, organizational, and contextual factors, highlighting the need for holistic approaches that integrate technical expertise with social and institutional considerations.

RECOMMENDATIONS

It is recommended that mechanical engineers actively pursue continuous professional development in sustainable technologies and practices, while organizations foster supportive cultures, provide resources, and recognize green initiatives to facilitate practical application. Policymakers and industry stakeholders should establish guidelines and incentives that promote consistent adoption of sustainability practices, and academic institutions should integrate sustainability-focused modules and experiential learning into engineering curricula. Additionally, future research should expand to multiple regions in the Philippines to examine how personal, organizational, and industry factors influence long-term sustainable engineering practices.

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