Design Thinking and Methodologies for the Transformation Between Material and Immaterial Products

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***Abstract*—The design transition between material and immaterial products has emerged as a critical research focus under the backdrop of digitalization and sustainable development. Grounded in design thinking theory, this paper proposes a three-phase theoretical framework: Frame Taking, Frame Merging, and Frame Giving, systematically exploring the pathways and methodologies for integrating material and immaterial product designs. By incorporating user behavior data, Life Cycle Assessment (LCA), and dynamic optimization mechanisms, this research establishes a design model that balances user needs, technological integration, and environmental sustainability. Case studies involving virtual reality devices and smart home systems validate the applicability and effectiveness of the framework, while also extending the potential of design thinking across various industries. This study not only addresses theoretical gaps in the field of design but also provides practitioners with practical tools and strategies to tackle future design challenges.**

Keywords—Material Products; Immaterial Products; Design Thinking; Transformative Design; Sustainability

I. INTRODUCTION

With the advancement of global digitalization and the sustainable development agenda, the transformative design between material and immaterial products is becoming a critical direction for product innovation (Ghobakhloo et al., 2021). The limitations of traditional material products have been increasingly evident under the impetus of digital technologies. User demands are shifting from single-functionality toward higher-level immersive experiences, customized services, and environmentally friendly designs (Mondejar et al., 2021). For instance, in fields such as smart homes, virtual reality, and digital education, immaterialized design is rapidly gaining traction. By reducing resource consumption, optimizing user experiences, and enhancing product flexibility, such designs have generated immense value for society and industry (Parida et al., 2019).

However, immaterialization is not without burdens. While reducing the use of material resources, it may introduce new environmental challenges, such as the rapid growth of digital service energy consumption, challenges in electronic waste management, and increasingly complex issues surrounding data security and privacy (Yin et al., 2022). The contradiction between resource conservation and environmental impact remains underexplored, particularly in the fusion of material and immaterial product designs. How designers balance user needs, technological innovation, and environmental sustainability in this process continues to be a pressing academic and practical challenge (Hao et al., 2023).

This study focuses on the theoretical and practical issues of transformative design between material and immaterial products, aiming to address the following key questions.

- How can functional virtualization reduce resource consumption while optimizing the energy consumption and environmental burden of immaterialized design (Ching et al., 2022).
- How can a universal design model applicable to various industries be constructed to meet the diverse needs of material and immaterial integrated design (Li et al., 2022).
- How can user behavior data and environmental assessment information be utilized to achieve dynamic optimization in the design process (Nayal et al., 2022).
- What profound impacts do cutting-edge technologies such as the metaverse, artificial intelligence, and the Internet of Things have on the design of material and immaterial products (Wang et al., 2021).
- How can designers play a more active role in addressing data security, privacy protection, and design ethics (Rusch et al., 2023).

Addressing these questions not only contributes to theoretical advancements but also provides significant guidance for design practice (Luo et al., 2023).

Based on the theory of design thinking, this paper proposes a three-phase theoretical framework: Frame Taking, Frame Merging, and Frame Giving. This framework is expanded from multi-dimensional perspectives, including sustainability, user behavior data, and cutting-edge technologies (Ghobakhloo et al., 2021). The applicability and innovativeness of the framework are validated through multiple industry case studies, such as virtual reality devices, medical systems, and smart homes (Parida et al., 2019). Furthermore, this study explores how designers can balance innovation and sustainability in practice by incorporating lifecycle assessment (LCA) methods and user behavior data analysis (Ma et al., 2022). Specifically.

- In the Frame Taking phase, differences in user needs and environmental requirements across industries are analyzed, and data-driven optimization of design objectives is emphasized (Liu et al., 2022).
- In the Frame Merging phase, pathways for the deep integration of material and immaterial characteristics are investigated, and design strategies centered on

resource conservation and energy efficiency are proposed (Ren et al., 2022).

In the Frame Giving phase, methods for enhancing societal recognition of immaterialized designs through market dissemination and user education are explored (George et al., 2021).

By combining theoretical and empirical approaches, this study makes several innovative contributions.

It proposes a design framework based on sustainability and dynamic data optimization, addressing the neglect of environmental impact and dynamic adjustments in traditional design thinking theories (Yin et al., 2022).

It constructs a cross-industry transformative model for material and immaterial products, validating its applicability in areas such as virtual reality, medical devices, and smart homes, thereby providing guidance for multi-domain design practices (Ching et al., 2022).

It introduces user behavior data and lifecycle assessment methods, revealing the critical role of data-driven approaches in immaterialized design, offering new methods for academic research (Luo et al., 2023).

It examines the transformative impact of technologies such as the metaverse and artificial intelligence on the design of material and immaterial products, expanding the foresight and breadth of design research (He et al., 2024).

It focuses on design ethics and privacy protection, proposing an "ethics-sensitive design" sub-framework aimed at constructing societal trust, thereby enhancing the social impact of design research (Rusch et al., 2023).

II. Related Work

In recent years, research on the integration of material and immaterial product design has achieved significant progress across multiple domains, providing essential references for the theoretical framework and practical strategies proposed in this study (D'Amato et al., 2021). However, existing studies still exhibit certain limitations and areas that remain underexplored (Veelaert et al., 2020). This section provides a comprehensive review of the core issues, theoretical foundations, and academic contributions of existing research, analyzing their implications and shortcomings for this study.

A. *Preservation of Intangible Cultural Heritage and Sustainable Design*

The preservation and modernization of intangible cultural heritage (ICH) are crucial topics in the integration of material and immaterial design. A study on the practice of bamboo basketry demonstrates that design technologies significantly optimize traditional craft processes, reduce resource waste, and enhance product innovation (Ren et al., 2021). This research underscores the pivotal role of design intervention in promoting cultural heritage and modernization. However, its case-specific approach lacks a universal framework (Chapman, 2024). Building on this foundation, this paper expands the scope to include cross-industry integration of material and immaterial design.

B. *Quantitative Decision-Making Models in Narrative Design*

Narrative design plays a critical role in improving the market compatibility of immaterial cultural products. A study based on the AHP-TOPSIS model proposed a scientific approach to selecting narrative themes, reducing subjective biases in design decisions through quantitative analysis (Sabatini, 2019). While this research offers a quantitative tool, it insufficiently addresses the adaptability to dynamic market demands and user behavior changes (Bauer et al., 2023). This paper incorporates real-time user data into the design process, developing a dynamic optimization model to address this gap.

C. *Material Innovation and Sustainable Design*

In the field of materials science, research has focused on high-performance, sustainable cobalt-free nickel-rich layered cathodes, proposing viable solutions to reduce reliance on scarce resources (Kirschner, 2022). By combining green design principles and lifecycle analysis (LCA), this study provides an environmentally friendly solution for energy storage technologies. However, its emphasis on single-material optimization overlooks the environmental impact assessment of immaterialized products (Lou, 2019). This paper integrates LCA models further to encompass the lifecycle assessment of hybrid material-immaterial products.

D. *Lifecycle Optimization Design*

Research in the furniture industry has proposed a sustainable design framework emphasizing lifecycle optimization, covering the full process from design to use and disposal (Avilés-Palacios et al., 2021). This study highlights the critical role of user needs in extending product life and reducing waste, providing valuable insights for this research. However, its approach is primarily industry-specific, lacking cross-sector applicability analysis (Fisher et al., 2019). This paper extends the scope by exploring a cross-industry applicable design framework for the integration of material and immaterial products.

E. *Positioning and Innovations of This Research*

Based on the literature review, this study advances existing research in three key ways.

Development of a Cross-Industry Universal Framework: This paper verifies the applicability of the framework in smart homes, medical devices, and educational tools, demonstrating its versatility across industries.

Incorporation of Real-Time User Data and Market Feedback: The introduction of dynamic optimization mechanisms enhances design flexibility and responsiveness to evolving user needs and market conditions.

Lifecycle Assessment Models for Environmental Impact Analysis: By integrating LCA, this paper comprehensively evaluates the environmental impact of hybrid material-immaterial products, proposing optimization strategies (Chamberlain et al., 2019).

Additionally, this study emphasizes design ethics and privacy protection by proposing an "ethics-sensitive design" sub-framework, addressing challenges related to user trust and privacy.

III. Theoretical Framework of Design Thinking for Material-Immaterial Transformation

A. *Essence and Value of Design Thinking*

Design thinking is a human-centered innovation methodology that provides a structured approach to solving complex design problems by redefining issues and generating creative solutions (Nilsson, 2022). In the transformation between material and immaterial products, the key value of design thinking lies in redefining product functions and meanings, while integrating the characteristics of material and immaterial products to meet both user experience and market demands (Frisk et al., 2022).

In the context of digitalization, design must not only focus on technological feasibility but also explore the diversity of user needs (Pankina, 2020). For instance, material products satisfy basic user needs through tactile and functional attributes, while immaterial products enhance personalized services through their extensibility and dynamic nature (Diepenmaat et al., 2020). Consequently, design thinking must balance technology, user experience, and market value to provide systematic guidance for integrating material and immaterial products (Törnroth et al., 2022).

B. *Three-Phase Theoretical Framework for Material-Immaterial Transformation*

To systematically analyze the pathways of transformation between material and immaterial products, this paper proposes a three-phase theoretical framework comprising Frame Taking, Frame Merging, and Frame Giving. This framework highlights the tasks and strategies for designers at each stage, offering guidance for design innovation in the era of digital transformation.

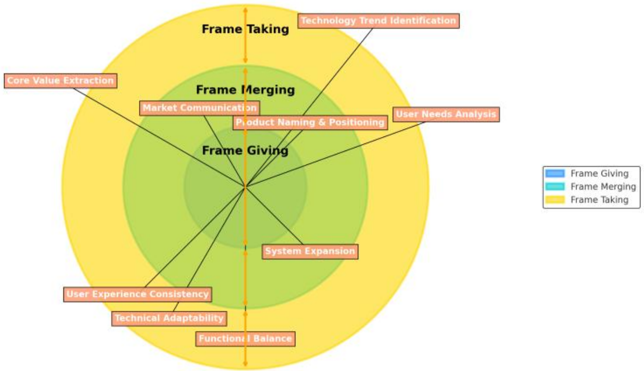

Fig. 1. Three-Stage Hierarchical Interactive Cycle Diagram (New Colors)

C. *Frame Taking*

The core objective of the Frame Taking phase is to analyze the core value of traditional products and identify potential entry points for digital transformation. Designers must redefine design objectives by integrating user needs, technological trends, and market environments. Key strategies include:

1) Analyzing User Behavior Data: Identifying limitations of traditional material products, such as singular functionality or inadequate interactivity.

2) Identifying Digital Optimization Opportunities: Leveraging emerging technologies, such as virtual interaction, data analytics, and remote services, to redefine traditional product functionalities.

3) Extracting Unique Values: Repositioning the unique value of traditional products in a digital context to uncover new design opportunities.

D. *Frame Merging*

The Frame Merging phase focuses on the deep integration of material and immaterial product characteristics, addressing the optimization of functionality and user experience. Designers need to address the following challenges:

1) Technological Compatibility: Ensuring seamless connectivity between physical products (hardware) and digital services (software). For example, iterative optimization of interaction between head-mounted devices and virtual scenarios.

2) Consistency in User Experience: Achieving clear and intuitive interaction logic between material and immaterial products. This requires aligning physical attributes (e.g., touch) with digital feedback (e.g., visual and auditory cues).

3) Balancing Functionality: Avoiding excessive complexity that detracts from core user needs. For instance, Sony optimized hardware comfort and balanced resolution with power consumption to enhance the overall user experience in PS VR.

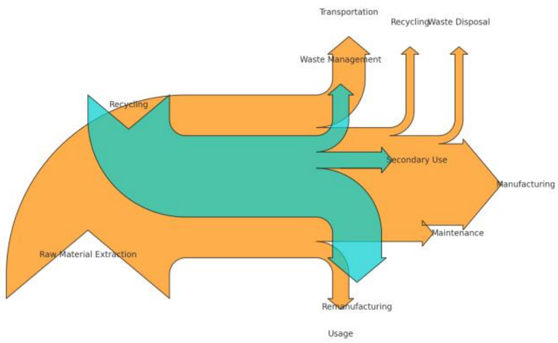

Fig. 2. Enhanced Sankey Diagram for Life Cycle Assessment (LCA) Flow

E. *Frame Giving*

The Frame Giving phase emphasizes communicating the innovative aspects of the design clearly to users and the market. Key tasks include:

1) Product Naming and Positioning: Employing branding strategies to highlight innovative features, such as how digital functionalities redefine the utility of traditional material products.

2) Market Dissemination and User Education: Using real-life scenarios and interactive activities to lower user learning barriers and enhance market acceptance.

3) Expanding Product Ecosystems: Integrating with other digital products or services to establish interconnected product ecosystems.

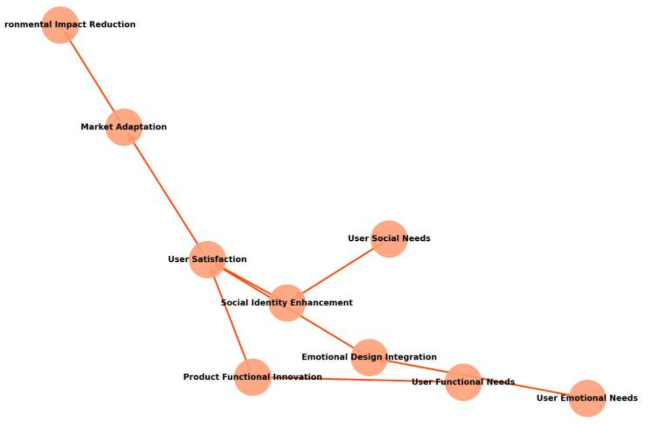

Fig. 3. Causal Loop Diagram: Relationship between User Needs and Design Strategies

IV. Case Study: Integration of Material and Immaterial Products

A. Background

Sony's PlayStation VR (PS VR) serves as a prototypical example of integrating material products (hardware) with immaterial products (virtual content) (Patel et al., 2020). As a virtual reality (VR) headset, PS VR combines digital technologies and hardware devices to deliver an immersive gaming experience (Manukonda et al., 2024). Its innovative design redefined the boundaries of traditional gaming while providing valuable insights for designing VR devices (Raji et al., 2024).

The primary design objective of PS VR was to transcend the physical limitations of traditional gaming equipment, enabling users to interact with virtual worlds in novel ways (Nugroha et al., 2024). Sony faced the challenge of deeply integrating material hardware with immaterial content while ensuring user experience, comfort, and market adaptability (Lantano et al., 2022).

B. Implementation of the Three-Phase Framework in PS VR

Frame Taking: Sony leveraged user research, technological trend analysis, and market insights to define the design objectives of PS VR.

1) User Demand Analysis: Research revealed that traditional gaming devices could not meet users' demands for immersive experiences. Users prioritized more realistic interactions, enhanced natural interactivity, and hardware comfort.

2) Technological Trend Analysis: Sony examined advancements in VR technologies, such as high-resolution displays, 3D audio, and motion tracking, identifying their potential to enable innovative gaming experiences.

3) Redefining Design Objectives: PS VR was repositioned not merely as an accessory to the gaming console but as a platform for creating immersive experiences.

C. Frame Merging: Sony tackled the integration of hardware and virtual content during this phase

1) Technological Compatibility: PS VR was equipped with high-resolution head-mounted displays featuring a 120Hz refresh rate to reduce latency and motion sickness. The PlayStation Camera was used to capture precise head movements, ensuring real-time responsiveness in virtual environments.

2) User Experience Optimization: The headset was designed for lightweight comfort, with adjustable straps to accommodate various head sizes. Integrated 360-degree surround sound further enhanced audio immersion.

3) Physical-Virtual Interaction: PS VR incorporated PlayStation Move controllers to enable users to interact with virtual environments through real-world actions, achieving consistency between physical feedback and virtual visuals.

D. Frame Giving: Sony effectively communicated the innovative aspects of PS VR to users and the market

1) Product Positioning: PS VR was positioned as "next-generation immersive gaming," emphasizing its transformative features and lowering technical barriers for users through intuitive design.

2) Market Dissemination: Sony showcased PS VR at gaming expos and partnered with prominent game developers to release exclusive VR titles, increasing market traction.

3) User Education: Sony shared design stories highlighting innovations, such as reduced motion sickness through high refresh rates and enhanced immersion through audio and motion capture technologies.

Outcomes and Insights

The successful integration of material and immaterial products in PS VR demonstrates the practical value of the proposed three-phase framework. PS VR's design effectively balanced hardware performance and user comfort, establishing it as a benchmark in the VR industry and accelerating the mainstream adoption of virtual reality devices. By mid-2024, global sales of PS VR exceeded 5 million units, underscoring its impact on the market.

V. Methodology and Design Strategies

A. Methodological Framework

The methodological framework of this study is grounded in design thinking theory, proposing a three-phase framework—Frame Taking, Frame Merging, and Frame Giving. It combines qualitative research with quantitative analysis to explore the key stages and innovative pathways of material-immaterial integration. Utilizing tools such as case studies, user behavior analysis, and lifecycle assessment (LCA), the study examines the critical processes and strategies for hybrid design across multiple dimensions. By validating cases across industries, this research offers adaptive design methods centered on user needs and environmental sustainability

B. Core Design Strategies

1) Multi-Dimensional Analysis of User Needs

User needs are the starting point of design thinking. Designers must analyze user needs across three dimensions: functional, emotional, and social. Explicit needs refer to clear user expectations regarding product functionality and convenience, such as immersive experiences in VR devices and ease of operation in smart homes. Implicit needs include latent desires for emotional connection and identity reinforcement, such as aligning virtual content with personal values. Data collection methods, including interviews, surveys, and observation, combined with semantic analysis tools, enable the extraction of key insights, providing a solid foundation for subsequent design phases.

C. *Dynamic Adjustments in the Design Process*

Product design must adapt to the dynamic changes in user behavior and market conditions throughout its lifecycle. This study emphasizes strategies for dynamic adjustments, including.

- Real-time adjustments of product functions and interaction modes based on user behavior data and market feedback.
- Rapid prototyping and iterative user testing to refine design details.
- Post-launch dynamic monitoring of user data through IoT technologies to continuously improve user experience.

D. *Functionality Integration and Sustainable Design*

During the Frame Merging phase, designers must balance functionality and sustainability. Key strategies include.

- Optimizing material use to reduce resource consumption and replacing hardware reliance with virtual functionalities, such as virtual displays.
- Utilizing LCA tools to evaluate environmental impacts across the entire lifecycle, from production to disposal, and optimizing resource allocation accordingly.

E. *Cultural and Market Adaptability in Design*

Cross-cultural markets demand diverse design solutions. Designers must balance localization and global adaptability. Strategies include.

- Incorporating cultural symbols, such as language, visual elements, and traditional customs, into designs for specific target markets.
- Using market feedback data to evaluate product acceptance and user behavior across different cultural backgrounds.

F. *Design Ethics and Building User Trust*

In data-driven design, user privacy and data transparency are paramount. Designers must.

- Clearly define the scope of data collection, avoiding the over-collection of unrelated data.
- Use interaction design to demonstrate transparency and security in data usage, thereby enhancing user trust.

G. *Implementation Pathways*

1) Demand Analysis and Goal Definition

Conduct user research and technological trend analysis to clarify design goals, extract core values from traditional material products, and redefine their functions in the digital context.

2) Cross-Disciplinary Collaboration and Iterative Design

Form interdisciplinary teams to ensure efficient collaboration across hardware, software, and user experience design. Rapidly prototype and test designs iteratively to refine critical details.

3) Data Analysis and Evaluation

Collect user behavior data and market feedback, using data analysis tools to validate design effectiveness. Combine LCA tools to assess environmental impacts and propose data-driven optimization strategies.

4) Design Output and Market Promotion

Through branding, naming, and promotional strategies, translate design outcomes into perceivable product value for users. Develop user education strategies to lower adoption barriers and foster acceptance of innovative designs.

VI. Empirical Research

To address the insufficiency of data validation, this study incorporates a comprehensive empirical research plan that combines quantitative and qualitative methods to validate the effectiveness of the proposed three-phase framework. The plan details the execution steps, data recording and management, and processes for data organization and preprocessing.

A. *Research Objectives*

The goal of this empirical study is to validate the applicability and effectiveness of the three-phase framework in material-immaterial transformation design. Specifically, the study quantifies the framework's impact on user satisfaction, market acceptance, and environmental optimization through user testing and market feedback analysis. Additionally, it provides data support to enhance the scientific rigor and practicality of the theoretical model.

B. *Research Steps*

1) User Testing

The objective is to evaluate product performance in terms of user experience and functionality. One hundred users are selected to test virtual reality devices and smart home equipment. User testing involves 30-minute sessions in controlled environments, measuring satisfaction, interaction intuitiveness, and behavioral metrics (e.g., button presses, voice command usage).

2) Market Feedback Analysis

This step evaluates the effectiveness of market dissemination and user education during the Frame Giving phase. Data on sales and user reviews are collected from e-commerce platforms, and text analysis tools are used for sentiment analysis and topic clustering. Social media discussions are monitored to quantify the effectiveness of market campaigns.

3) Environmental Impact Assessment

Using lifecycle analysis (LCA) tools, this step evaluates the optimization outcomes achieved during the Frame Merging phase. Resource usage and energy consumption data from manufacturing, usage, and disposal phases are analyzed to calculate carbon footprints and energy efficiency, identifying further areas for improvement.

C. *Data Recording and Management*

- Data Recording Methods: User testing data are recorded via electronic surveys and monitoring devices in real-time. Market feedback is collected using web scraping, and environmental data are structured using LCA tools.

Data Protection Measures: All user information is anonymized, stored in encrypted databases with restricted access, and managed in compliance with GDPR requirements.

D. Data Organization and Preprocessing

Data Cleaning: Removing duplicates, invalid entries, and outliers to ensure data completeness and consistency.

Handling Missing Data: Applying mean imputation or model-based estimation for missing values to prevent sample bias.

Data Categorization: Classifying data into user testing, market feedback, and environmental evaluation, and organizing it by indicators such as satisfaction and environmental impact.

Data Standardization: Normalizing quantitative data for comparability and converting qualitative data (e.g., user reviews) into sentiment scores for quantitative analysis.

E. Enhancing Data Quality and Reliability

To enhance data quality, the study employs multiple rounds of user testing and market feedback analysis. Cross-validation of data through diverse tools (e.g., surveys, LCA, and web scraping) ensures reliability. Dynamic monitoring of market feedback and behavioral data over time further validates analytical outcomes.

VII. Discussion and Implications

A. Challenges and Opportunities in the Integration of Material and Immaterial Product Design

The integration of material and immaterial product design presents multifaceted challenges for designers, including technological compatibility, user experience optimization, and effective market communication. Simultaneously, this process offers ample opportunities for innovation. Through case studies and empirical analysis, this study validates the effectiveness of the proposed three-phase framework, revealing several key considerations.

1) Complexity of Cross-Domain Integration

The integration of material and immaterial characteristics requires deep collaboration across disciplines, particularly in complex ecosystems like smart homes. For instance, the synchronization of hardware devices and digital services involves not only technological compatibility but also the consistency of user experience.

2) Dynamic Optimization and Continuous Design

Adapting to evolving user behaviors and market demands is essential. Real-time data plays a pivotal role in supporting design optimization, yet it also requires designers to possess advanced data analysis skills and strategic flexibility.

3) Environmental Costs of Immaterialization

Although immaterial design reduces material resource consumption, it may lead to increased energy demands for digital services. Lifecycle analyses show that the environmental trade-offs of immaterialization are often overlooked in early design phases, necessitating enhanced evaluation and optimization.

4) Cultural Adaptability in Global Markets

Cultural diversity significantly influences product acceptance and user engagement. Incorporating cultural symbols into design can strengthen emotional connections and boost market competitiveness.

B. Implications of the Study

This research emphasizes a systematic approach from demand analysis to design delivery, demonstrating how design thinking can address the complexities of integrating material and immaterial products. Key insights include:

1) Systematic Design Thinking

By applying a structured framework, designers can effectively navigate the challenges of technological and functional integration, improving both the efficiency of the design process and the reliability of its outcomes.

2) Data-Driven Design Optimization

Empirical validation highlights the role of dynamic data in enabling flexible and adaptive design strategies. Real-time feedback mechanisms help designers respond promptly to user needs and market changes.

3) Sustainability as a Core Objective

Balancing functionality and sustainability is critical for future innovation. Strategies such as optimizing material use and extending product lifecycles through virtual functionalities reduce environmental impact while enhancing product longevity.

4) Ethical Design and Trust Building

As user privacy and data transparency become increasingly important, the proposed "ethics-sensitive design" sub-framework provides theoretical support for safeguarding user trust. This positions designers as responsible actors in ethical data management.

C. Future Research Directions

Future studies can expand the scope of this research by exploring the following areas:

1) Cross-Industry Validation and Framework Expansion

While the proposed framework has been validated in virtual reality and smart home contexts, its applicability to other domains, such as healthcare devices and educational tools, requires further examination.

2) Environmental Costs of Immaterialization

Further studies should analyze the hidden environmental costs of immaterialization, including data center energy consumption and electronic waste management. Advanced lifecycle assessment tools can help reconcile the conflict between digital services and sustainability.

3) Cultural Diversity and User Behavior Analysis

Understanding variations in user behavior and market acceptance across cultural contexts can inform the development of more adaptable and inclusive design models.

4) Integration of Emerging Technologies

The rapid development of technologies such as artificial intelligence, the Internet of Things, and the metaverse offers new possibilities for hybrid design. Future research should explore how these advancements can synergize with design thinking to push the boundaries of material-immaterial integration.

VIII. CONCLUSION

A. Research Findings and Contributions

This study explores the transformative design between material and immaterial products, proposing a three-phase theoretical framework—Frame Taking, Frame Merging, and Frame Giving—and validating its applicability through case studies and empirical data. The research demonstrates that design thinking plays a pivotal role in this process, enabling designers to extract value from traditional material products, innovate through digital optimization, and enhance user experience and market adaptability. The key contributions of this study are as follows.

1) Development of a Systematic Design Framework

The three-phase framework provides theoretical guidance for the transformative design of material and immaterial products, addressing a critical gap in the design literature.

2) Integration of Empirical Data

By incorporating user behavior data, market feedback, and lifecycle assessment, this study strengthens the empirical foundation of the framework, enhancing its scientific rigor.

3) Cross-Industry Applicability

The framework's applicability to various domains, such as virtual reality devices, smart homes, and medical equipment, expands its relevance and provides actionable strategies for multi-industry design practices.

B. Theoretical and Practical Implications

From a theoretical perspective, this study fills a gap in the research on systematic frameworks for integrating material and immaterial products. By introducing dynamic data-driven design optimization methods, it extends the boundaries of design thinking. Practically, the research offers a set of actionable methodologies, supported by case studies and data analysis, to clarify key pathways and optimization strategies for transformative design. This provides valuable guidance for designers and businesses navigating digitalization and sustainable development.

C. Research Limitations and Future Directions

Despite its advancements, this study has certain limitations.

1) Validation Scope:

The framework's validation is primarily focused on virtual reality and smart home applications. Its generalizability to other domains, such as educational tools and industrial equipment, requires further exploration.

2) Environmental Costs of Immaterialization:

The hidden environmental costs of immaterial design, such as data center energy consumption and e-waste management, have not been thoroughly analyzed. Further research using advanced models is needed.

3) Cultural Diversity and User Behavior:

This study does not fully address the impact of cultural diversity on user behavior and market acceptance, which is critical for globally adaptive design.

D. Future Research Directions

Building on these findings, future research can explore the following directions.

1) Broader Industry and Cultural Validation

Conducting cross-industry and multi-cultural case studies will help refine and extend the proposed framework, ensuring its adaptability to diverse markets and contexts.

2) In-Depth Environmental Analysis

Advanced lifecycle assessment tools can be employed to comprehensively evaluate the environmental trade-offs of immaterial design, particularly in data-heavy applications.

3) Synergy with Emerging Technologies

Exploring the integration of cutting-edge technologies, such as artificial intelligence, the Internet of Things, and the metaverse, with the framework will further enhance its innovation potential.

E. Summary

The transformative design of material and immaterial products is a complex and multi-dimensional process. Designers must balance user needs, technological feasibility, and sustainability to achieve successful integration. Through theoretical framework development and empirical analysis, this study provides systematic guidance for this process, addressing key challenges and outlining strategies for future innovation. Continued exploration and application of these principles will enable designers to drive the integration of material and immaterial products, creating value for society and the environment.

IX. CONCLUSION

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