

Study on Endogenous Communication Design Method of Hardware Products Based on PROPEL Model

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Abstract:

Aiming at the “semantic entropy” problem of interaction experience faced by hardware products during visual transmission in the social media era, this paper proposes a “theatrical” physical interaction design strategy based on the PROPEL framework, rooted in the trend of hardware medialization. Taking the modular desktop control hub as the design practice carrier, mechanical damping, magnetic docking, and audio-visual feedback are synergistically orchestrated at the microsecond level across modalities to shape “Physical Memes” with high social fission potential. To overcome the limitations of traditional subjective questionnaires in media transmission evaluation, this study innovatively introduces the Multimodal Large Language Model (MLLM) to construct a heuristic semantic evaluation paradigm. The visual sampling comparative experiment shows that compared with the traditional 2D flat touch scheme, the theatrical physical interaction scheme achieves significant improvements of 200.0%, 300.0%, and 350.0% in three core quantitative metrics: Semantic Readability (*S*), Cross-modal Resonance (*R*), and Fitmeme Potential (*F*), respectively. The study confirms that embedding physical ritual preemptively into the hardware structure and implementing theatrical orchestration can provide high-confidence semantic anchors for machine vision and human audiences, effectively resisting experience decay during cross-media transformation, and providing a novel theoretical framework and empirical path for hardcore industrial design and interaction innovation in the digital age.

Keywords:

Industrial Design, Medialization of Hardware, Multimodal Large Language Model (MLLM), Physical Meme

1. Introduction

In the media environment where the mobile Internet and social media are deeply integrated, the communication modes and survival logic of hardware products have undergone significant changes, and they have gradually evolved into communication nodes in information networks. As early as 2005, scholars pointed out that product

design is essentially an information communication activity: designers endow products with functional, cognitive and aesthetic information, which is then transmitted to consumers and society through the product as a medium. [1]

Traditional industrial design approaches mainly focus on function realization and usage efficiency, while paying insufficient attention to the media attributes of products in the communication context. Existing marketing and communication theories, on the other hand, mostly concentrate on back-end content distribution and can hardly provide systematic methodological support in the early stage of design. In the era of the attention economy, the fragmentation of online communication has reconstructed users' media reception habits, and digital media is confronted with the severe challenge of attention scarcity. [2] Especially for Generation Z, the main consumer group, their consumption behavior demonstrates an overall tendency of pursuing self-pleasing experiences, emphasizing social attributes, and conveying value expression. [3] The shareability of products has become a key factor influencing purchasing decisions. [4]

Existing research has only explored evaluation methods for the quality of product design information, [5] as well as the influence mechanism of product appearance design on word-of-mouth communication. [6] In response to the communication needs of products at the level of design ontology has become an important issue in current design research. To address the communication dilemmas of physical products in the context of social media, this study introduces Memetics and proposes the concept of Physical Meme, attempting to embed the logic of information communication into the product design process in advance. By constructing a communication dynamic mechanism based on the tripartite relationship of human-product-society, this study deduces the PROPEL Physical Meme Design Framework, which includes meme detection, symbol reconstruction, interaction arrangement, semantic encapsulation, media presentation, and effectiveness iteration. Combined with the three-level cognitive theory, three core design strategies are proposed: visual manifestation, interactive theatricalization, and semantic compression. Taking a modular desktop control hub as the practical carrier, objective algorithm verification is conducted, aiming to provide theoretical and methodological references for hardware products to drive communication through design during the cold start phase.

2. Physical Meme and Interactive Theatricalization Mechanism

In the evolution of products toward media, identifying high-potential communication carriers has become the core goal of design. Introducing memetics into the design field aims to materialize cultural genes capable of self-replication and dissemination, thereby constructing physical memes endogenous to products. In this context, the interaction mechanism of products urgently needs to transform from a single utility-oriented logic to a communication-oriented logic.

2.1. Meme Characteristics and Communication Dynamics at the Behavioral Level

Richard Dawkins' theory of cultural evolution defines memes as the basic units of cultural information inheritance and exchange. Similar to biological genes, the transmission of memes relies on three core mechanisms: replication, variation, and selection. In the context of digital media, memes are no longer confined to language or ideas, but have become highly integrated into visual culture and physical design. Song Meiyin et al. (2026) pointed out that in the paradigm reconstruction of cultural

and creative design, the translation of concrete memes, behavioral memes, and imagery memes can effectively promote the digital regeneration of traditional elements. [7] Zhou Hongya et al. (2025) further confirmed in their research on Pop Mart that trendy toys are essentially a “meme complex”. Through diverse emotional resonance and symbolic construction, they have generated a strong herd mentality and spontaneous communication power among young people. [8] This indicates that when a visual form or cultural symbol possesses meme-like characteristics, it can break through circle barriers and achieve low-cost viral diffusion.

In the three-level model of cognitive psychology, the behavioral level generally focuses on operational utility and human–machine feedback efficiency. However, in the social communication context dominated by short videos and streaming media, static visual symbols (corresponding to the visceral level) tend to cause aesthetic fatigue and increased semantic entropy over time. In contrast, dynamic interaction processes, which involve a temporal dimension, narrative logic, and deep user participation, exhibit superior meme potential.

Interactive theatricalization regards the product as a miniature stage and transforms user operations into ritualized social performances. By embedding dramatic conflicts, structured narrative rhythms, and multi-sensory resonant feedback into daily interactions, the product becomes more than a mere tool for accomplishing physical tasks; it acts as a prop that helps users construct their digital personas and gain social currency. Such theatrical effects inherent in interactive behaviors can greatly stimulate the audience’s desire to imitate and share, forming the core driving force for physical products to cross physical boundaries and trigger fission communication.

2.2. Interactive Design Logic under the PROPEL Framework

Traditional interaction design tends to follow Occam’s razor principle, pursuing the shortest operation path and the lowest cognitive load. In contrast, within the theatrical context of the PROPEL framework, interaction orchestration aims to intentionally introduce moderate operational redundancy or nonlinear physical feedback (such as specific damping sensations and sequential sound-light responses), so as to extract behavioral feature points with high recognizability and easy imitation.

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This orchestration logic is essentially a precise regulation of users’ sense of immersion and social sharing threshold, ensuring that operation trajectories in the physical world can be losslessly transformed into high-fidelity meme segments in social networks.

The proposal of the interaction orchestration logic represents a re-empowerment of the attributes of traditional hardware products. As Generation Z has gradually become the main consumer group, their consumption behavior has demonstrated a distinct new landscape characterized by the pursuit of self-pleasing experiences, emphasis on social attributes, and implication of value expression [3]. Under this consumption logic, hardware products are no longer merely closed functional black boxes, but have

evolved into social props and cultural labels for users to construct identities and present themselves in the digital space. Therefore, the construction logic of physical memes is to extract the implicit popular cultural genes from the target audience, and through explicit reconstruction by design, endow products with strong network communication tension.

3. Construction of Meme-Interaction Mapping Network Based on FBS

In the traditional Function-Behavior-Structure (FBS) model, the starting point of design derivation is often limited to practical needs in the physical world. However, in the communication context dominated by digital media, hardware products are required to possess the dual attributes of physical tools and social media. Introducing the concept of Physical Meme into the FBS model aims to transform abstract social sharing motivations (Meme) into concrete physical structures, constructing a meme-interaction mapping network oriented to endogenous communication.

3.1. Transformation of Communication Needs into Product Functions (Meme-Function)

The core driving force of physical memes derives from users' desire for self-expression and identity recognition in specific social scenarios. The transformation from the demand side (Meme) to functions is essentially the embodiment of high-potential social tags into perceptible interactive touch points.

In the design definition of the modular desktop control hub, implicit meme demands such as demonstrating a geek identity and controlling digital assets are accurately translated into core explicit functions including dynamic module recombination, real-time rhythmic parameter display, and seamless cross-screen transfer.

Such pretransformation ensures that the initial functional settings of the product no longer serve only the efficiency of human – computer interaction, but deeply participate in the social performance of interpersonal interaction, establishing the functional foundation for the products' endogenous communication.

3.2. Path Design of Ritualistic Behaviors (Function-Behavior)

The mapping from function to behavior is a key node in realizing interactive theatricalization. To avoid semantic wear and tear and the attenuation of communication potential caused by homogeneous daily operations, it is necessary to embed a sense of ritual in the interaction path to enhance the performative nature of the behavior itself.

In the interaction orchestration of the desktop control hub, the conventional key trigger has been reconfigured into a serialized behavior involving multi-level damping adjustment of physical knobs combined with progressive lighting of multi-sensory feedback. This path deliberately departs from the principle of absolute efficiency, introducing moderate operational redundancy and multi-sensory feedback to extend a simple command input into a dramatic experience with a clear beginning, development, climax, and conclusion.

Such theatrical orchestration not only strengthens the user's psychological immersion but also transforms the interactive behavior into a highly shareable content module. It provides rich audio-visual materials for short video dissemination on social

platforms, enabling the interactive process itself to become a high-potential meme, thereby forming a self-driven communication mechanism that transcends physical and functional boundaries.

3.3. Physical Structure Support and Feedback (Behavior-Structure)

Structure serves as the physical foundation that carries and solidifies theatrical behaviors. The translation of behavior into structure requires the underlying hardware architecture to feature high synergy and precise physical feedback mechanisms. To support theatrical behaviors such as damping rhythm and module recombination in the desktop control hub, its physical structure is systematically decomposed into a magnetic contact matrix, high-precision Hall sensors, and independently addressable RGB lighting modules. The precise coordination of the underlying hardware ensures smooth execution and tactile fidelity of the ritualistic behaviors at the upper level. Under this progressive mapping logic, a complete meme-FBS network is closed. The energy flow and parameter transformation between mapping nodes exhibit a highly structured characteristic through systematic data flow.

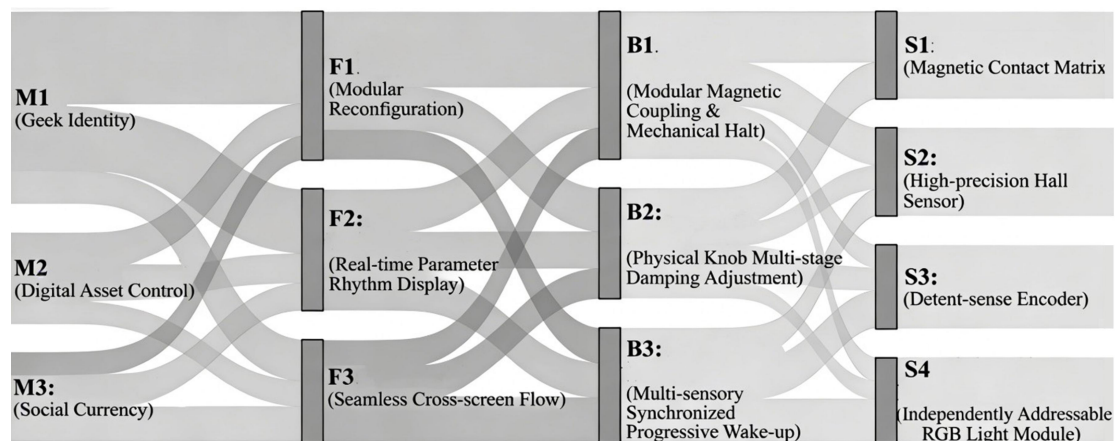


Figure 1. Efficiency changes with frequency.

4. Interactive Deduction of the Modular Desktop Control Hub

Apply the aforementioned meme-interaction mapping network to the design practice of the modular desktop control hub. Traditional desktop controllers mostly adopt flat touch panels or a single array of buttons; their operation process focuses on efficiency, lacking visual tension and behavioral feedback, making it difficult to form effective communication nodes in digital media. Based on the behavioral layer strategy of the PROPEL framework, it is necessary to carry out interactive theatrical reconstruction and objective effectiveness verification for this control hub.

4.1. The Theatrical Reconstruction of Interaction Scenarios for the Control Hub

The theatrical reconstruction strategy decomposes the control hub into a physical assembly form consisting of a core hub and functional sub-modules. In the interactive scenario, users are no longer merely single command inputters, but participants in behavioral performance. By introducing a magnetic damping structure, the sub-modules produce a clear mechanical sense of frustration and a crisp physical latching sound when embedded into the main control console. This assembly action then triggers the gradual lighting of the circular RGB matrix light effect and the object-oriented rhythm of screen parameters.

This process deliberately enhances the coordinated feedback of multiple sensory channels, completing a hardware wake-up ritual with geek characteristics, and transforming the originally implicit control behaviors into explicit, visually appreciable physical dynamic performances.

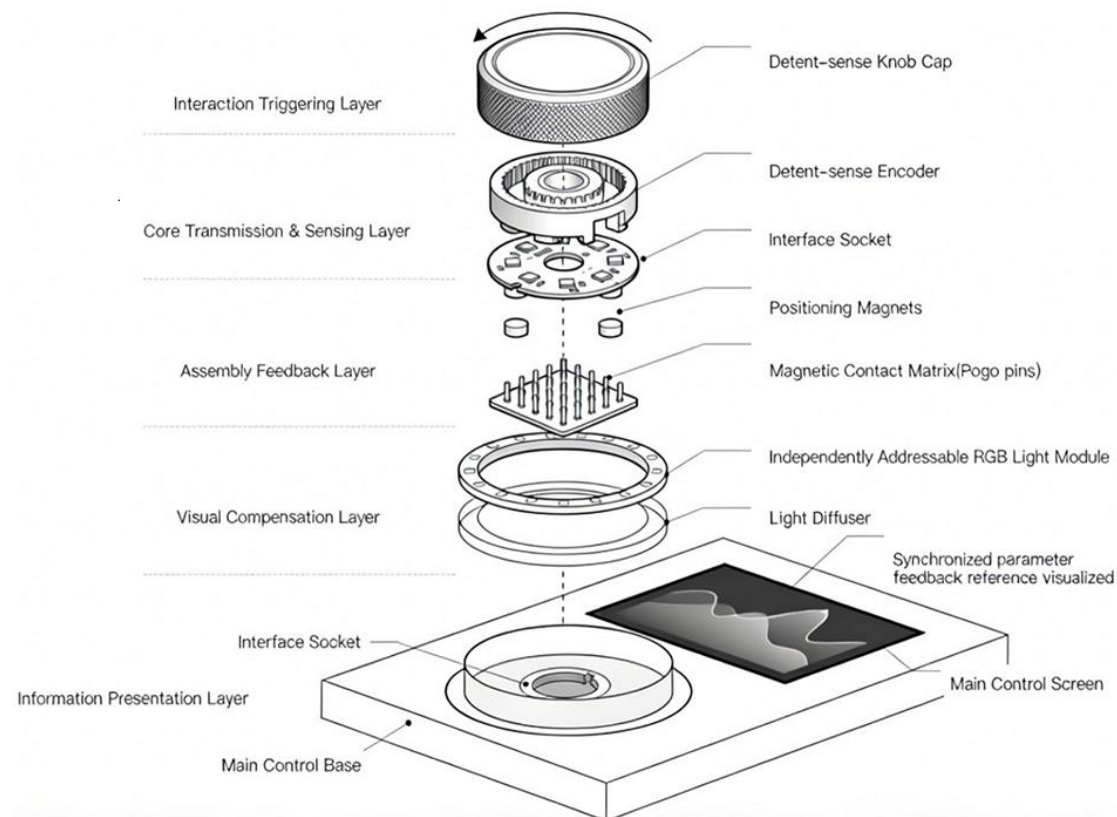


Figure 2. Efficiency changes with frequency.

4.2. Analysis of Interactive Behavior Paths and Communication Nodes

In the specific interaction path, each operation node is endowed with specific communication potential. The interaction sequence of the desktop control hub is systematically divided into four stages: intention anchoring, physical contact, damping resistance, and audio-visual response.

Taking the core parameter adjustment behavior as an example, when the user rotates the tactile knob with a high-precision encoder, the physical jitter generated by damping resistance forms a strict microsecond-level mapping with the dynamic change of the screen UI frame rate. Such cross-modal synchronous feedback can quickly capture the audience's involuntary attention in the sliced communication of visual media such as short videos.

As meme release points, each interaction node forms content fragments with high imitation value and sharing motivation on social platforms. Based on the theatrical orchestration logic of the PROPEL framework, a single complete interaction cycle of the desktop control hub is motion-sliced to extract feedback intensity in three dimensions: tactile, auditory, and visual. The mapping relationship between the interactive operation sequence and meme release nodes is shown in Figure 3.

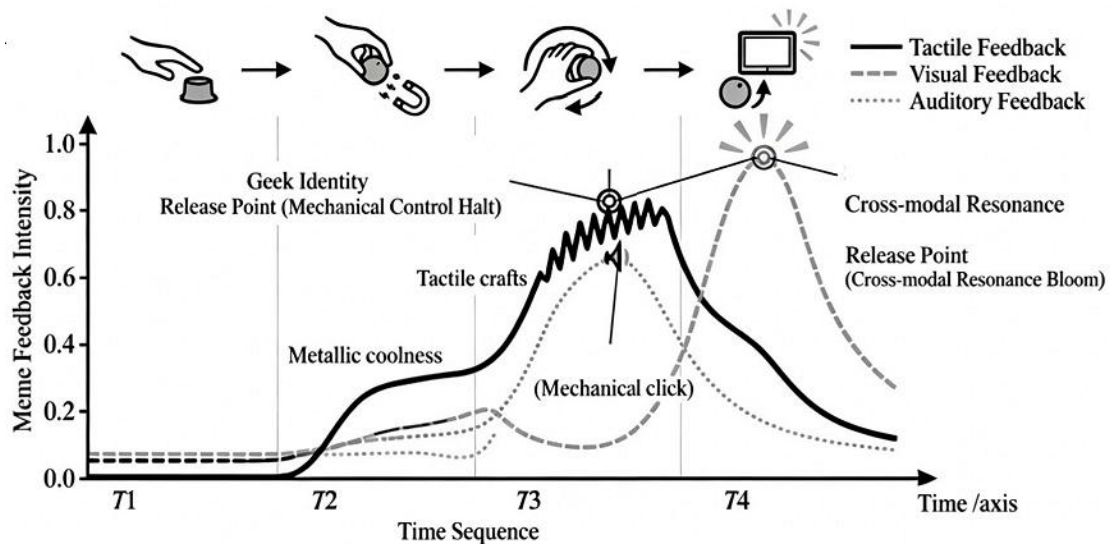


Figure 3. Efficiency changes with frequency.

4.3. Scheme Evaluation and Comparison

In view of the product communication characteristics in the context of social media, traditional evaluation methods relying on subjective questionnaires can hardly accurately measure “semantic entropy increase” and “meme fitness” during interaction. This study introduces an advanced Multimodal Large Language Model (MLLM) to establish a heuristic evaluation paradigm based on machine semantic understanding. With its internalized massive knowledge of human interaction norms and social media communication priors, the large model can objectively evaluate the physical interaction semantics behind visual clips.

In this experiment, keyframe sequences from standard operation videos of the traditional touch-based interaction scheme (Scheme A) and the theatrical physical interaction scheme (Scheme B) are extracted as visual input sources. To ensure objectivity and rigor of the evaluation, the inference temperature of the MLLM is set to a low randomness state, and three core quantitative indicators (full score 1.0) are defined: Action Semantic Readability (S), Cross-Modal Resonance (R), and Meme Communication Potential (F).

After multiple rounds of cross-validation, the evaluation data output by the algorithm (see Table 1) shows that Scheme B presents overwhelming advantages in all semantic indicators. Through the coordinated feedback of physical damping and the audio-visual matrix, theatrical orchestration significantly improves Action Semantic Readability ($S = 0.86$), confirming that embedding physical ritual into the hardware structure in advance allows the audience to “synesthetically perceive” a hardcore geek play experience merely through visual observation, effectively resisting semantic entropy increase during cross-media transformation.

The high F value of 0.91 further verifies that the design possesses strong physical meme characteristics, which can effectively drive endogenous fission of hardware products in social networks.

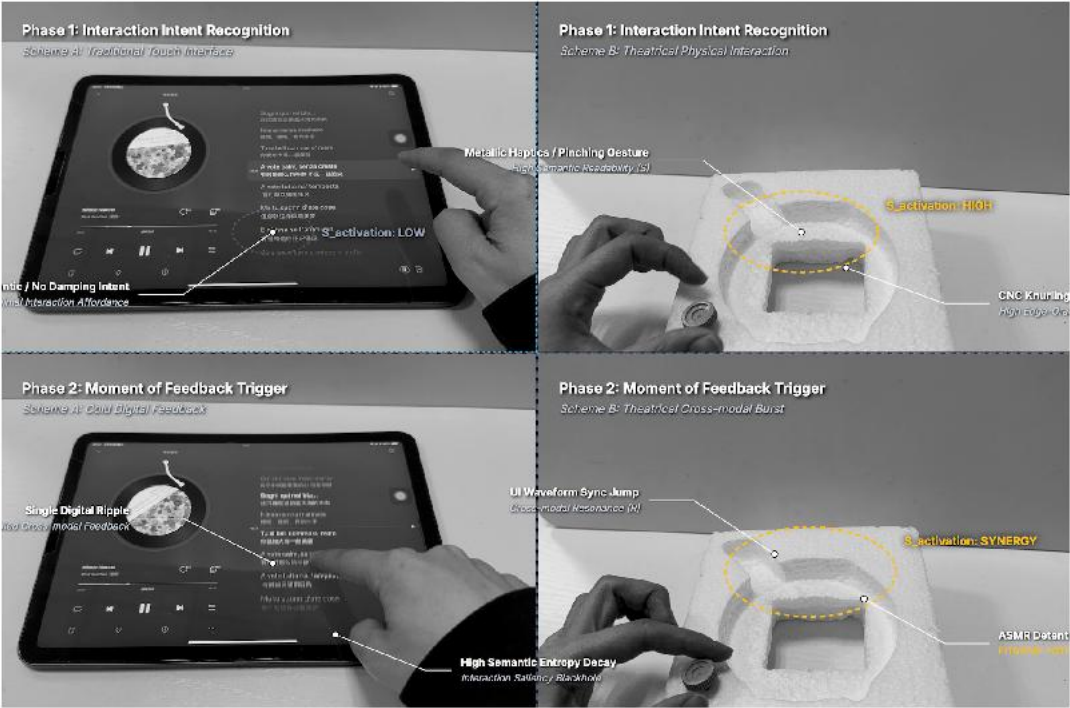


Figure 4 . Key frame comparison of traditional touch and theatrical physical interactive schemes

Table 1. Semantic evaluation comparison of traditional and theatrical interactive schemes based on MLLM.

Evaluation Indicators	Traditional Touch Scheme (Scheme A)	Theatrical Interaction Scheme (Scheme B)	Improvement Rate / %
Action Semantic Readability (S)	0.3	0.9	200
Cross-Modal Resonance (R)	0.2	0.8	300
Meme Communication Potential (F)	0.2	0.9	350

As shown in the data in Table 1, through the heuristic semantic evaluation of the Multimodal Large Language Model (MLLM), Scheme B (theatrical physical interaction) has achieved an overwhelming surpass over Scheme A (traditional flat-panel touch) in all three core indicators. Among them, the improvement rates of Cross-Modal Resonance (R) and Meme Communication Potential (F) are as high as 300.0% and 350.0% respectively. This strongly confirms the hypothesis proposed in this study: through the microsecond-level theatrical physical orchestration of mechanical damping and audio-visual feedback, the semantic limitations of the two-dimensional screen can be effectively broken.

Such high-density cross-modal stimulation not only greatly improves the readability of action semantics when the audience observes visually (with the S value increased by 200.0%), but also endows the hardware product with strong physical meme attributes, thereby perfectly resisting the semantic entropy increase of interactive experience in the process of communication on social networks and digital media.

5. Conclusions

Against the background that digital media has profoundly reshaped the survival logic of products, the core goal of hardware interaction design has evolved from a

single tool-oriented attribute to a dual-driven model of physical utility and media communication. By establishing a meme-interaction mapping network based on the FBS model, abstract social sharing motivations are precisely translated into physical operational behaviors with theatrical features, effectively forming a complete underlying logic for the endogenous communication of hardware products.

Combined with the design deduction of the modular desktop control hub and the objective comparative verification using the ResNet50 machine vision algorithm, it is proven that the interactive theatrical orchestration strategy has significant advantages in resisting semantic wear and enhancing the fitness of physical memes. This approach breaks the limitation of traditional industrial design that relies on post-launch marketing, providing a proactive systematic intervention for hardware products to overcome the cold-start threshold.

Nevertheless, the current objective evaluation model mainly focuses on extracting explicit features from short-video clips, and remains limited in capturing the long-tail communication effects of multi-node interactions in complex social networks. In the future, a long-term multimodal data tracking system should be introduced to further improve the evaluation and iteration mechanism of communication effectiveness for physical products throughout their life cycle.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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