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Upcycling Urban Styrofoam Waste into Aesthetic 3D Wall Decor: A Sustainable Design Solution for Modern Living

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ABSTRACT

This study aims to formulate knowledge regarding the creative processes in sustainable design through Practice-Led and Practice-Based Research approaches, using styrofoam waste utilization as a case study. As a non-biodegradable solid waste, the volume of styrofoam continues to escalate due to its extensive use in the industrial and household packaging sectors. This research explores the potential of such waste as a primary material for three-dimensional wall decorations that integrate sustainability principles. Through an exploratory method, the study encompasses stages of form development, surface design treatment using cement coating, and the application of spray-painting techniques to create dynamic visual effects. Experimental results demonstrate that styrofoam waste can be transformed into aesthetic elements characterized by structural integrity and artistic surface values. Beyond expanding the horizons of art and design practice, this research offers a tangible contribution to mitigating plastic-based waste that adversely affects the environment and health. Both theoretically and practically, this study generates novelty in material development, techniques, and waste-based design structures that support the advancement of Sustainable Design within the 3R (Reduce, Reuse, Recycle) framework applicable to urban societies.

Keywords: upcycling; styrofoam waste; modern interior wall décor; practice-based research; sustainable design

ABSTRAK

***Upcycling* Limbah Styrofoam Perkotaan menjadi Dekorasi Dinding 3D yang Estetis: Sebuah Solusi Desain Berkelanjutan untuk Hunian Modern.** Penelitian ini bertujuan untuk merumuskan pengetahuan mengenai proses kreatif dalam desain berkelanjutan melalui pendekatan *Practice-Led* dan *Practice-Based Research*, dengan studi kasus pemanfaatan limbah styrofoam. Sebagai limbah padat non-biodegradabel, volume styrofoam terus meningkat seiring tingginya penggunaan di sektor industri dan kemasan produk rumah tangga. Penelitian ini mengeksplorasi potensi limbah tersebut sebagai material utama dekorasi dinding tiga dimensi yang mengintegrasikan prinsip keberlanjutan. Melalui metode eksploratif, penelitian mencakup tahapan pengembangan bentuk, pengolahan desain permukaan (*surface design*) dengan pelapisan semen, serta aplikasi teknik cat semprot untuk menciptakan efek visual yang dinamis. Hasil eksperimen menunjukkan bahwa limbah styrofoam dapat ditransformasikan menjadi elemen estetis yang memiliki keunggulan pada kekuatan struktur dan nilai artistik permukaan. Selain memperluas cakrawala praktik seni dan desain, penelitian ini memberikan kontribusi nyata dalam mitigasi limbah plastik yang berdampak buruk pada lingkungan dan kesehatan. Secara teoretis dan praktis, studi ini menghasilkan kebaruan mengenai pengembangan material, teknik, serta struktur desain berbasis limbah yang mendukung pengembangan

Desain Berkelanjutan melalui kerangka kerja 3R (*Reduce, Reuse, Recycle*) yang dapat diterapkan di masyarakat urban.

Kata kunci: upcycling; limbah styrofoam; dekorasi dinding interior modern; penelitian berbasis praktik; desain berkelanjutan

1. Introduction

Styrofoam, or expanded polystyrene (EPS), has become a ubiquitous material in global packaging and food industries, valued for its lightweight, insulating properties, and cost-effectiveness. However, its environmental footprint is disproportionately high; EPS is derived from petroleum and is inherently non-biodegradable, often taking centuries to fragment into harmful microplastics (Geyer et al., 2017). In Indonesia, the management of EPS waste remains a critical challenge. Inefficient waste-to-energy systems and low recycling rates result in a substantial portion of EPS accumulating in landfills or leaking into fragile marine ecosystems, exacerbating the national waste crisis (Jambeck et al., 2015).

While technical engineering solutions for EPS recycling exist, there is a burgeoning need for interdisciplinary approaches that integrate environmental science with creative industries. Preliminary observations in various public facilities in Indonesia reveal a "spatial void" in architectural interiors, where lobbies and entrance areas often lack aesthetic focal points that reflect contemporary environmental values. This gap presents a strategic opportunity to integrate artistic elements with ecological solutions.

This study explores the potential of styrofoam waste as a viable medium for three-dimensional wall decorations, shifting the focus from mere material experimentation to a structured design inquiry. Adopting a circular economy framework and the 'waste-to-art' principle, this research seeks to re-evaluate waste not as a liability, but as a high-value resource for interior design (Rauschnabel et al., 2021). Consequently, this research addresses three pivotal questions:

1. How can the physical and chemical properties of styrofoam waste be optimized as a primary material for large-scale interior design?
2. What processing techniques—ranging from heat treatment to solvent manipulation—are most effective for achieving structural durability and aesthetic appeal?
3. How does this transformation contribute to the theoretical discourse on "sustainable aesthetics" and offer a replicable model for practice-led research in art and design?

By positioning the research at the intersection of material innovation and spatial aesthetics, this study contributes to a more nuanced understanding of how creative intervention can drive the circular economy.

2. Literature Review

The discourse on expanded polystyrene (EPS) upcycling in art and design has evolved from simple material reuse to complex structural and aesthetic manipulation. Current scholarship primarily gravitates towards two domains: material reinforcement and surface-driven aesthetics.

2.1. Material Manipulation and Structural Integrity

Recent studies emphasize the duality of EPS as both a fragile waste product and a versatile medium. Susanto & Rahayu (2021) demonstrated that the structural limitations of EPS can be mitigated by compounding waste with specialized adhesives to create lightweight, load-bearing composites. While such techniques facilitate complex shaping and texturing, existing research primarily focuses on the physical transformation of the material, often overlooking the 'aesthetic longevity' required when transitioning from functional objects to large-scale spatial focal points.

The inherent vulnerability of EPS to environmental degradation and mechanical impact remains a central challenge in sustainable design. Kan, A., & Demirboğa, R. (2009); Miller, A., & Johnson, L. (2019. proposed that the durability of wall reliefs could be significantly extended through strategic layering and protective coating. Evidence in material science suggests that applying eco-friendly coatings can substantially increase material resistance, enabling EPS to meet the rigorous demands of long-term installations. Furthermore, the selection of water-based pigments is critical to ensure color stability while maintaining the material's structural integrity, as they prevent the chemical dissolution typically caused by solvent-based alternatives. Yet, much of this existing research is conducted within controlled laboratory settings or small-scale artisanal contexts, leaving a void in how these treatments perform under the high-traffic conditions of public environments.

2.2. Synthesizing the Research Gap: Toward a Scale-Specific Methodology

Despite the comprehensive exploration of EPS processing, a critical synthesis of these literature reveals a significant methodological gap. Most current research remains "object-oriented," focusing on small-scale furniture or isolated art pieces (Susanto & Rahayu, 2021. There is a distinct lack of inquiry into the systemic integration of these techniques for large-scale, three-dimensional wall decorations that must fulfill both the aesthetic requirements of modern living and the maintenance demands of public lobbies. Furthermore, the Indonesian context—characterized by high humidity and specific urban spatial voids—necessitates a more tailored approach that balances artistic expression with structural durability. This study addresses this gap by offering a comprehensive framework for upcycling EPS waste into high-value, large-scale interior elements. In the context of "Waste-to-Art," this approach functions as a medium for social critique against unsustainable disposal patterns while assigning new economic value to discarded materials (Whiteley, 2011).

3. Methods

This study employs a hybrid methodological framework of Practice-Led Research (PLR) and Practice-Based Research (PBR) (Hendriyana, 2021) to explore the transformation of expanded polystyrene (EPS) waste. While conventional qualitative methods, such as phenomenology or grounded theory, focus on observing and interpreting external phenomena, this research positions the creative act as the primary "engine of inquiry" (Candy & Edmonds, 2018). This approach is uniquely suited for addressing the research questions, as it facilitates the generation of "tacit knowledge" through iterative material manipulation—knowledge that cannot be captured through purely descriptive or theoretical analysis.

The research is executed through a systematic three-phase process that integrates action, reflection, and physical evidence:

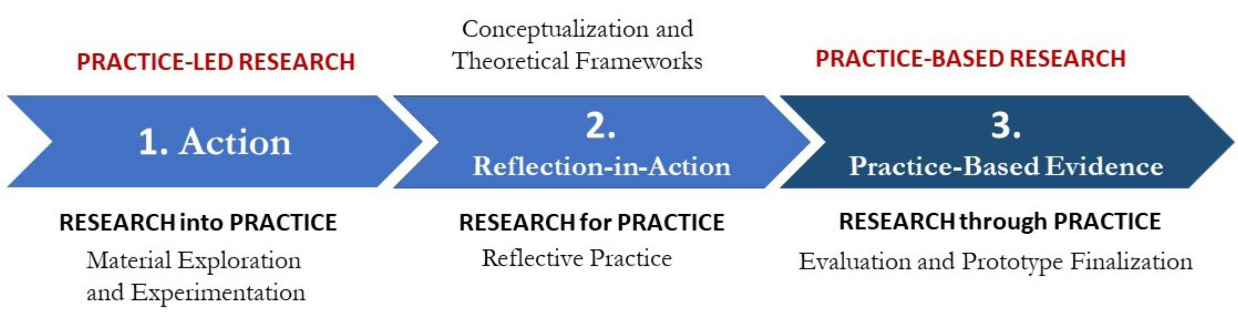

Figure 1: Hybrid methodological framework of PLR and PBR

Phase 1: Material Exploration and Experimentation (Action)
The initial phase focuses on "thinking through making." Unlike standard qualitative inquiries that might prioritize interviews to gauge waste perception, this study utilizes direct physical experimentation. The researcher engages in a series of technical trials including thermal cutting, chemical bonding, and structural layering to identify the mechanical limits of EPS waste. This phase is critical for discovering the technical nuances of the material, such as its response to various solvents and its structural load-bearing capacity when repurposed into large-scale 3D forms.

Phase 2: Reflective Practice (Reflection-in-Action)
Adopting Schön's (1983) framework of the "reflective practitioner," every stage of the design and fabrication process is documented and scrutinized. This phase involves a critical analysis of the synergy between material behavior and aesthetic intent, particularly regarding the effectiveness of eco-friendly protective coatings and water-based pigments. To ensure academic transparency and rigor, this study employs methodological triangulation. The research cross-references experimental data (technical outcomes), visual documentation (process-based evidence), and reflective journals (subjective insights) to validate the emerging design framework.

Phase 3: Evaluation and Prototype Finalization (Practice-Based Evidence)
The final phase culminates in the production of a three-dimensional wall decoration prototype, serving as the primary evidence of the research findings (Candy, 2006). In this context, the physical artifact is not a mere byproduct; it is an embodied form of the research results that validates the study's theoretical propositions.

The artifact serves three strategic functions within the research:
- Proof of Concept: It addresses the "spatial void" in urban public facilities by demonstrating how non-biodegradable EPS can be elevated into high-value interior elements. It embodies technical solutions such as optimized coating thickness and structural interlocking systems.
- Validation through Performance: The finished work is subjected to a simulated evaluation within a lobby environment to test its visual impact and resistance to environmental factors (e.g., humidity and physical pressure). This formal validation distinguishes the study from purely theoretical discourse, providing a replicable model of "waste-to-art."
- Dissemination of Embodied Knowledge: By presenting a physical prototype, the study ensures that the knowledge gained is communicated both textually and tactilely. This fulfills the standards of rigorous design research, where the artifact itself contributes to the advancement of sustainable design discourse and offers a visible benchmark for future urban waste utilization.

4. Discussions

4.1. Styrofoam as a Critical Environmental Pollutant
Styrofoam, technically known as Expanded Polystyrene (EPS), is a synthetic aromatic polymer synthesized from styrene monomers through a polymerization process with the addition of a blowing agent such as pentane (C_5H_{12}) (Geyer et al., 2017).

While it excels in terms of lightweight properties, water resistance, and thermal insulation, EPS possesses a highly stable molecular structure that renders it non-biodegradable. Consequently, it requires hundreds to thousands of years to decompose naturally, making it a persistent threat to both terrestrial and marine ecosystems.

Data from UNEP (2021) indicates that approximately 36% of global plastic production is allocated for single-use packaging, with EPS serving as a significant component. In the Indonesian context, data from the Ministry of Environment and Forestry (2020) reveals that Styrofoam waste generation reaches

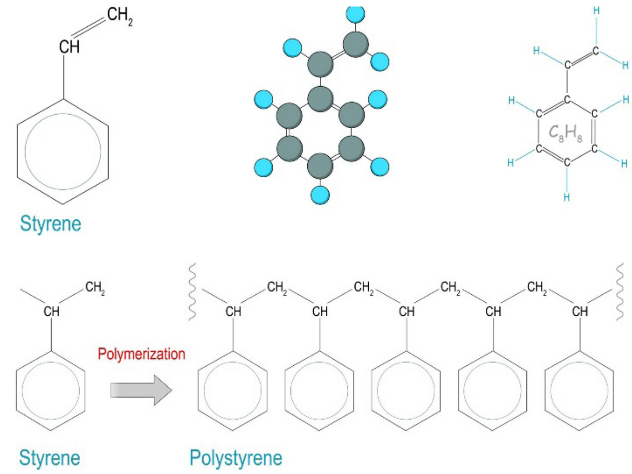

Figure 2: The chemical structure of Styrene and the Polymerization process into Polystyrene

1.3 million tons per year. The primary challenge lies in its low economic recycling value and high-volume, low-density characteristics, which render conventional waste management systems inefficient and economically unviable.

4.2. Methodological Integration: Bridging Practice and Theory

a) Integrating Practice-Led and Practice-Based Research

The integration of Practice-Led Research (PLR) and Practice-Based Research (PBR) provided a unique advantage in discovering the "tacit knowledge" of material manipulation—a nuance often overlooked by purely quantitative studies. The empirical finding that water-based pigments preserve the material's physical integrity validates the importance of "reflection-in-action" (Schön, 1983). This research contributes to the methodological discourse by demonstrating that design decisions—such as technique selection and layering—are not merely aesthetic choices but rigorous scientific responses to material limitations. Thus, the final artifact stands as embodied proof that sustainable design can bridge the gap between technical durability and artistic expression.

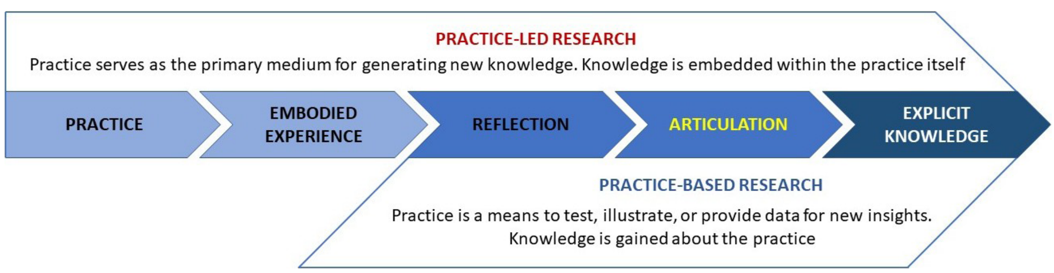

Figure 3: Structural flow, substantive positioning, and discussion

Figure 4: Preliminary material mapping and initial sketching on EPS panels to bridge artistic concept with material constraints. (Photo: Caraka Aji PJ, 2024)

b) Sustainable Design and the Upcycling Movement

The sustainable design approach represents a synergy between visual aesthetics and ecological responsibility. In their *Cradle-to-Cradle* theory, McDonough and Braungart (2002) emphasize the necessity of designing products with full consideration of a closed-loop material life cycle. Within the discourse of contemporary art, the "Waste-to-Art" movement has emerged as a critical response to consumer culture (Whiteley, 2011). This approach transcends the mere transformation of waste into aesthetic objects; it functions as a medium for social critique against unsustainable disposal patterns while simultaneously assigning new economic value to materials previously perceived as worthless.

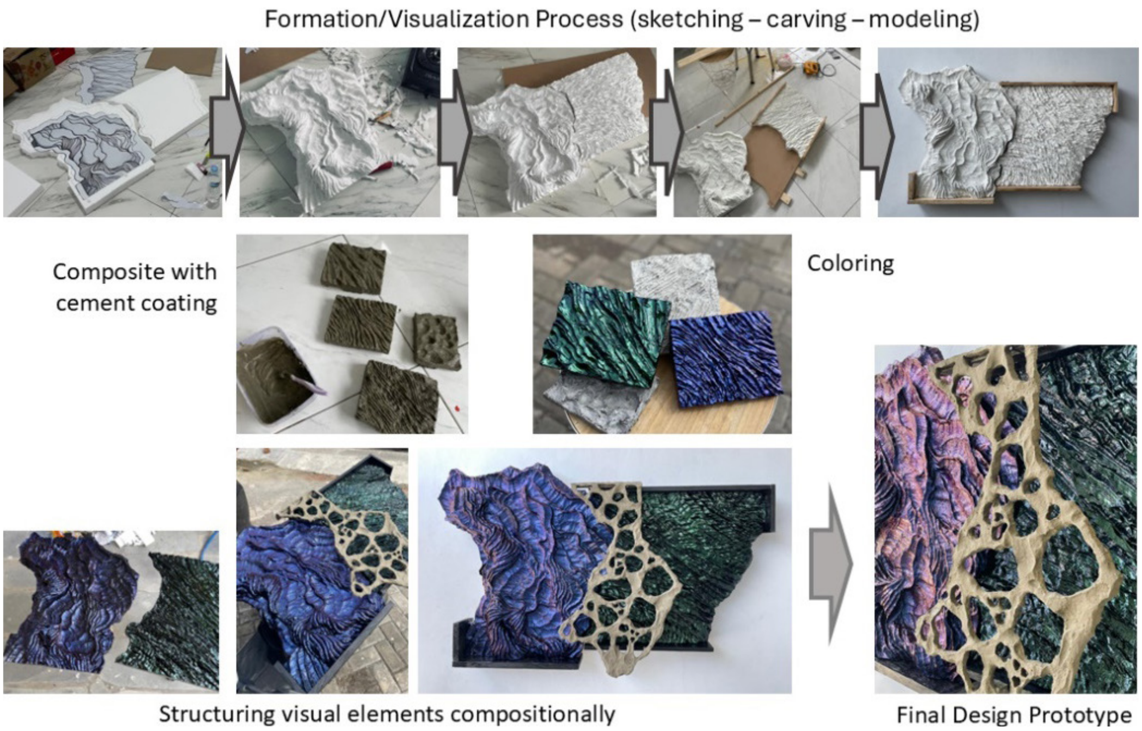

Figure 5: Comprehensive flowchart of the formation, visualization, and coloring process leading to the final design prototype

4.3. Technical Execution and Material Transformation

a) Technical Approaches in EPS Transformation

The transformation of Styrofoam waste into artworks requires specific material manipulation techniques. Artists such as Aurora Robson have demonstrated that the thermoplastic characteristics of EPS can be explored through thermal application and manual shaping to create organic installations (Royte, 2019). This research extends these existing practices by focusing on the textural aspects and modular structures of EPS waste, specifically sourced from electronic packaging.

Figure 6: The subtractive process: manual carving and shaping of the EPS substrate to create organic, sinuous forms. (Photo: Caraka Aji PJ, 2024)

b) Shaping, Texturing, and Coating Techniques

The process begins by transferring organic design patterns onto the EPS surface. The use of a hot-wire foam cutter, combined with manual carving tools, enables the creation of precise, sinuous forms. A key innovation in this phase is the "controlled burning" technique.

Figure 7: Visual comparison between raw EPS surface and the sinuous textures achieved through carving and thermal application. (Photo: Caraka Aji PJ, 2024)

Thermal application generates a porous, rugose texture and naturalistic cracked effects. Beyond providing aesthetic value reminiscent of natural stone, this coarse texture enhances the mechanical interlocking between the Styrofoam substrate and the subsequent cementitious coating.

Figure 8: Experimental modules testing the adhesion and structural integrity of cementitious coatings on varied textures. (Photo: Caraka Aji PJ, 2024)

Experimental results indicate that a mixture of white cement and polyvinyl acetate (PVAc) adhesive yields optimal results for the coating. White cement was selected for its high degree of whiteness, facilitating the subsequent polychromatic coloring process. The addition of PVAc serves as a bonding agent that enhances the flexibility of the cementitious layer to prevent cracking on the elastic substrate, while simultaneously sealing the pores to prevent excessive pigment absorption.

c) Material Potential and Technical Challenges

Experiments demonstrate that EPS waste possesses unique characteristics as an artistic medium, summarized in the following table:

Aspect	Characteristics
Advantages	Low density, ease of subtractive manipulation, excellent affinity for cementitious coating, and versatile surface texturing.
Challenges	Inherently brittle nature, sensitivity to organic solvents (thinners/solvent-based adhesives), and the requirement for specific surface treatments for adhesion.

The finishing process involves fine sanding followed by a layered coloring method:

- Base Coat: Black paint to create depth and shadowing within textural recesses.
- Primary Colors: Purple and green gradients applied to establish visual dimensionality.
- Clear Coating: A glossy coat for moisture protection and enhanced color vibrancy.

The finishing process involves fine sanding followed by a layered coloring method. Experiments demonstrate that by using specific pigments, we can achieve high-value aesthetic results that mask the original "plastic" look of the waste.

Figure 9: Preparation of the structural frame and finalization of carved modules prior to composite application. (Photo: Caraka Aji PJ, 2024)

Figure 10: Polychromatic color testing on cement-coated modules to determine optimal light reflection and color depth. (Photo: Caraka Aji PJ, 2024)

4.4. Analytical Interpretation and Implications

a) **Interaction between Material Behavior and Thermal Techniques**
The application of controlled thermal cutting transcends mere shaping; it represents a strategic manipulation of the cellular structure of EPS. Upon exposure to localized heat, the air-filled cells undergo rapid contraction, leading to a deliberate densification of the surface layer. This technique creates "organic erosion" textures that mimic natural stone or coral, effectively stripping away the "industrial" identity of the plastic.

Figure 11: High-contrast polychromatic panels demonstrating the synthesis of thermal texturing and gradient coloring. (Photo: Caraka Aji PJ, 2024)

b) **Structural Reinforcement and Light Manipulation**
To mitigate the inherent fragility of EPS, a multi-layered resin-based coating system was implemented. Beyond providing durability, this intervention was analyzed for its transformative optical properties. The selection of a semi-gloss coating serves a dual purpose: as a binding agent to prevent surface chipping and as a reflective medium. In public lobbies with limited natural light, this creates a dynamic interplay of light and shadow, enhancing the perceived depth of the 3D relief within large-scale spatial voids.

Figure 12: High-contrast polychromatic panels demonstrating the synthesis of thermal texturing and gradient coloring. (Photo: Caraka Aji PJ, 2024)

Figure 13: Final application in a public lobby: The 3D relief enhances spatial presence through light and shadow interaction.

c) **Synthesis of 3R Framework and Design Longevity**

The integration of water-based pigments demonstrates a successful synthesis of the 3R framework (Reduce, Reuse, Recycle) and design longevity. By avoiding solvent-based pigments, the research prevented unintended chemical melting ("pitting"), thereby preserving structural fidelity. This proves that sustainable design does not necessitate a compromise on elegance; instead, it offers a replicable model for bridging the gap between raw urban waste and refined architectural elements.

Figure 14: Integration of the upcycled 3D wall decor within a modern residential interior, emphasizing aesthetic longevity.

d) Sustainable Aesthetics and the Circular Economy

The visual appeal of the 3D wall decor serves as a medium for environmental communication, supporting the theory of "aesthetic ecological intervention." By replacing the "plastic identity" of Styrofoam with geological textures, the design challenges the stigma of waste as a burden. This aligns with the principles of the Circular Economy, particularly "upcycling" (Rauschnabel et al., 2021). By localizing the transformation of waste into functional art, this study offers a practical model for reducing environmental leakage into Indonesian marine ecosystems, fulfilling both environmental responsibility and high-value aesthetic appeal.

Figure 15: Close-up of the final prototype, showcasing the refined "aesthetic resource" created from repurposed EPS. (Photo: Caraka Aji PJ, 2024)

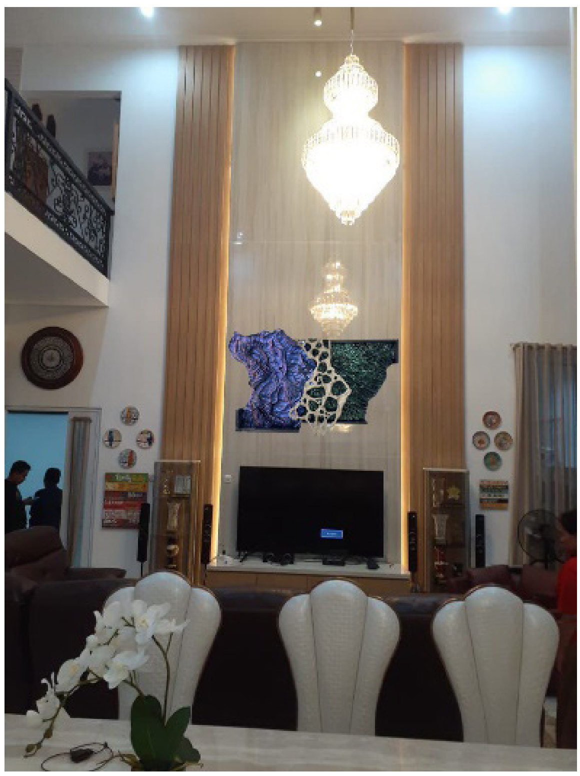

Figure 16: Professional office application: Demonstrating the high-value aesthetic status achieved through creative waste intervention.

5. Conclusions

This study successfully formulates the "Aesthetic Ecological Intervention" model, shifting the paradigm of Expanded Polystyrene (EPS) waste from an environmental burden into a high-value aesthetic resource. The tangible contributions to sustainable design theory and practice are as follows:

1) Innovation in Composite Material Engineering: This research introduces a technical novelty through a cementitious coating system (a blend of white cement and Polyvinyl Acetate) applied to EPS substrates. The findings demonstrate that this technique not only enhances the structural integrity and durability of an inherently fragile material but also creates a mechanical interlocking effect that optimizes surface adhesion.
2) Thermal Manipulation as an Identity Deconstruction Strategy: The exploration of controlled burning techniques provides a theoretical contribution to "sustainable aesthetics." This process scientifically alters the cellular structure of the EPS surface through localized densification, creating organic textures reminiscent of natural stone. This effectively deconstructs the material's "industrial plastic identity."
3) Methodological Synthesis of PBR/PLR: Scientifically, this research proves that the Practice-Based Research (PBR) approach generates precise tacit knowledge regarding material chemical interactions. A key finding is the validation of water-based pigments as a mandatory requirement to maintain the structural stability of EPS, preventing material failure (*pitting*) typically caused by organic solvents.
4) Circular Design Solutions for "Spatial Voids": This study offers novelty in addressing urban architectural gaps by integrating circular economy principles. The resulting artifacts prove that upcycling industrial-scale waste can meet modern interior aesthetic standards without compromising the 3R (Reduce, Reuse, Recycle) framework, while simultaneously generating new economic value for non-biodegradable materials.

This study recommends that design practitioners implement cementitious coating systems and water-based pigments to ensure the structural stability and durability of Expanded Polystyrene (EPS) waste in interior applications. Furthermore, the optimization of controlled thermal manipulation is suggested to deconstruct the industrial identity of waste into high-value organic textures, providing a decorative solution that aligns with circular economy principles. Additionally, a Practice-Based Research (PBR) approach is highly encouraged for future sustainable material development to ensure that design innovations are precise, systematic, and practically viable.

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