PROCEEDINGS OF ASIA DESIGN AND INNOVATION CONFERENCE
5–6 DECEMBER, 2024, SHANGHAI, CHINA

MEANING GENERATION THEORY: A BAYSEIAN APPROACHI TO SIGN × CONTEXT = MEANING

Shotaro KUSHI[1,2]**, Kouhei NAKAJI**[3] **and Hideyoshi YANAGISAWA**[2]
[1] NEW STANDARD Inc
[2] Graduate School of Engineering, University of Tokyo
[3] University of Toronto

ABSTRACT
This study proposes the "Sign × Context = Meaning (Meaningful Value)" theory for ideation in design engineering. By integrating abduction and Bayesian inference, the framework generates new meanings by shifting the contexts of signs. Case studies conducted with NEW STANDARD, Inc., validated its application in 10 product and customer experience (CX) development. While the framework demonstrates reproducible innovation, its effectiveness is influenced by cultural and contextual factors. Future research should explore AI-driven tools to enhance meaning generation across diverse contexts.

Keywords: Idea generation theory, Bayesian Inference, Product Development, Innovation of Meaning

1 INTRODUCTION

In recent years, the needs of consumers and users in the fields of design engineering and innovation have shifted beyond mere functionality to include emotional and experiential aspects [1], [2]. This shift underscores the need to delve into the socio-cultural meanings that users associate with products. Interpretive methodologies provide a valuable lens for this exploration. Schutz [3] emphasizes that individuals' daily experiences are imbued with subjective meanings shaped by their social worlds, suggesting that the meanings users attach to products are deeply embedded in their cultural and social contexts. Furthermore, hermeneutics [4] and phenomenology [5] argue that such meanings are not inherent to the objects themselves but emerge through the interaction between individuals and their cultural, emotional, and social environments. For example, a coffee cup can hold various meanings depending on the context. It might serve as a functional tool for drinking coffee, symbolize mindfulness in a quiet morning routine, represent energy and focus for work, or even act as a status symbol in specific social settings. These perspectives collectively highlight the importance of understanding products not merely as functional items but as vessels of socio-cultural significance. Therefore, in design, this suggests that consumers and users engage with products not merely as functional items but also as objects through which they express and interpret their identities and values. Notably, "innovation of meaning," one of the four categorized approaches within design thinking, has gained attention as consumers and users increasingly find special emotional and socio-cultural significance in products [6], [7]. To achieve innovation of meaning, the potential for recognizable and reproducible methodologies in design-driven research has been suggested [8]. Verganti has long emphasized an inside-out approach using design discourse [9] and a hermeneutic framework based on interpretive methodologies [10], though these concepts remain primarily theoretical, with limited empirical validation. Accordingly, we proposed and conducted empirical testing on new design-driven approaches for creating and delivering meaningful value [11].

The development of products and services has two critical aspects: first, the generation of ideas, and second, the process of realizing them. Idea-generation methods focus on creating new combinations of existing knowledge and elements through reasoning [12]. Various methodologies, such as brainstorming, the KJ method, and TRIZ, have been developed to support this process. However, methods specifically designed to generate ideas centered on meaning creation have yet to be fully established. Developing methods specifically for meaning generation would allow products and services within design engineering to evolve with more flexible, culturally and socially adaptable meanings. This, in turn, fosters the "semantic turn" [13], which enhances the experiential and affective value that consumers seek, strengthening the competitive edge of products and services.

This study proposes a theory, "Sign × Context = Meaning," rooted in meaning generation and addressing ideation through abduction from the perspectives of design engineering and consumers' and users' needs. As demonstrated by the case studies of Kartell and Luceplan by Dell'Era et al. [14], this framework aims to balance meaning generation with consistency and flexibility through the interplay between technology and design. Additionally, the framework theoretically supports context-based meaning generation by explaining how the interpretation of signs changes based on context through Bayesian inference. In the future, probabilistic changes in meaning based on context can be anticipated through Bayesian reasoning, enabling a systematic approach to flexible generation of meaningful value. This framework allows for the creation of meaningful value aligned with the observed context, enhancing adaptability to diverse consumers' and users' needs without relying solely on implicit sense-making. In this study, we adopt a design science framework to validate the effectiveness of the "Sign × Context = Meaning" theory in achieving contextual meaning interpretation by integrating design science with practical application. Specifically, in collaboration with NEW STANDARD Inc., we evaluated how this framework could accommodate meaning generation across diverse cultural backgrounds and contexts in product design and customer and user experience (CX) development through case studies. Furthermore, through empirical research on ten product development projects, we demonstrate that this framework provides a recognizable and reproducible methodology for "innovation of meaning" in the design process.

2 METHODOLOGY

The implicit cognitive bias in creativity research has failed to adequately explain designers' creative practices, cultural aspects, and sensitivities. Implicit cognitivism refers to the tendency to adopt cognitive-oriented perspectives and assumptions without explicitly recognizing or acknowledging them. This suggests that cognitive approaches and principles are often unconsciously integrated into theory, practice, culture, and management [15]. Therefore, this study examines the "Sign × Context = Meaning″ theory using a design science framework of Figure 1 that bridges creativity research and practical design applications [16] in Figure 2.

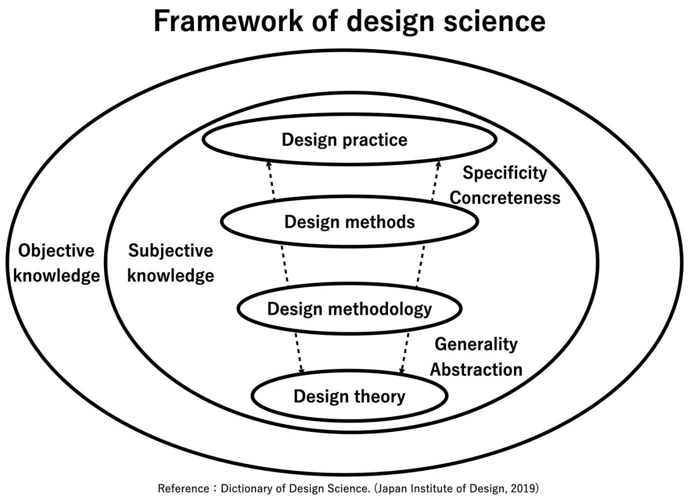

Figure 1: Framework of Design Science

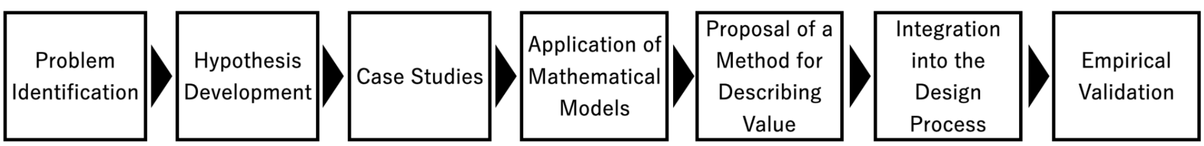

Figure 2: Research Methodology Utilizing the Design Science Framework

Contextual design [17] positions “context” as a framework to comprehensively capture users’ activities, environments, behaviors, challenges, and needs. It emphasizes the importance of deeply understanding users’ real-life and work environments when designing products and services, and of basing designs on that understanding. Semiotics, communication design studies, and Krippendorff’s [13] “semantic turn” also highlight that people’s interpretations of signs and artifacts are dependent on context. For example, the contextual interpretation of an object like beer differs between the contexts of holidays and sports viewing. In a holiday context, beer signifies relaxation, while in a sports-viewing context, it signifies excitement. Consequently, we hypothesize that by analyzing existing contexts associated with signs relevant to consumers and users, identifying new contexts that capture their attention, and combining these new contexts with signs to interpret their meanings, it is possible to generate meaningful value. Based on this hypothesis, we propose a framework grounded in design semiotics to proactively design new interpretations of meaning. As a theory of meaning generation, this study proposes the theory “Sign × Context = Meaning” a method to achieve contextual meaning interpretation.

Next, case studies were conducted. Based on the foundational concepts of the “Sign × Context = Meaning” theory, we investigated cases and considered examples of innovation of meaning to test its validity. While there is no single pattern or meaning associated with the context of a sign, we compiled several illustrative examples. To improve the reproducibility and reliability of the framework, Bayesian inference models and the free-energy principle were applied to evaluate mathematically the process by which signs and contexts interact. Furthermore, we proposed a method for describing meaningful value based on “Sign × Context = Meaning” and systematized how specific products are reinterpreted in response to different contexts, acquiring new meanings. Additionally, we explored the role of this framework within the design engineering process, clarifying how context-based meaning generation influences product design beyond mere technical functions and structures. Finally, through empirical research on 10 product development projects, we validated the practicality and effectiveness of the framework, confirming its potential as a reproducible idea-generation theory across diverse contexts. This study forms a part of the ongoing study outlined in [11], Kushi, S., & Yanagisawa, H. 2024. Innovation of meaning: Design-driven study based on the interpretive theory of new meaning.

3 RESULTS

3.1 Meaning Generation Theory: “Sign × Context = Meaning”

Building on these foundations, this study proposes a novel theory, “Sign × Context = Meaning”, which extends beyond traditional methods by actively designing new meanings through the deliberate application of new contexts to signs in Figure 3. This approach systematizes the creation of meaningful value, thereby enabling a reproducible theory of idea generation for innovation of meaning.

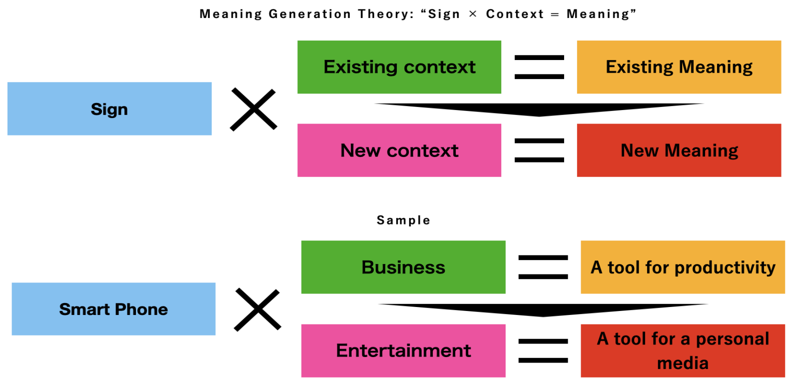

Figure 3 : Meaning Generation Theory: "Sign × Context = Meaning"

3.2 "Sign × Context = Meaning" Case Study

To test the "Sign × Context = Meaning" as framework, we explored how the meaning of a sign changes across contexts, focusing on both domestic and international examples Figure 4. This framework suggests that a sign's meaning is not fixed, but shifts based on the context in which it is interpreted.

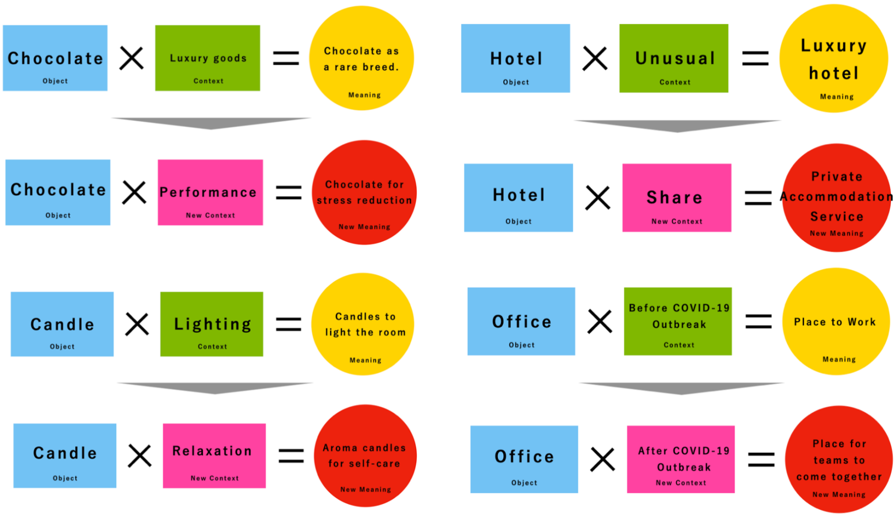

Figure 4 : Samples of Meaningful value "Sign × Context = Meaning"

Japanese culture provides a rich example of this reinterpretation through cultural practices. One prominent example is Japanese curry. Originally an Indian dish, curry was adapted and reinterpreted in Japan as part of "home mother cooking." The Japanese curry is mild and sweet, often associated with comfort and family, unlike the spicier original. This shift reflects a cultural association between sweetness and maternal love in Japan, transforming curry into a symbol of "mom's love comfort food." Another example is Japanese traditional tea ceremonies. Although Japanese tea was originally introduced from China, it has been reinterpreted over the centuries within Japanese culture. Objects like "tea" and "tea bowls" were given new meanings beyond their basic functions. Tea bowls, for instance, are no longer just containers but symbols of "wealth and cultural refinement" within the unique context of the tea room. As Sen Ryo Iwamoto, a tea master from the Urasenke school, notes, "The contextual reinterpretation within Japanese tea ceremonies transforms ordinary signs into artworks, understood only within their unique setting." These examples demonstrate how cultural practices in Japan have long involved reinterpretation of foreign signs in new contexts, giving them distinct meanings.

3.3 Bayesian Theorem and "Sign × Context = Meaning"

Bayes' theorem is widely applied in cognitive sciences to explain how the brain interprets stimuli by balancing prior beliefs with new evidence. For example, whether a smile indicates happiness depends on prior experience, causal knowledge, and context. Building on Bayes' theorem, the Free Energy Principle [18] posits that the brain minimizes prediction errors by aligning its internal models with external stimuli. Predictive coding, grounded in Bayesian inference, suggests that the brain continually refines its internal model based on discrepancies between expected and actual inputs, using Bayesian updating to ensure coherence between perception and reality. Bayesian inference also applies to aesthetic and emotional design evaluations. Predictive coding explains how aesthetic judgments evolve through new sensory inputs. Yanagisawa et al. [19] quantified beauty as a balance between novelty and complexity aligned with Bayesian principles. The Hybrid-GAN architecture [20] further optimizes the aesthetic design by integrating novelty, complexity, and user feedback.

"Sign × Context = Meaning" theory structured using Bayes' theorem, mathematically represents meaning generation by modeling the relationships between objects (which function as signs), contexts, and meanings. In this updated framework. Object (Y) represents the design target object, but also functions as a sign, encompassing both its physical form and potential symbolic interpretations, depending on the context. X represents the meaning of the object (sign) within a given context (e.g., business, mindfulness, or entertainment). C represents the context in which the object (sign) is interpreted.

The probabilistic relationships are defined as follows. $p(x|y, c)$ represents the posterior distribution of a meaning x given object (sign) y in context c. This distribution indicates the meaning inferred based on an observed object (sign) within a specific context. $p(x|c)$ is the prior distribution of meanings in a given context, reflecting the preconceived meaning within a certain context before considering an object (sign). $p(y|x)$ is the likelihood representing the probability of observing the object (sign) y, given meaning x. $p(c)=\sum_x p(c)p(x)$ is the model evidence for the sign in context c, which is a marginalized likelihood. This represents the likelihood of a sign occurring within a context. The posterior distribution of meaning x in a specific context c is then calculated as:

$$P(x|y, c)= \frac{p(x|c)\, p(y|x)\}}{p(y|c)} \tag{1}$$

This formula illustrates how meaning changes based on the given context and observed object (sign). Additionally, surprise or unexpectedness is quantified by

$$Surprise=- \ln p(y|c) \tag{2}$$

This reflects how unexpected the observation of object (sign) y is within context c. Changing context c alters the generative model and consequently shifts the inferred posterior distribution of meaning x, even for the same observed object (sign) y. Examples: Contextual Changes in the Meaning of an Object (Sign). 1. Smartphone × Mindfulness Context: Initially viewed as a "communication tool" $p(x|y, c1)$, the smartphone in a mindfulness context $c2$ shifts to a "relaxation tool" $p(x|y, c2)$. Here, the change in context from $c1$ (communication) to $c2$ (mindfulness) alters the inferred meaning of the smartphone even though the observed object y (smartphone) remains the same. This shift in meaning corresponds to a change in the conditional probability distribution from $p(x|y, c1)$ to $p(x|y, c2)$. The amount of free energy reduction in this process is quantified as:

$$\Delta F = D_{KL}[p(y, c1)||p(y, c2)] \tag{3}$$

This formula represents the KL-divergence between two probability distributions and is derived from the research of Yanagisawa et al. [21] on free-energy models. 2. Smartphone × Entertainment Context: Initially interpreted as a "communication tool" $p(x|y, c1)$, the smartphone in an entertainment context $c2$ shifts to a "personal cinema" $p(x|y, c2)$. The context shift from $c1$ (communication) to $c2$ (entertainment) changes the inferred meaning of the smartphone, reinterpreting its role, while object y remains constant. This again reflects a transformation in the conditional probability distribution of meaning due to context changes.

3.4 "Sign × Context = Meaning" Theory: A Method for Describing Ideas

Formalizing a method for describing ideas is crucial for ensuring consistency and reproducibility in design and meaning innovation. By systematizing the reinterpretation of signs within different contexts, the ideation process becomes more consistent and efficient. This study proposes a framework for systematically describing new meanings of signs: "Sign proposed as Context for Purpose". This structure enables a reproducible method for interpreting signs based on their context and creating new meanings. Specific examples include: 1. A candle proposed as relaxation for personal bath time. 2. A candle proposed as lighting to brighten a room. 3. A smartphone proposed as a productivity improvement tool for business. 4. A smartphone proposed as an entertainment device for media consumption. By combining sign (A), context (B), and purpose (C), this framework enables the reinterpretation of signs to create new value applicable not only to design but also to innovation in various fields.

3.5 The Role of the "Sign × Context = Meaning" Theory: in the Design Engineering Process

The FBS model (Function → Behavior → Structure) is a widely used framework for analyzing the design process, focusing on function, behavior, and structure. In this model, the designer and engineer define the function (purpose) of the product, derive the necessary behavior to fulfill that function, and design a structure to support that behavior. The FBS model primarily addresses the technical and functional aspects of design. However, a successful design is not just about functionality; it is also about understanding users and the meaning the product conveys to them. While the FBS model focuses on technical realization, the "Sign × Context = Meaning" theory centers on creating meaning. Here, "meaning" refers to the significance a product takes on based on how it is interpreted within its context. V (Meaning Value) + FBS Structure. The entire design process can be reframed around V (Meaning Value). This not only influences the function, behavior, and structure but also serves as the foundation for the entire design process. 1. Value (Meaning Value): Designers and engineers first define the meaning that the product will offer to users or society. This implication drives all subsequent design decisions. 2. Function: Functions are determined to embody this meaning and clarify the technical roles that a product must fulfill. 3. Behavior: The behavior of a product, including its interaction with users, is designed to support these functions. 4. Structure: Finally, a physical structure is developed to materialize the product's meaning in a tangible form.

The Importance of Meaning. The "Sign × Context = Meaning" theory emphasizes that a product's value lies in its meaning, shaped by context and interpretation. By applying this approach, designers and engineers can focus on fulfilling technical requirements and delivering products with significant social and cultural value. Integrating the "Meaning Value + FBS" structure shifts the design process from a purely functional focus to a meaning-driven approach, enhancing both user experiences and the cultural relevance of products.

3.6 Experimental Validation Through Design Practice

In collaboration with NEW STANDARD Inc., a company specializing in supporting product and customer experience (CX) development, we conducted experiments to validate this methodology through practical product development. By applying the "Sign × Context = Meaning" theory to the product development process, 4 out of 10 projects were successfully developed during the experimental period, with 5 projects still in progress and 1 project resulting in failure.

Successfully commercialized four products

Total of ten projects in progress (as of August 2023)	Number of ongoing project	Number of successful projects	Number of failures projects
Development/manufacturing/sales		4	
3rd layer design: Interpret & create meaning by integrating words, visual, and function	2	4	
2nd layer design:Interpret & create meaning by integrating words and visual	1	6	1
1st layer design: interpret & create meaning with words	2	8	

Figure 5 : Summary of Project Outcomes in the Experimental Validation

4 DISCUSSION

In this study, we proposed "Sign × Context = Meaning" theory to address the challenges of reproducibility and reliability in traditional design processes by systematizing the interaction between signs and contexts to generate meaning. This framework, grounded in Bayesian inference, quantitatively evaluates how specific contexts influence the interpretation of signs. The results indicate that this framework has the potential to enable flexible value generation that can adapt to diverse cultural backgrounds and consumer and user needs. For instance, Japanese traditional tea ceremonies offer a compelling example of contextual reinterpretation. Although Japanese tea was originally introduced from China, it has been reinterpreted over centuries within Japanese culture to acquire meanings that extend beyond its basic function as a beverage. Tea bowls, for example, are no longer merely containers but have become symbols of "wealth and cultural refinement" within the unique context of the tearoom. As Sen Ryo Iwamoto, a tea master from the Urasenke school, observes, "The contextual reinterpretation within Japanese tea ceremonies transforms ordinary signs into artworks, understood only within their unique setting." This demonstrates how the framework can dynamically respond to cultural and emotional contexts, allowing for meanings to be generated in alignment with specific socio-cultural settings. Compared to traditional design processes, this approach captures the socio-cultural dimensions of meaning more effectively, fostering a deeper connection with users and consumers. Furthermore, applying a mathematical model based on Bayesian inference has proven effective in capturing the meaning generation process quantitatively. The framework also aligns with the existing FBS (Function → Behavior → Structure) model, proposing a new direction for function-centered approaches by integrating diverse interpretations of consumer and user value. This was further supported by the practical validation experiments, which confirmed the utility of the framework in product development. The approach of contextual meaning interpretation presents a more innovative and flexible methodology that can adapt to consumer needs and cultural backgrounds. This study aimed to address two core challenges in design: achieving reproducibility and reliability in meaning generation and creating value that aligns with the cultural backgrounds of consumers and users. The "Sign × Context = Meaning" theory, by systematizing the relationships between signs and contexts, has proven to be an effective approach for generating new value across diverse cultural contexts. This framework enables a shift away from traditional function-centered design methods, allowing for design processes that deliver broader consumer and user value. The framework's applicability extends beyond idea generation to the entire design process, highlighting its utility as a reproducible method for value generation in design practice. Furthermore, the results from practical testing showed that meaning generation through contextual interpretation contributes to developing products and services that cater to consumers' emotional and cultural needs, supporting the framework's validity. This approach of "contextual meaning interpretation" emphasizes its critical role in achieving innovation of meaning, distinct from Verganti's "design discourse" [9] and "hermeneutic framework" [10].

While the effectiveness of this framework has been demonstrated, there are limitations due to the susceptibility of meaning generation to cultural influences and individual differences. Currently, to improve the consistency of context-dependent interpretations across cultures, we are conducting context evaluation using AI and data analytics. Leveraging the "Context Word List" and "AI-driven Idea Generation Tool" can further enhance the accuracy of context-based value generation. Additionally, understanding the insights and needs of consumers is essential for effective meaning generation. The insight discovery approach that we are developing enables flexible value generation aligned with various contexts and consumer needs, contributing to further innovations in the design process [22]. In the future, research should aim to develop a more comprehensive and adaptable design process, advancing toward a systemized approach for creating meaningful value based on consumer and user needs and insights.

5 CONCLUSION

This study introduced the "Sign × Context = Meaning" framework, emphasizing its role in redefining ideas as new combinations of existing elements and demonstrating how meaning shifts based on context. Through this framework, designers and engineers can systematically generate meaningful value that aligns with diverse cultural and emotional needs. Case studies confirmed the framework's applicability across different contexts, highlighting its potential as a reproducible methodology for innovation in design and product development. By applying Bayes' theorem, this study further revealed how intuition and perception influence the idea-generation process, enabling reproducible ideas through contextual reinterpretation. This approach empowers designers and engineers to consider multiple contexts, creating meaningful products that resonate with users across diverse markets. Moreover, the ongoing development of tools such as the "Context Word List" and an "AI-driven Idea Generation Tool" aims to streamline the creative process and enhance adaptability to cultural nuances. While this research demonstrated the framework's practical value, limitations related to cultural dependencies and individual differences remain. Future research should focus on refining these tools and conducting empirical studies to validate meaning generation in a broader range of cultural contexts. These efforts will contribute to more innovative, culturally relevant designs and enhanced product development practices. We extend our gratitude to NEW STANDARD Inc. for their invaluable support and to all who provided insightful feedback during this research. Their contributions were instrumental in advancing this study.

REFERENCES

[1] Norman, D. *Emotional Design: Why We Love (or Hate) Everyday Things*, 2007 (Basic Books, London, England).

[2] Hassenzahl, M. *Experience Design: Technology for All the Right Reasons*, 2010, *Synthesis Lectures on Human-Centered Informatics* (Morgan & Claypool).

[3] Schutz, A. *The Phenomenology of the Social World*, 1967 (Northwestern University Press, Evanston, IL).

[4] Gadamer, H.-G. *Truth and Method*, 2014, Bloomsbury Revelations (Bloomsbury Academic, London, England).

[5] Heidegger, M. *Basic Writings: From Being and Time (1927) to The Task of Thinking (1964),* 1977 (Harper & Row, New York). Available: https://philpapers.org/rec/heibwf [Accessed on 2024, 20 November].

[6] Verganti, R. "Design, meanings, and radical innovation: A metamodel and a research agenda," *Journal of Product Innovation Management,* vol. 25, no. 5, pp. 436–456, 2008.

[7] Dell'Era, C., Magistretti, S., Cautela, C., Verganti, R., and Zurlo, F. "Four kinds of design thinking: From ideating to making, engaging, and criticising," *Creativity and Innovation Management,* vol. 29, no. 2, pp. 324–344, 2020. Available: https://doi.org/10.1111/caim.12353 [Accessed on 2024, 20 November].

[8] Norman, D.A., and Verganti, R. "Incremental and radical innovation: Design research vs. technology and meaning change," *Design Issues,* vol. 30, no. 1, pp. 78–96, 2014. Available: https://doi.org/10.1162/DESI_a_00250 [Accessed on 2024, 20 November].

[9] Verganti, R. *Design Driven Innovation: Changing the Rules of Competition by Radically Innovating What Things Mean,* 2009 (Harvard Business Press, Boston, MA).

[10] Verganti, R., and Ö, Åsa. "Interpreting and envisioning: A hermeneutic framework to look at radical innovation of meanings," *Industrial Marketing Management,* vol. 42, no. 1, pp. 86–95, 2013.

[11] Kushi, S., and Yanagisawa, H. "Innovation of meaning: Design-driven study based on the interpretive theory of new meaning," *Proceedings of the Design Society*, vol. 4, pp. 35–44, 2024.

[12] Young, J.W., and Reinhard, K. *A Technique for Producing Ideas*, NTC Business Books, 1975, p. 36.

[13] Krippendorff, K. *The Semantic Turn: A New Foundation for Design*, 2005 (CRC Press, Boca Raton, FL).

[14] Dell'Era, C., Marchesi, A., and Verganti, R. "Mastering technologies in design-driven innovation," *Research Technology Management*, vol. 53, no. 2, pp. 12–23, 2010.

[15] Rylander Eklund, A., Navarro Aguiar, U., and Amacker, A. "Design thinking as sensemaking: Developing a pragmatist theory of practice to (re)introduce sensibility," *Journal of Product Innovation Management,* vol. 39, no. 1, pp. 24–43, 2022.

[16] Japan Institute of Design (Ed.), Chief Editor Matsuoka, Y. *Dictionary of Design Science,* 2019 (Maruzen Publishing, Tokyo, Japan).

[17] Beyer, H., and Holtzblatt, K. "Contextual design," *Interactions,* vol. 6, no. 1, pp. 32–42, 1999.

[18] Friston, K., Kilner, J., and Harrison, L. "A free energy principle for the brain," *Journal of Physiology-Paris,* vol. 100, no. 1–3, pp. 70–87, 2006.

[19] Yanagisawa, H. "Free-energy model of emotion potential: Modeling arousal potential as information content induced by complexity and novelty," *Frontiers in Computational Neuroscience,* vol. 15, Article ID 698252, November 2021.

[20] Honda, S., Yanagisawa, H., and Kato, T. "Aesthetic shape generation system based on novelty and complexity," *Journal of Engineering Design,* vol. 33, no. 12, pp. 1016–1035, 2022.

[21] Yanagisawa, H., Wu, X., Ueda, K., and Kato, T. "Free energy model of emotional valence in dual-process perceptions," *Neural Networks,* vol. 157, pp. 422–436, 2023.

[22] Kushi, S., and Yanagisawa, H. "Insight and in-depth interviews: An interdisciplinary approach with the meta-perspective structure and insight discovery map," *10th International Conference on Kansei Engineering and Emotion Research (KEER2024): Proceedings,* 2024.