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Doctoral Dissertation

Knowledge Transformation and Creative Thinking in Design Education: A Study on the Semantic Stimulation

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Abstract

Within the context of a knowledge-based society, design education is increasingly expected to cultivate creative thinking while simultaneously responding to broader cultural, technological, and social challenges. Contemporary design practice has moved beyond the simple transmission of skills or stylistic knowledge and now functions as a critical medium for artistic innovation, cultural continuity, and social value creation. However, despite long-standing recognition of creativity as a core educational objective, design education still faces persistent difficulties in systematically supporting creative thinking, particularly with regard to how semantic stimulation is conceptualized, structured, and operationalized within teaching and learning processes.

Against this backdrop, this research, Knowledge Transformation and Creative Thinking in Design Education: A Study on the Semantic Stimulation, adopts an interdisciplinary perspective that integrates theories from knowledge science, cognitive psychology, and design studies. Focusing on the interaction between learners and knowledge, the study investigates how semantic stimuli function as a mediating process that supports knowledge transformation and creative thinking. By examining semantic stimulation as an instructional intervention rather than as incidental teaching content, the research aims to clarify how design education can foster creative cognition through the coordinated integration of science, technology, and art, thereby constructing a more rational and sustainable educational pathway for design innovation.

The study centers on the theme of “the promotion of semantic stimulation in fostering creativity in art and design education.” An intervention-based experimental design was implemented using expert commentary vocabulary as semantic stimuli, with creativity evaluation metrics reconfigured from traditional outcome-oriented assessment tools into process-oriented cognitive guides applied at the early stages of design ideation. Through a mixed-methods research framework combining quantitative analysis and qualitative inquiry, the study systematically examines the effects of different semantic categories, the proactive use of evaluation metrics, and individual learner differences on creative idea generation in design tasks.

The findings demonstrate that semantic stimulation plays a substantive role in enhancing learners’ creative thinking in design education. Both abstract and concrete semantic words were shown to effectively activate divergent associations and support ideation, albeit in different ways. Abstract semantic stimuli primarily facilitated conceptual expansion, originality, and aesthetic exploration, while concrete semantic stimuli supported structural clarity, functional reasoning, and practical feasibility. Moreover, the application of creativity evaluation metrics during the early conceptual design phase was found to positively guide learners’ cognitive processes, enabling them to align creative exploration with evaluative dimensions such as originality, aesthetics, structure, and functionality from the outset of the design process. The results further indicate that individual factors, including education level and professional background, significantly influence learners’ preferences for semantic stimuli and their creative performance, highlighting the need for differentiated instructional strategies in design education.

By examining the dynamic relationship between knowledge transformation and creative thinking, this research proposes a knowledge transformation model grounded in semantic stimulation. The study conceptualizes creative thinking as an emergent capability that develops through continuous cycles of interpretation, externalization, integration, and internalization of knowledge, rather than as an innate or spontaneous talent. Theoretically, the research introduces knowledge transformation as a central analytical lens for design education, contributing to the construction of an integrated educational framework that bridges science, technology, and art. Practically, it offers concrete pedagogical strategies and research methods that support the reciprocal development of creative expression and design innovation. Through these contributions, the study seeks to align design education more closely with the demands of social innovation, cultural preservation, and sustainable creative development in contemporary society.

Keywords: design education, knowledge transformation, creative thinking, semantic stimulation, tacit and explicit knowledge, creative cognition

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Introduction

Chapter I presents a comprehensive overview of the research background, current status, and objectives. This research centers on the semantic stimulation and seeks to examine its function in enhancing creative cognition, facilitating knowledge transformation, and advancing cultural innovation within the field of design education. Employing interdisciplinary mixed methods, this research undertakes empirical validation within the context of art and design education, providing systematic support and a practical roadmap for theoretical expansion, methodological innovation, and educational practice.

Chapter 1 Introduction

1.1 Background and Problem Statement

In the context of a knowledge society, design education is undergoing a shift, moving beyond traditional skill training to focus on knowledge transformation and the cultivation of creative thinking. Traditionally, design education centered on imparting principles such as form, function, and craftsmanship. However, in response to evolving social and cultural demands, the scope of design education has expanded. It is now expected to not only develop students' technical competencies but also to nurture their creative thinking and capacity for innovation within diverse cultural contexts. As a result, design education is increasingly recognized as a pivotal discipline that plays a crucial role in fostering creativity, driving innovation, and addressing the complex needs of society.

This shift reflects the growing recognition of design as a vital force in solving contemporary challenges. In addition to cultivating technical skills, design education now emphasizes the understanding of culture, creative expression, and innovation. This transformation highlights the need for a more comprehensive pedagogical approach — one that integrates knowledge acquisition with the development of creative capacities.

Despite these advancements, existing research on design education reveals gaps. Creative thinking is widely acknowledged as a fundamental objective, yet the methods for fostering creativity in design education lack a robust theoretical foundation. Much of the literature focuses on the influence of visual stimuli—such as images, colors, and forms—on idea generation, but there is limited investigation into the role of linguistic and semantic elements in the creative process. Although some scholars have recognized the importance of semantic stimulation, such as verbal prompts, in aiding concept integration and problem reframing, empirical studies on how different types of semantic stimulation (e.g., abstract versus concrete vocabulary) contribute to creative thinking are still sparse.

Moreover, while design education has begun to embrace knowledge transformation as a key focus, there is a lack of frameworks that explain how this transformation occurs, particularly through the lens of creativity. Knowledge transformation, especially in design, involves complex cognitive processes that require a deeper understanding of how learners move between tacit and explicit knowledge. This research aims to address this gap by focusing on the "semantic stimulation" within the context of design education.

By investigating how semantic cues facilitate creative cognition and knowledge transformation, this study seeks to provide both theoretical and empirical insights. The goal is to develop a pedagogical framework that integrates semantic stimulation as a tool for enhancing both creative thinking and knowledge restructuring in design education. Through this approach, the research aims to advance understanding of how semantic stimulation can act as a catalyst for creativity, fostering the generation of novel and original design ideas.

1.2 Research Objectives and Research Questions

The main research objective (MRO) of this thesis is to investigate two interrelated processes—knowledge transformation and creative thinking—in design education. The ultimate aim is to develop a systematic framework that enhances learners' creativity through semantic stimulation.

In line with this, the main research question (MRQ) guiding this study is:
MRQ: In what ways do design learners transform design knowledge through creative thinking processes to achieve educational objectives oriented toward social welfare?

To operationalize the MRO, this study proposes the following sub-research objective (SRO):
SRO: To develop a semantic stimulation-based instructional approach for design education and empirically examine how it stimulates creative cognition, facilitates idea generation in the early conceptual design phase, and accounts for individual differences in learners' creative performance.
This objective is addressed through the corresponding sub-research question (SRQ):
SRQ: To what extent can semantic stimulation activate creative cognition in art and design education, and how do different types of semantic stimulation, creativity evaluation metrics, and

individual learner characteristics influence the idea generation process?

Relationship between MRO and SRO

As illustrated in Figure 1.1, the sub-research objective(SRO) and sub-research question(SRQ) operationalize the main research objective (MRO) and the main research question (MRQ) by examining how semantic cues facilitate learners' movement between tacit and explicit knowledge while simultaneously stimulating the generation of novel, original design ideas. This process not only supports learners in bridging different forms of knowledge but also nurtures their creative potential. Through this study, both theoretical and empirical foundations are established to understand how semantic stimuli act as catalysts for knowledge transformation and creativity within the context of design education.

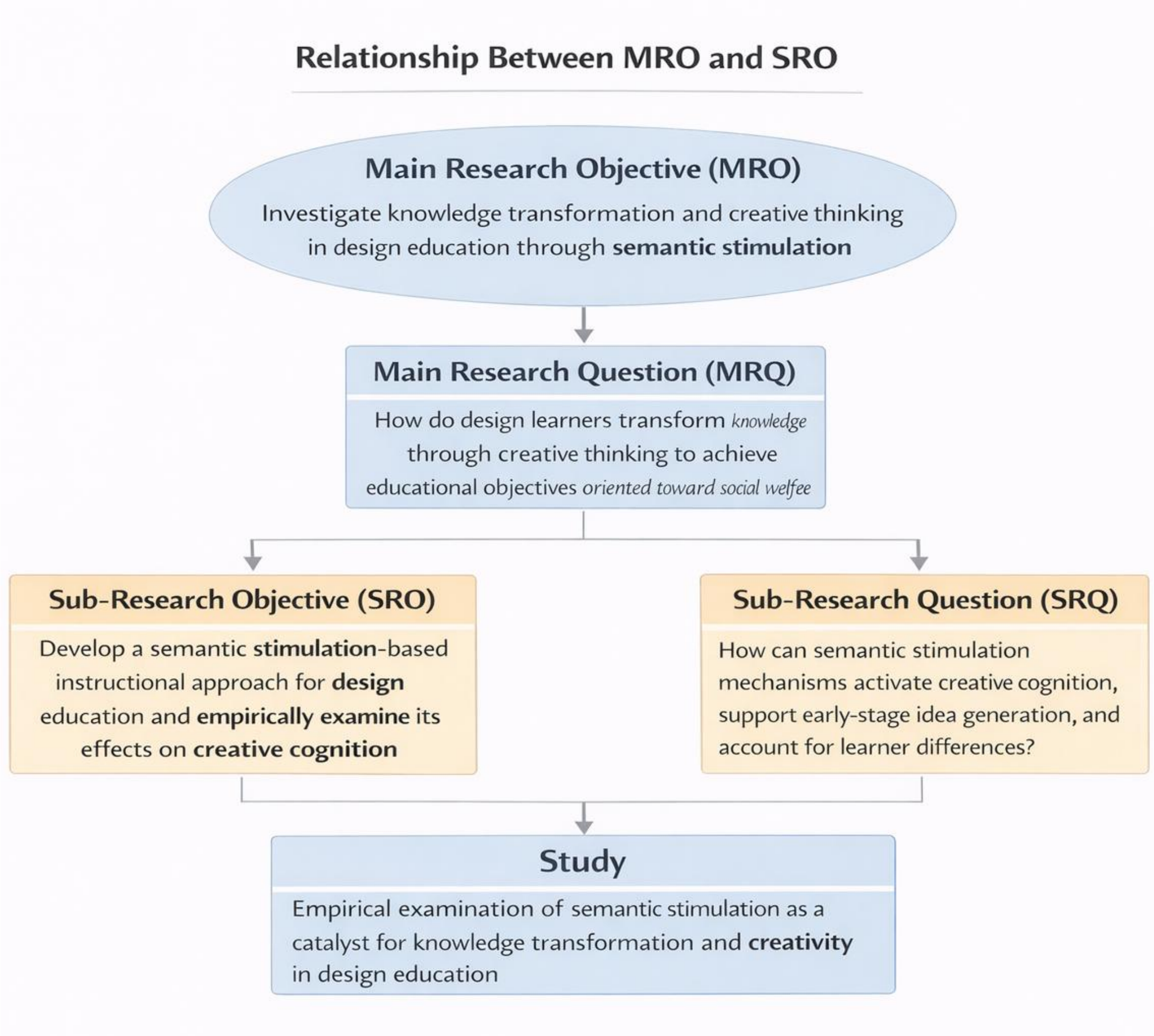

Figure 1.1 The relationship between objectives, questions and studies

The research will explore how specific semantic stimulation — like expert commentary, terminology variation, and evaluative language—trigger the restructuring of design knowledge, thereby fostering innovative thinking. By investigating the semantic stimulation in the creative process, this research will contribute to an integrated pedagogical framework that informs the development of teaching strategies. These strategies will be aimed at enhancing both knowledge transformation and creative output among design learners (Table 1.1).

Table 1.1 Alignment of Research Objectives, Research Questions, and Research Design

Research Level	Research Objective	Corresponding Research Question(s)	Research Design / Methodological Link
MRO	To develop a systematic framework for understanding how design knowledge is transformed in design education and how this transformation supports the development of creative thinking through semantic stimulation.	**MRQ:** In what ways do design learners transform design knowledge through creative thinking processes in design education?	An integrated research framework combining theoretical model construction with empirical investigation to explain the relationship between knowledge transformation and creative thinking.
SRO	To develop a semantic stimulation – based instructional approach for design education and empirically examine how semantic stimuli support knowledge transformation, activate creative cognition, guide in idea generation in the early stages, and account for individual differences in creative performance.	**SRQ:** To what extent can semantic stimulation activate creative cognition in design education, how do different types of semantic stimuli, creativity evaluation metrics, and individual learner characteristics influence the idea generation process?	Quantitative experimental research employing semantic stimulation interventions, creativity evaluation dimensions (e.g., originality, aesthetics, structure, function), and statistical analysis to examine their effects on creative performance.

1.3 Methodology and Technical Approach

This section outlines the methodological and technical approach adopted to address the Main Research Objective (MRO) and the associated research questions through the studies conducted in this dissertation. The research follows an interdisciplinary mixed-methods framework, integrating empirical testing with design-based methodological development to investigate knowledge transformation and creative thinking in design education (Figure 1.2). The research adopts an empirical approach to examine the cognitive mechanisms of semantic stimulation and its effects on creative thinking in design education. This empirical investigation is structured to support the Main Research questions (MRQ), by exploring the role of semantic stimuli in facilitating knowledge transformation and fostering creativity. The study employs a combination of quantitative and qualitative research methods to provide a comprehensive understanding of the phenomena under investigation.

Quantitative Approach

The quantitative component of this study involves survey-based data collection through Likert-scale instruments, which are designed to capture participants' perceptions of the effectiveness of different types of semantic stimuli (abstract vs. concrete) and their corresponding creativity evaluation tendencies (structure, function, aesthetics, originality). The data collected through this approach enable a statistical examination of the relationships among semantic stimuli, creativity dimensions, and individual differences, such as academic background, educational level, and practical experience. To analyze these relationships, the research uses various statistical techniques, including descriptive statistics, correlation analysis, and chi-square tests. These analyses help identify the associations between semantic types and creativity evaluation metricsand provide empirical evidence for the role of semantic stimuli in the knowledge transformation process.

Qualitative Approach

Complementing the quantitative analysis, the research also adopts a qualitative approach to explore the nuances of how semantic stimuli influence creative thinking in design education. This is achieved through semi-structured interviews with a subset of participants, which allow for an in-depth exploration of individual experiences and insights related to the use of semantic stimuli in the design process. Qualitative data analysis involves thematic coding and inductive reasoning to identify recurring themes, patterns, and underlying factors that contribute to creative thinking development.

Empirical Validation and Technical Construction

The methodology is structured in a way that empirical validation directly informs the construction of the research’s methodological framework. In the first phase, the empirical data obtained from the quantitative survey and qualitative interviews help refine the theoretical understanding of how semantic stimuli influence creative thinking. The quantitative findings establish foundational relationships between the constructs, while the qualitative insights offer a deeper understanding of the mechanisms involved. In the second phase, these empirical insights are integrated into the technical framework for the design and implementation of pedagogical interventions aimed at fostering creativity in design education. The research provides concrete recommendations for educators on how to use semantic stimuli to guide students’ cognitive processes during idea generation in the early conceptual design phase and throughout the design process.

The integration of these methods provides a holistic understanding of the cognitive mechanisms involved in creative thinking and their interaction with various contextual factors, such as educational background and practical design experience. This combined approach ensures that the findings are not only comprehensive but also contextually grounded, enabling the development of a robust framework for enhancing creative thinking through semantic stimulation in design education. By following a structured progression from cognitive mechanism analysis to applied design innovation and pedagogical validation, the study directly addresses the Main Research Objective (MRO), ensuring its fulfillment. The empirical validation of these methods forms the core of the research approach, contributing to a deep, nuanced understanding of how semantic stimulation fosters creative thinking and drives knowledge transformation in design education. The coherence between the methodological approach, data collection strategies, and technical analysis guarantees that the research produces rigorous, evidence-based findings, which offer significant contributions to both design education and creativity research.

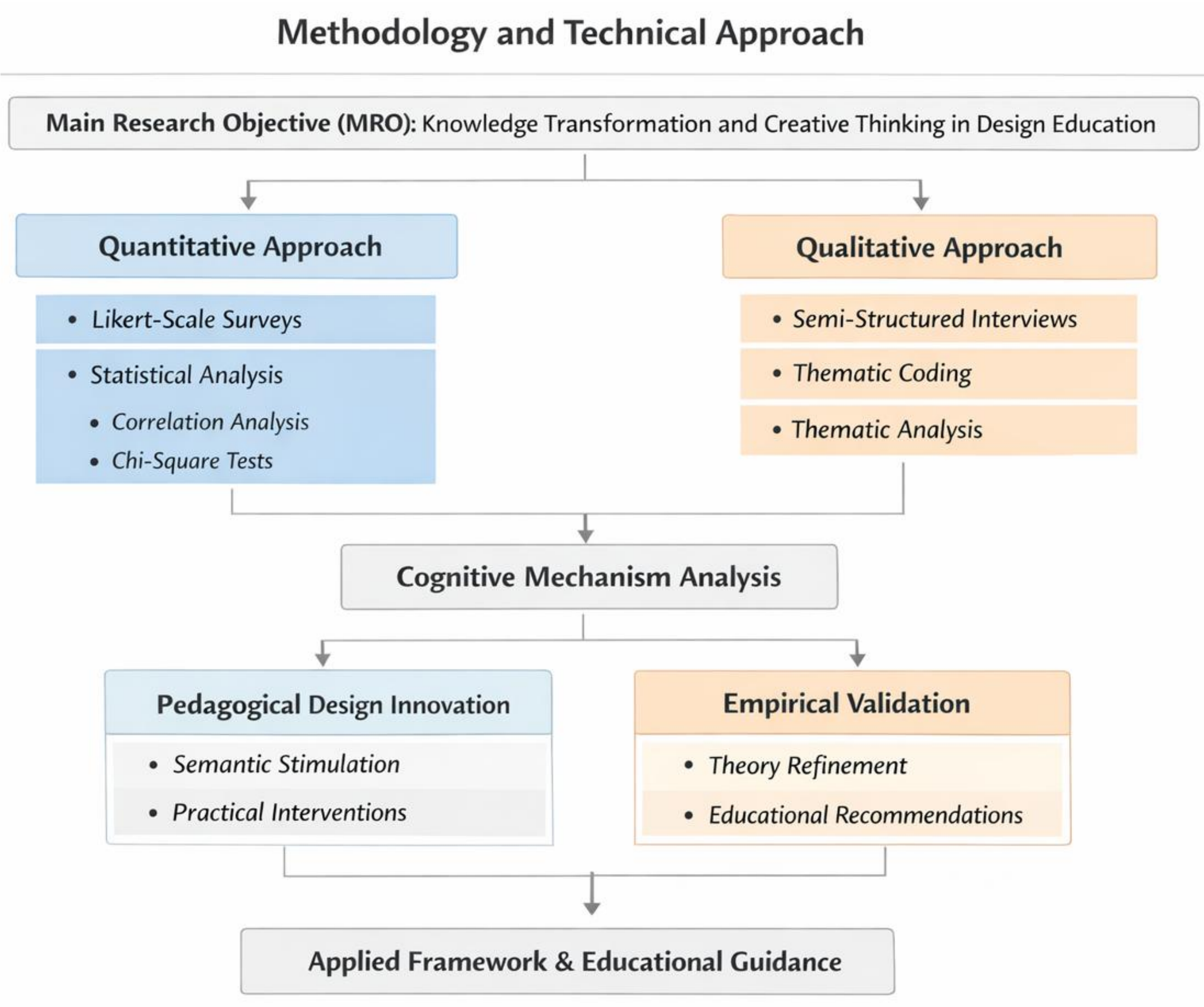

Figure 1.2 Outline of methodology and technical approach

1.4 Significance of the study

1.4.1 Theoretical Contributions

This research introduces the theory of knowledge transformation into the field of design education, offering a model that integrates semantic stimulation as a key mechanism. Traditional design education has predominantly relied on experiential learning and visual inspiration, often lacking a theoretical framework to explain how creative thinking evolves. By constructing a model that incorporates semantic stimulation as a medium, evaluation metrics as a cognitive framework, and individual differences as moderating factors, this study bridges this gap. It provides an in-depth theoretical explanation of how knowledge transformation and creative thinking interact in the context of design education, offering fresh perspectives on students' idea generation processes. Through this, the research not only advances the understanding of creative cognition in design education but also establishes a foundation for future studies exploring how learners transform and apply design knowledge through creative thinking.

1.4.2 Methodological Innovation

The research introduces a methodological approach by employing expert commentary terminology as semantic stimuli, systematically categorizing these terms according to semantic types and their role in creative evaluation. By embedding multidimensional evaluation metrics into the early stages of the design process, the study offers valuable guidance to enhance students' creative thinking. Furthermore, it investigates how individual differences — such as academic background, educational attainment, practical experience, and gender — affect the impact of semantic stimulation, thus providing a nuanced understanding of how various learners engage with creative prompts. This approach establishes a language-based instructional intervention model, providing empirical support for the processes of knowledge transformation and the development of creative thinking in design education.

This research adopts a comprehensive mixed-methods strategy, combining both quantitative and qualitative techniques such as literature review, interviews, surveys, experimental design, and case studies. By drawing on interdisciplinary perspectives from education, design, knowledge science, and cultural creativity studies, the research integrates semantic stimulus experiments.

Through multi-phase data collection and analysis, this study ensures the robustness and generalizability of its findings, laying a strong empirical foundation for future research in design education.

1.4.3 Practical Value

Teaching Strategies for Higher Design Education

The findings from this study offer practical insights for the development of art design and creativity courses. The proposed teaching framework, grounded in the principles of semantic stimulation and cultural semantic transformation, equips educators with tools to enhance creativity training in the classroom. This framework supports the effective application of knowledge transformation by providing a structured approach to stimulate learners' creative thinking. By validating the operational model through empirical studies, the research offers tangible contributions to the development of students' creative thinking skills and their competence in cultural expression and design innovation.

Alignment with Social Welfare-Oriented Design Education Aims

This research reinforces the notion that design education should extend beyond the mere transmission of technical knowledge, aligning with broader social welfare goals. Through the mechanisms of knowledge transformation and the cultivation of creative thinking, this study emphasizes the potential for design education to contribute to societal value. By enabling students to generate original, socially relevant ideas, the research promotes the realization of creative work that directly addresses societal challenges. Furthermore, the study presents a replicable model and methodologies that can be applied to future design education initiatives, particularly those focused on design innovation, art education, and social impact. By integrating social welfare objectives into the design education framework, this research ensures that educational outcomes contribute to the broader mission of fostering social responsibility through creative practice.

1.5 Research Scope and Thesis Structure

1.5.1 Research Scope

This research focuses on undergraduate and graduate students enrolled in higher education institutions with a specific emphasis on art and design disciplines. It particularly targets students pursuing design-related, given the central role of design education in shaping creative professionals. The scope of the research is twofold: first, it delves into the semantic stimulation in the context of design education, and second, it explores how these mechanisms influence the transformation of knowledge and creative cognition among design students.

Additionally, it does not address non-design related educational contexts, nor does it focus on purely technical or engineering-based design education, as these fields typically emphasize functional over conceptual design. Thus, the research is narrowed to explore the dynamic intersection of semantics, creativity, and knowledge transformation within higher-level design education programs.

1.5.2 Thesis Structure

Part I: Introduction

This study outlines the background, current state, and research objectives, focusing on core themes: the semantic stimulation mechanism. It also clarifies the overall framework, laying the foundation for subsequent theoretical and empirical research.

Part II: Theoretical Framework and Literature Review

This part provides a comprehensive review and conduct a bibliometric analysis of the relevant literature across the domains of design education, knowledge transformation, creative cognition, semantic stimulation mechanisms. It identifies existing deficiencies in methodological frameworks, pedagogical roadmaps, and the incorporation of semantics, thereby offering a theoretical underpinning for the development of this research framework and methodological design.

Part III: **Empirical Study:** Semantic Stimulation Mechanism

This empirical investigation examines the function of "semantic stimulation" within design education. Utilizing pedagogical experiments, expert commentary vocabulary is selected as semantic stimulation and systematically categorized according to semantic type and dimensions of creativity. Student-generated textual outputs are collected for quantitative and semantic analysis. It culminates in the formulation of a "semantic stimulation-knowledge transformation-creative cognition" model, which provides a data-driven methodological approach to inform pedagogical practice.

Part IV: Comprehensive Discussion

This part provides a holistic analysis of the empirical study, investigating the complementary functions of semantic stimulation mechanisms in the processes of idea generation. It introduces a creativity cultivation framework centered on "knowledge transformation," effectively bridging theoretical concepts and practical application, and offering a methodology for instructional design.

Part V: Research Conclusions and Outlook

This part summarizes the key findings and innovations, delineates theoretical advancements, methodological practices, and contributions to the science of knowledge; addresses interdisciplinary design education, cultural innovation, and design implementation; identifies existing research limitations; and outlines prospective directions for further investigation, thereby offering valuable insights for future research endeavors(Figure 1.3).

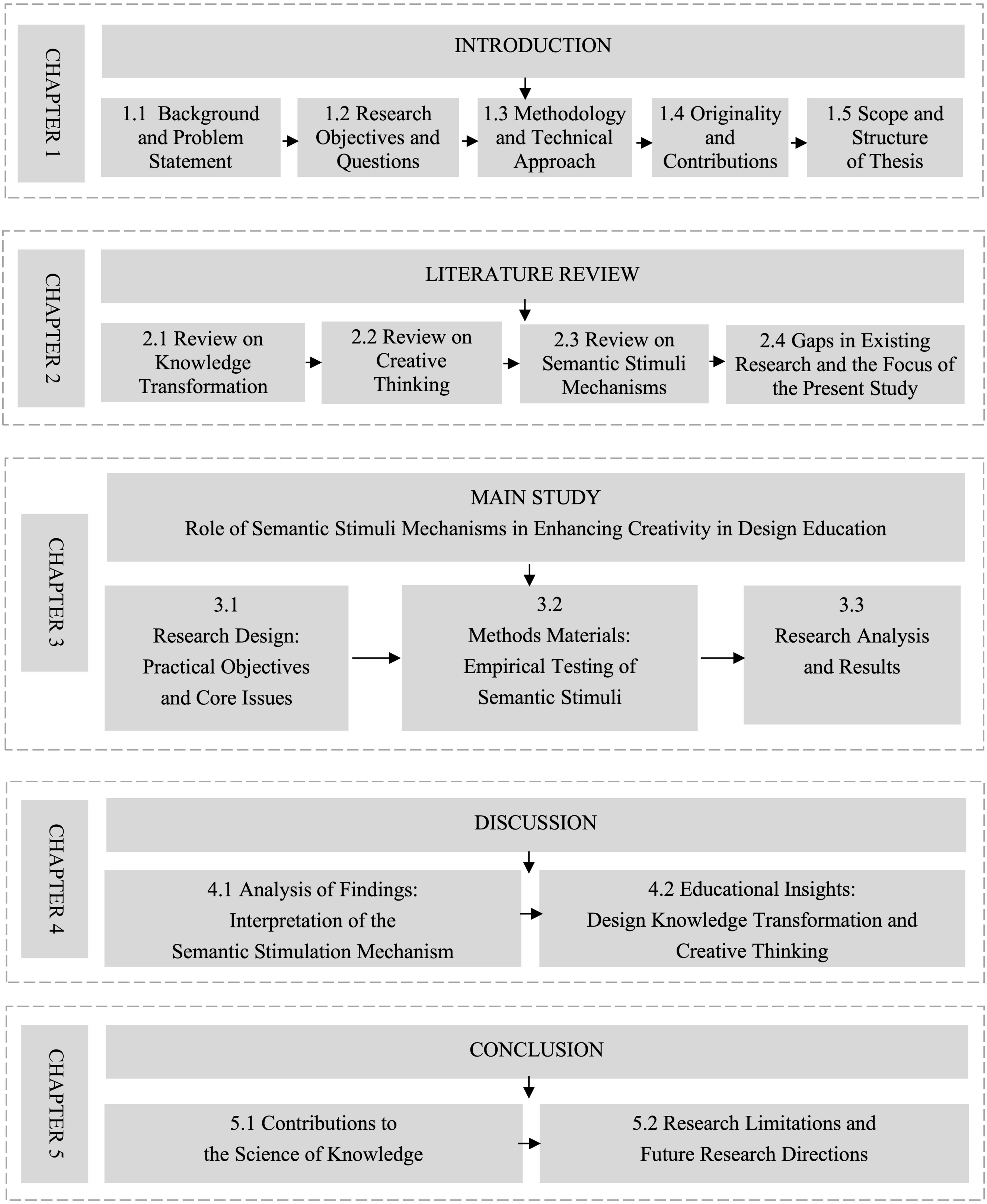

Figure 1.3 Structure of the Thesis

2

Literature review

Chapter 2 provides a comprehensive review of the research progress concerning knowledge transformation and creative thinking within design education, alongside investigations into the mechanisms of semantic stimulation. It identifies a prevailing deficiency in the systematic development of transformation mechanisms and instructional models, highlighting the need for further exploration of how these mechanisms can be effectively integrated into design education to enhance both creative thinking and knowledge application.

Chapter 2 Literature Review

2.1 Research Developments in Knowledge Transformation within Design Education *(for MRO)*

2.1.1 Foundational Theories and Progress in Knowledge Transformation Research

In the field of design education, it is essential to differentiate "knowledge transformation" from the general transmission of skills, given the inherently tacit nature of design knowledge. Designers accumulate experiential insights related to aesthetics, intuitive judgment, cultural context, and stylistic perception, which are often challenging to communicate explicitly. Concurrently, design education mandates that students acquire "explicit knowledge"—such as methodologies, tools, standards, and design documentation—that can be clearly communicated and assessed. Therefore, a critical issue in design education research is how to effectively transform tacit knowledge (or facilitate its externalization) into explicit knowledge, and subsequently promote the re-internalization of explicit knowledge back into tacit competencies.

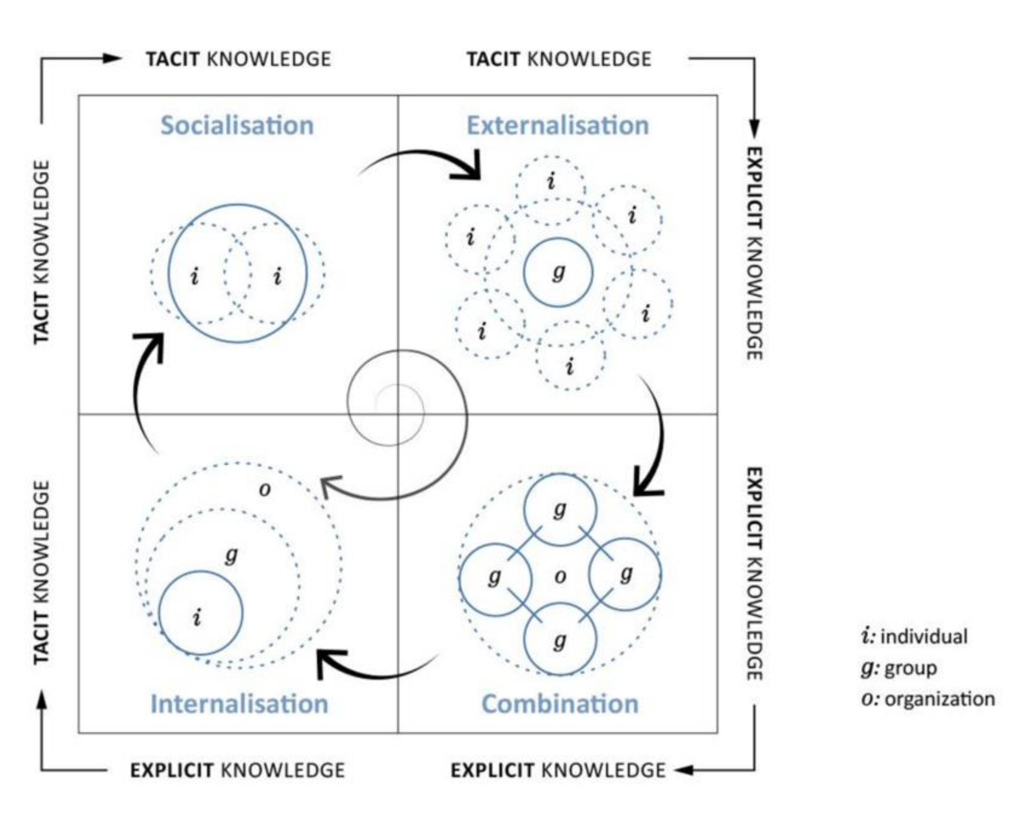

Figure 2.1 The SECI model. (Nonaka & Takeuchi, 1995)

Several studies have incorporated established knowledge transformation frameworks into design education. For example, the Nonaka,et al's SECI model [1] (See Figure 2.1) elucidates the cyclical interaction between tacit and explicit knowledge. Recent research by Fleischmann, K.demonstrates that online peer-critique serves as a mechanism to assist students in converting tacit experiences into explicit understanding [2].

Simultaneously, there is a growing body of research focusing specifically on tacit knowledge within the design discipline. For instance, the study "Demystifying Tacit Knowledge in Graphic Design" employs interview-based analyses to identify the characteristics of tacit knowledge among graphic designers, outlining its core components, modes of action, and functional purposes. This research by Son, K. et al indicates that tacit knowledge in design education is not an intangible concept but can be systematically examined through rigorous inquiry[3].

Existing literature reveals two primary traits: on the one hand, there is recognition of the distinction and importance of tacit/explicit knowledge and their interconversion; on the other hand, there are still limited empirical investigations into the pedagogical mechanisms, process models, and roadmaps facilitating the conversion from tacit to explicit knowledge and its subsequent re-internalization within design education. In other words, while studies have explored the "construction of tacit knowledge" and the "instruction of explicit knowledge" independently, there is a gap in research that integrates these aspects to explicate the "conversion" processes, teaching methodologies, and the impact of educational interventions.

2.1.2 Application of Knowledge Transformation in the Design Education

From a macro-level educational perspective, the mechanism of knowledge transformation fulfills several critical functions in design education. Its role extends beyond the mere transmission of instructional content; it also facilitates students' progression from being "skill learners" to becoming "creators of design knowledge."

Firstly, educators not only impart instruction on tools and methodologies but also employ instructional design strategies to externalize tacit knowledge such as practical experience and design intuition into explicit knowledge. This process enables students to grasp not only the procedural aspects (how to do) but also the underlying rationale (why to do), thereby progressively developing a systematic framework of design cognition. For instance[4], recent research by Novo, C. et al on the "design thinking teaching" model in secondary education highlights that integrating elements such as user-centered approaches, prototype iteration, and feedback optimization into pedagogy assists students in organizing their experience into transferable design knowledge, ultimately enhancing their creative capacities.

Secondly, knowledge transformation acts as a vital conduit linking educational settings with industry demands in design education. Through the establishment of effective mechanisms, theoretical classroom knowledge is converted into practical skills and innovative practices. Thus, students acquire not only the ability to "design" but also to "think about design" and continuously generate new design knowledge. A study by Albay et al. investigating the incorporation of design thinking instruction in teacher education demonstrated a significant enhancement in participants' capacity to apply acquired knowledge within organizational contexts, thereby facilitating conversion of academic knowledge into practical competence [5].

The most existing research remains confined to teaching practices without systematically analyzing the structural transformation of knowledge throughout the instructional process. The current literature inadequately addresses aspects such as knowledge transfer, evaluation mechanisms, and customization to individual learner differences within instructional design. This deficiency highlights a gap in the development of measurable and replicable models of knowledge transformation, thereby presenting a theoretical opportunity for further investigation into operational mechanisms for knowledge generation, integration, and innovation in design education.

2.1.3 Bibliometric Analysis of Knowledge Transformation

1. Research Instruments and Data Sources

This research utilizes CiteSpace 6.4.R1 to perform a visual bibliometric analysis of research related to "Knowledge Transformation" within the domain of design education. CiteSpace is a tool designed to assess trends in scholarly literature, identify emerging research frontiers, and forecast developmental roadmaps[6]. The data were sourced from the Web of Science Core Collection (WOS). With the keywords "Knowledge Transformation" and "Design Education," relevant literature published between 2018 and 2025 was retrieved. Following the exclusion of irrelevant records, a total of 254 valid publications were retained for analysis.

2. Publication Volume Distribution

An annual analysis of publication volume reveals that the number of studies was relatively modest during 2018 and 2019, increasing to 33 publications in 2020 and reaching 39 in 2022. The period from 2024 to 2025 marks a phase of accelerated growth, with the number of publications rising from 41 to 61 (see Figure 2.2). This upward trend signifies that the intersection of knowledge transformation and design education has emerged as a prominent area of scholarly interest, with research efforts focusing on optimizing design education frameworks and enhancing innovation capabilities through the application of knowledge transformation.

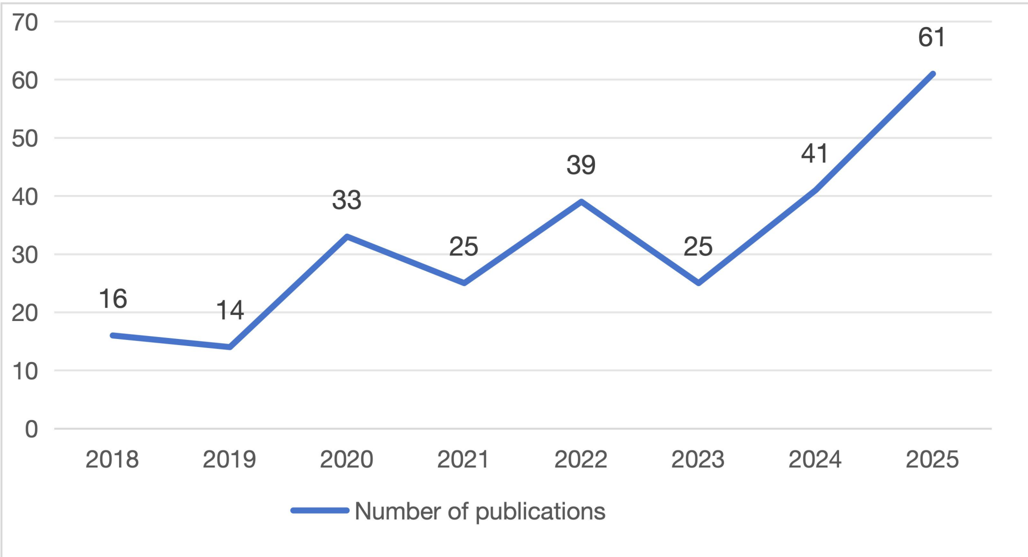

Figure 2.2 Distribution of the Number of Knowledge Transformation Publications

3 Regional Distribution and Leading Institutions with High Citation Impact

The top ten regions by publication volume indicate that the United States (50 papers) and China (43 papers) serve as the primary contributors, followed by Germany, Australia, the United Kingdom, and other regions (see Figure. 2.3). Among the institutions with the highest citation counts, four are based in the United States, including Harvard University and its affiliates, underscoring the nation's significant research influence. Additionally, Fudan University in China, along with Freie Universität Berlin and Charité in Germany, are ranked within the top ten, although their citation impact is comparatively modest. These findings reflect a pronounced trend toward internationalization, while regional disparities in research output persist.

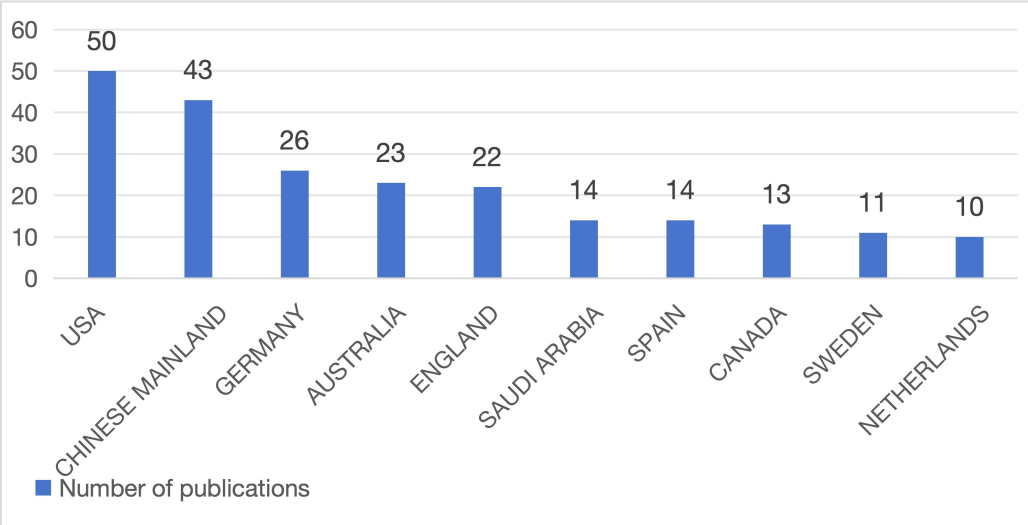

Figure 2.3 Top ten Regions by Number of Knowledge Transformation Publications

4. Distribution of Highly Cited Literature within Existing Research Outputs

A co-citation analysis was performed utilizing "Reference" as the node type. The resulting network demonstrated high clustering quality, with a modularity value of Q=0.9751 and a silhouette score of S=0.8659, which identified several relatively independent research subfields. The largest connected subgraph comprised 79 nodes, representing 15% of the total, which indicates the existence of core literature clusters within the domain. Notably, key documents such as Kavanagh JM (2021) and Terry G (2017), despite not being highly cited, address the application of knowledge translation across diverse educational contexts and serve as foundational references supporting this research.

5. Keyword Cluster Analysis of Existing Research Outputs

The keyword co-occurrence network, consisting of 164 nodes and 367 edges with a network density of 0.0275, yielded nine principal clusters (modularity Q = 0.5897, silhouette score S = 0.8006). This analysis reveals that this research predominantly concentrates on three dimensions: educational settings, knowledge processes, and instructional methodologies (see Figure 2.4): Educational Settings: Primarily focused on higher education and medical education; however, interdisciplinary collaboration across different settings remains limited; Knowledge Processes: Emphasis on knowledge organization, dissemination, and management, reflecting a progressive transition from mere "knowledge transmission" toward comprehensive "systematic management"; Instructional Methodologies: Approaches such as flipped classrooms, reflective learning, and scaffolded teaching substantially enhance knowledge transformation, although the multi-method collaborative frameworks require further advancement. Additionally, the peripheral cluster #8 (organizational change), indicates a promising avenue for exploring knowledge transformation at the organizational level, although a fully developed conceptual framework has yet to be established.

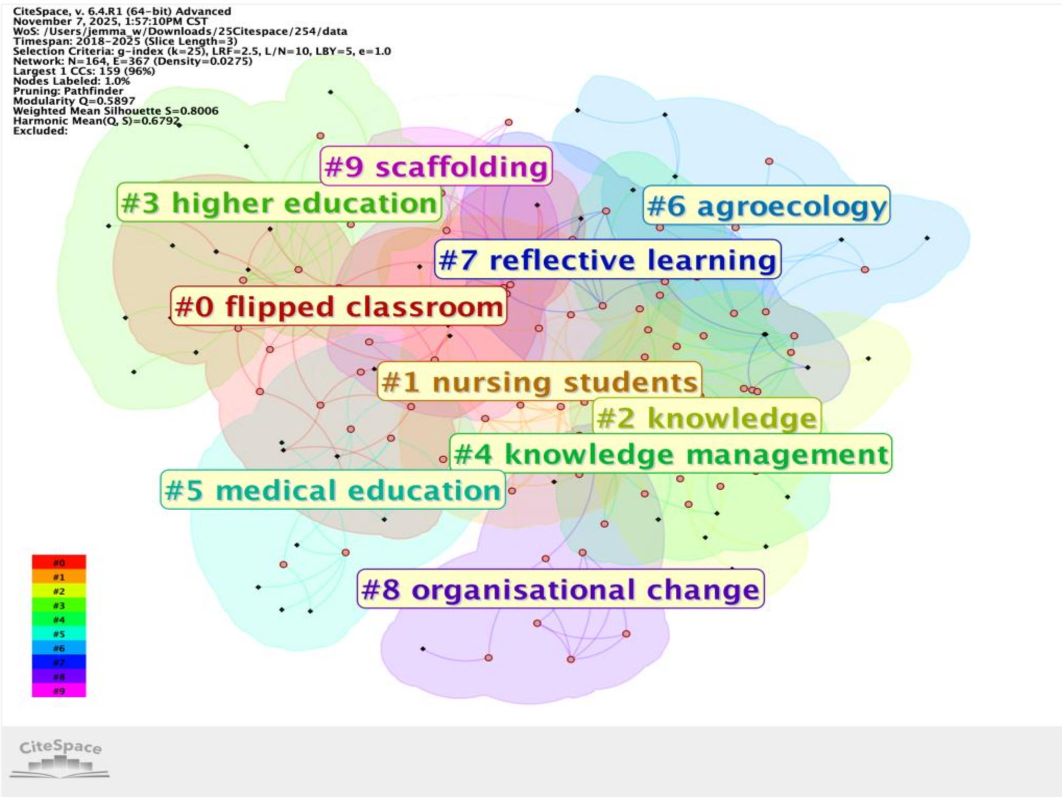

Figure 2.4 Keyword Cluster Map of Knowledge Transformation

6 Research Implications

A comprehensive analysis reveals that studies on “knowledge transformation” and “design education” have formed a fundamental conceptual framework characterized by the interplay of “context-knowledge-methodology.” Nonetheless, certain deficiencies persist, including limited collaboration across different contexts, an absence of coordinated multi-method approaches, and inadequate interdisciplinary integration. Future research endeavors should prioritize the integration of knowledge transformation within diverse educational settings, the development of collaborative teaching strategies employing multiple methodologies, and the establishment of interdisciplinary theoretical frameworks to advance the systematization and cohesion of the discipline.

The bibliometric analysis of knowledge transformation serves as a macro-level justification for this study. By examining publication trends, regional distribution, citation networks, and keyword clusters, this section positions knowledge transformation within the broader academic landscape of design education research.

The analysis demonstrates that although research on knowledge transformation has steadily increased in recent years, existing studies primarily focus on specific educational contexts, instructional techniques, or knowledge management perspectives. There remains a lack of integrative frameworks that systematically explain how knowledge transformation operates as a dynamic cognitive mechanism within design learning processes. In particular, few studies explicitly connect tacit – explicit knowledge conversion with the development of creative thinking.

This gap informs the present research, which seeks to construct a systematic framework explaining how knowledge transformation functions as a foundational mechanism supporting creative cognition in design education. The bibliometric findings therefore provide empirical evidence that: The field is expanding but conceptually diverse. Interdisciplinary integration remains limited. The models linking knowledge processes and creativity are underdeveloped.

By identifying these limitations, the bibliometric analysis not only validates the necessity of this research but also clarifies its theoretical positioning: the present study extends beyond descriptive analysis of knowledge conversion and instead investigates how semantic stimulation facilitate the transformation between tacit and explicit knowledge in ways that actively enhance creative thinking.

Thus, this section establishes the theoretical foundation for integrating knowledge transformation into the MRO framework and prepares the ground for examining its interaction with creative cognition.

2.2 Research Developments in Creative Thinking within Design Education *(for MRO)*

2.2.1 Cognitive Foundations of Creative Thinking

Within the field of design education, creative thinking is widely recognized as a fundamental competency. It is conceptualized as an individual's capacity to generate solutions that are both innovative and practical within a given context, employing cognitive processes such as association, analogy, metaphor, and divergent-convergent thinking. From the standpoint of cognitive development, this creative process generally covers dimensions including fluency, flexibility, originality, and elaboration/integration. In academic literature, creative thinking is conceptualized as the cognitive capacity to generate ideas that are both novel and useful within a given context, involving unusual and effective responses to open-ended problems, and the reflective evaluation and development of those ideas into practical solutions.

In this study, creative thinking is defined as the cognitive process through which learners generate diverse, flexible, and original design ideas when responding to a given design task, based on the transformation and reinterpretation of existing knowledge. Consistent with Torrance ' s framework, creative thinking in this research is reflected through three core dimensions: fluency, referring to the ability to produce a large number of ideas; flexibility, referring to the capacity to approach a design problem from different perspectives; and originality, referring to the generation of novel and uncommon ideas. Within the context of design education, these abilities are further understood as emerging from the interaction between learners ' prior knowledge and external semantic stimuli. Therefore, in this study creative thinking is operationalized as the ability of design students to transform existing knowledge structures and generate multiple, varied, and original design concepts during the ideation process under semantic stimulation.

Concurrently, the Design Thinking model [7] (Figure 2.5) has been extensively adopted in design education. The conventional five-stage framework- Empathize, Define, Ideate, Prototype, and Testing- offers a systematic approach to fostering creative cognition. A recent study by Antunes, P. et al. [8]introduced a pedagogical model specifically designed to nurture students' dispositions toward design thinking. This study emphasized that beyond knowledge and skills, "dispositions" such as empathy, inquisitiveness, and resilience constitute critical components of design thinking competence. The model delineates design thinking ability into three core elements: knowledge, skills, and dispositions, and its efficacy was empirically validated within undergraduate curricula. Findings indicated that by structuring instructional elements around context, problem identification, user engagement, and prototyping, students' empathy, questioning mindset, and resilience were significantly enhanced.

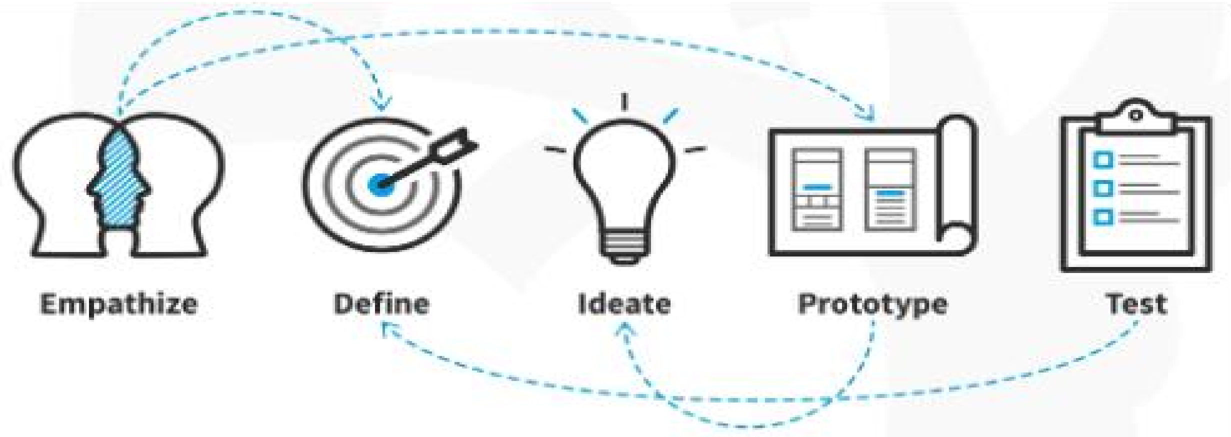

Figure 2.5 Design thinking / five-stage, (Pande, M., & Bharathi, S. V. 2020)

Moreover, empirical studies have explored the practical application of creative thinking as a pedagogical methodology. For instance, "Design Thinking as Pedagogy in Practice" (Hatt et al., 2023) [9]documented the integration of creative thinking within an Executive MBA module at a UK business school. Through processes centered on human-focused problem definition, prototype development, and iterative user feedback, students developed heightened creativity, empathy, and the capacity to identify opportunities for innovation.

In summary, creative thinking offers a practical and teachable framework conducive to the cultivation of creative cognition. Nonetheless, from the perspective presented herein, further rigorous investigation is warranted to systematically translate the aforementioned cognitive dimensions (such as fluency, flexibility, originality, and elaboration) into instructional design components within design education; to tailor creative thinking development to students' diverse backgrounds, including varying levels of design experience and interdisciplinary expertise; and to devise robust methods for assessing the relatively intangible element of "dispositions" in design education.

2.2.2 The Implementation of Creative Thinking in Design Education

At the teaching practice level, design education has established a task-centered pedagogical framework characterized by long-term, contextualized assignments primarily based on Project-Based Learning (PBL)[10], complemented by short-term skill training and structured creative thinking methodologies. PBL emphasizes authentic or simulated design scenarios as the core of the curriculum. Through phased deliverables, active user engagement, and iterative cycles, students engage in continuous processes of problem identification, solution ideation, and prototype validation. This approach not only cultivates divergent thinking capabilities but also fosters the integration of convergent and implementation-focused reasoning. Recent literature reviews and empirical by Sanchez-Garcia, R., et al. investigations have demonstrated that systematic, sustained PBL significantly enhances students' competencies in recognizing design problems, refining solutions, and realizing user value. Nonetheless, the efficacy of PBL is contingent upon factors such as task complexity, the quality of classroom feedback mechanisms, and the extent of collaboration with industry partners or end-users[11].

Collaboration and interdisciplinary teamwork are widely acknowledged as essential pedagogical strategies for enhancing cognitive flexibility and originality. The research by Georgiev et al.,[12] which integrates design students with peers from engineering, business, or social sciences introduces diverse cognitive frameworks and knowledge bases, thereby broadening conceptual scope and fostering cross-domain connections. However, research underscores the necessity of deliberately structuring collaborative activities (through explicit role definitions, rotation systems, periodic team reorganization, and process evaluation checkpoints) to prevent premature convergence on familiar solutions and to encourage authentic divergent exploration.

Regarding divergent idea generation techniques, brainstorming and its structured variants, such as a study by Kemmer, M. on brainwriting and the 6-3-5 method[13], remain prevalent. Brainstorming typically follows a sequence of "individual idea generation, anonymous or semi-anonymous idea exchange, and collective iteration," thereby maximizing individual output while mitigating social inhibition and conformity pressures(Figure 2.6). Recent advancements in digitizing these techniques facilitate the documentation of idea trajectories and provide empirical data to support process analysis.

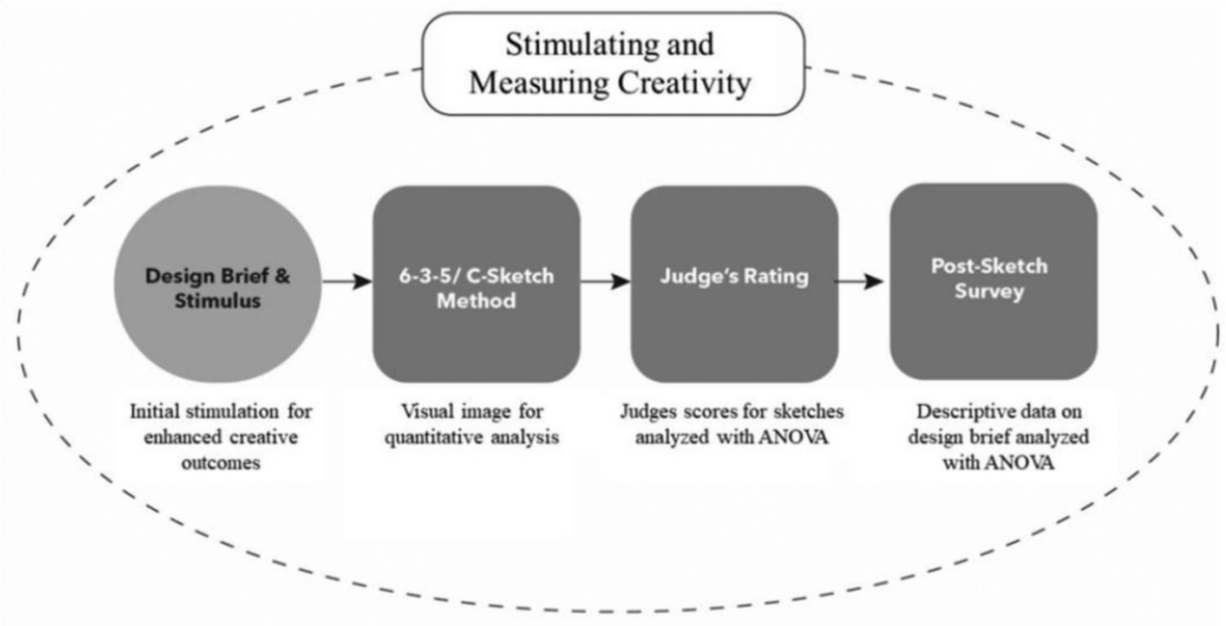

Figure 2.6 The model for stimulation and measurement of creativity, (Creswell & Clark 2018)

Semantic stimulation, metaphors, and analogical reasoning have been incorporated as pedagogical tools to stimulate "creative thinking" within the classroom. Studies by Kim, Eunyoung et al. [14]indicate that the provision of remote analogies, or cross-domain word pairs effectively reduces functional fixedness and promotes unconventional associations, thereby enhancing the novelty and symbolic richness of conceptual outputs. Conversely, employing more structured or functionally oriented semantic cues during the convergent and implementation phases aids in solution refinement and feasibility enhancement. Additionally, semantic features serve as analytical metricsin examining classroom dialogues and idea flows, functioning as predictors of creative outcomes.

In terms of assessment, traditional creative thinking metrics (fluency, flexibility, originality, and elaboration) remain the predominant quantitative measures. However, exclusive reliance on these measures in design education tends to neglect product- and user-centered value judgments. Thus, an increasing body of research advocates for the integration of product-oriented metrics such as feasibility, user value, and innovation value within evaluation frameworks. Mixed-method approaches, incorporating expert evaluations, peer reviews, user testing, and self-assessments, are employed to mitigate biases inherent in single-source assessments. Li, G. et al. 's systematic reviews of creativity self-assessment instruments reveal their utility in monitoring individual developmental trajectories throughout courses, although concerns regarding their reliability, cross-cultural validity, and correlation with external evaluations persist[15].

Furthermore, research conducted by Avinç Kara et al. [16]indicates a rapid increase in studies on design thinking in education since 2010, with emphases on fostering creativity, experiential learning, and higher education environments. Their findings underscore design thinking as a pivotal roadmap for advancing students' critical thinking and collaborative innovation.

In conclusion, design education has implemented a variety of practical approaches to fostering creative thinking and establishing assessment protocols, encompassing long-term contextualized PBL, structured collaboration, divergent thinking tools, semantic and analogical stimuli, and preliminary assessment explorations. These methodologies provide actionable foundations for classroom instruction. Nevertheless, to transition from isolated innovations toward systematic, differentiated pedagogical reform, there is a pressing need for empirical studies, detailed process data analyses, and comparative research on multi-learner adaptability to develop replicable and scalable closed-loop teaching-assessment models.

2.2.3 Bibliometric Analysis of Creative Thinking

1. Research Methods and Data Sources

Adhering to the previously established methodology, the keywords “Creative Thinking” and “Design Education” were utilized to retrieve relevant literature from the Web of Science Core Collection. Following a rigorous screening process, a total of 280 relevant articles were identified. CiteSpace 6.4.R1 was employed to visualize various dimensions, including publication years, geographic distribution, authorship, and keyword occurrences, thereby elucidating prevailing research trends and focal areas.

2. Publication Volume Distribution

An analysis of the 280 articles by publication year (see Figure 2.7) reveals that from 2018 to 2019, the average annual number of publications was 16, indicative of an exploratory phase. In 2020, this figure increased to 27, signifying the growing recognition of the topic within the academic community. Between 2021 and 2023, publication volume exhibited fluctuations, reaching a peak of 40 before a slight decline to 36. The period spanning 2024 to 2025 demonstrates rapid growth, with publications rising from 52 to 62, corresponding to an average annual growth rate exceeding 18%. This upward trajectory underscores the emergence of creative thinking integrated with design education as a prominent research focus, highlighting its role in optimizing design education frameworks and enhancing innovative practice capabilities.

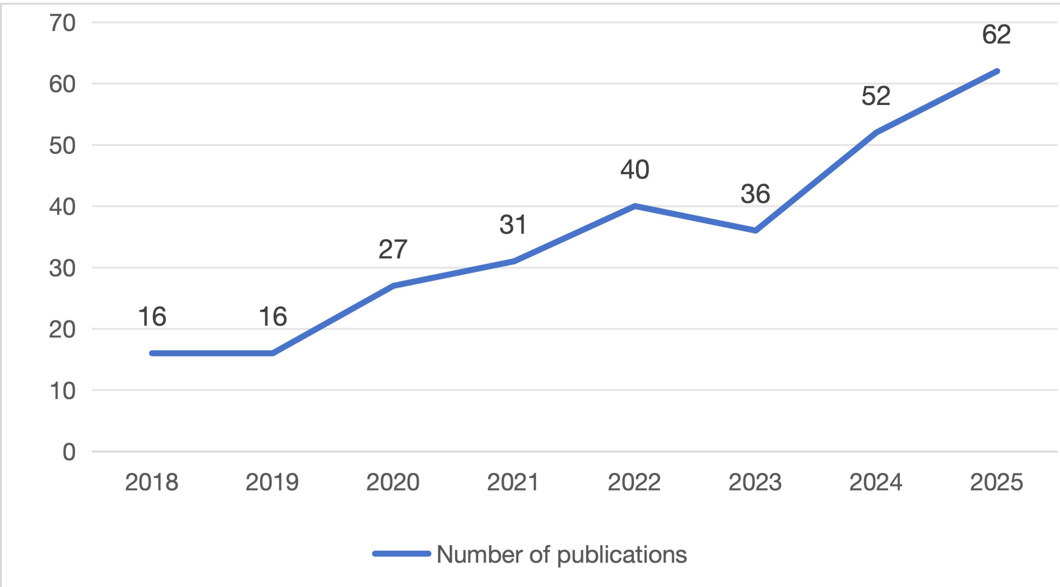

Figure 2.7. Distribution of the Number of Creative Thinking Publications

3. Geographic Distribution of Existing Research Findings

Analysis of the top ten countries and regions by publication volume identifies Chinese mainland (60 articles) and the United States (59 articles) as the leading contributors, with other regions averaging approximately 16 articles each (see Figure 2.8). Among the foremost institutions, four are based in China, including Chang Gung University of Science and Technology and The Chinese University of Hong Kong. Delft University of Technology in the Netherlands leads with seven citations, followed by the University of Toronto in Canada with six citations, reflecting extensive and diverse international engagement in this research domain.

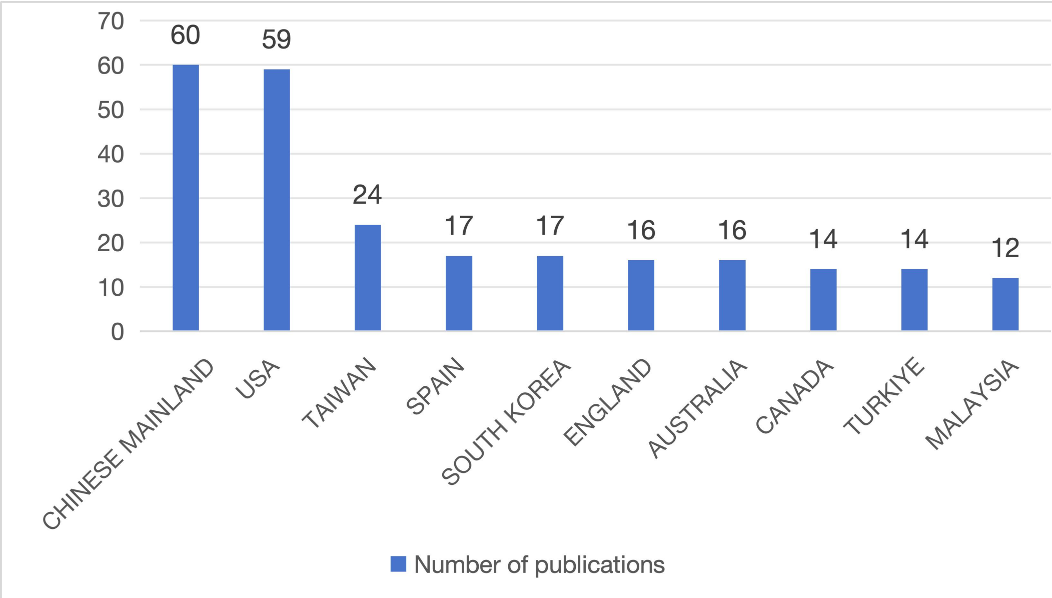

Figure 2.8. Top 10 Regions by Number of Creative Thinking Publications

4. Distribution of Journals Containing Existing Research Findings

The author co-occurrence network comprises 244 nodes and 316 links, exhibiting a network density of 0.0107, a modularity Q value of Q=0.9368, and a silhouette score of S=0.9906. These metricsreflect a highly clustered and internally coherent structure; however, the overall network remains dispersed and weakly connected, suggesting that the field is still in an exploratory phase. In accordance with Price's Law, there are seven core authors within this domain, representing only 7% of the total publications. This implies that a prolific author group has yet to emerge, and research efforts remain fragmented.

5. Distribution of Highly Cited Literature within Existing Research Outputs

The co-citation network consists of 458 nodes and 940 edges, with a network density of 0.009, a modularity Q value of Q=0.9368, and a silhouette value of S=0.9906, indicating distinct clustering and strong internal consistency. Seminal works, such as McLaughlin JE (2019), cited eight times, function as pivotal "bridges" linking educational practice with interdisciplinary applications. Literature on educational practice primarily addresses the integration of creative thinking into medical education, STEM, and computer science, whereas cross-domain application studies extend to product innovation and related fields, thereby offering interdisciplinary insights related to design education.

6. Keyword Cluster Analysis of Existing Research Outputs

Keyword clustering yielded nine principal clusters (Q = 0.6319, S = 0.8434, harmonic mean = 0.7225; see Figure 2.9), which can be categorized into two primary domains: Cross-domain associations of creative thinking: including clusters such as #0 human-AI interaction, #1 responsible innovation, and #9 knowledge graphs, reflecting the expansion of creative thinking into technological, ethical, and professional sectors. Practical applications of design education: including clusters #4 design studio education and #8 teacher training, which delineate the instructional contexts and agents responsible for fostering creative thinking. Furthermore, clusters such as #2 ADHD, #5 cross-cultural adaptation, and #6 applications in chemistry illustrate the research diversity and interdisciplinary growth.

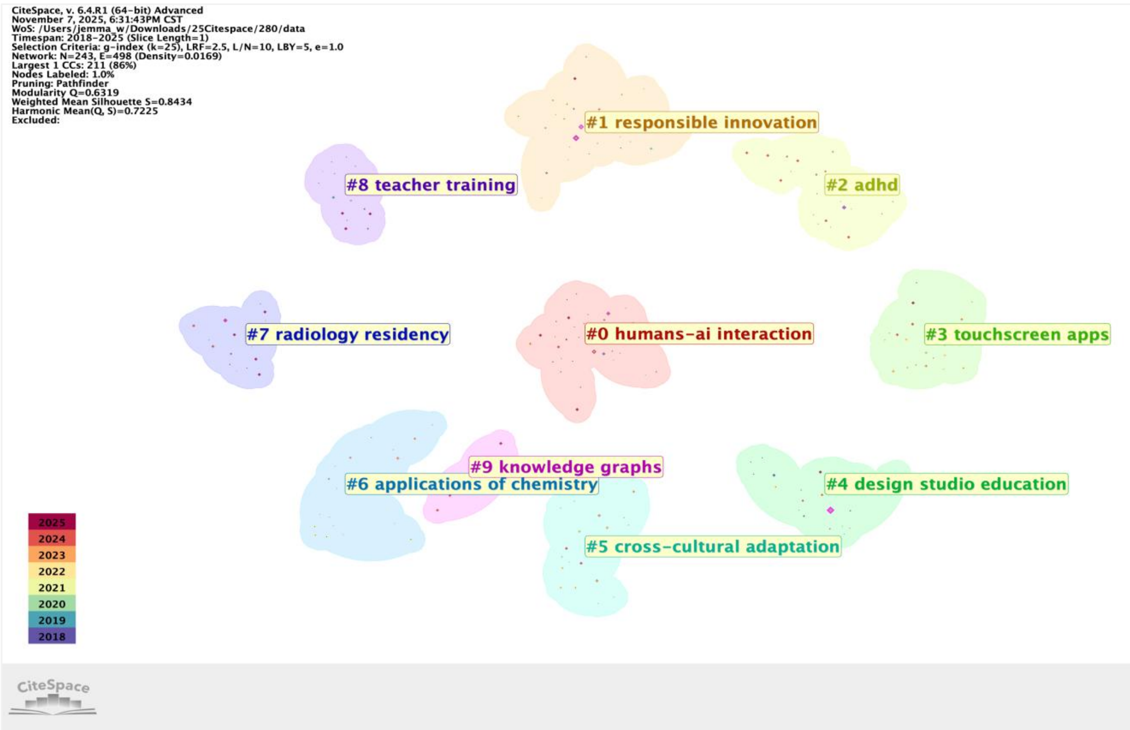

Figure 2.9 Keyword Cluster Map of Creative Thinking

The bibliometric analysis of creative thinking complements the previous section by mapping the intellectual structure and developmental trajectory of creativity research within design education. Through publication trends, co-citation networks, authorship distribution, and keyword clustering, this section reveals both the expansion and fragmentation of the field.

The analysis indicates that creative thinking research has grown significantly, particularly in higher education and interdisciplinary contexts. However, several structural characteristics emerge: The research network remains dispersed, with no dominant theoretical core. Studies frequently emphasize classroom practices or outcome-based evaluation metrics rather than cognitive mechanisms. Cross-domain applications (e.g., AI, responsible innovation, knowledge graphs) are increasing, yet systematic pedagogical models integrating these perspectives remain insufficient.

Collectively, these findings indicate the emergence of a dual-core framework characterized by "cross-domain associations" and "practical applications," demonstrating both openness and adaptability. These findings directly relate to the MRO by demonstrating that, while creative thinking is widely acknowledged as a central objective in design education, the mechanisms through which it develops—particularly in relation to knowledge transformation—are not yet fully theorized or operationalized.

More importantly, the bibliometric evidence highlights a missing integrative pathway: creative thinking is often studied independently from knowledge transformation processes and rarely examined through the lens of semantic mediation. This observation reinforces the necessity of the present research, which proposes that semantic stimulation functions as a cognitive catalyst linking knowledge restructuring and creative idea generation.

Therefore, this section supports the MRO in three key ways: It confirms the academic relevance and rapid growth of creative thinking research. It reveals conceptual fragmentation and methodological dispersion. It justifies the need for a structured, the framework that connects creative cognition with knowledge transformation through semantic stimulation.

Together, Sections 2.1.3 and 2.2.3 provide empirical level validation for the thesis's central contribution: the development of an integrated model in which semantic stimulation mediates the dynamic interaction between knowledge transformation and creative thinking in design education.

2.3 Research on the Impact of Semantic Stimuli on Creative Thinking (*for SRO*)

2.3.1 Inspiration Stimuli and Semantic Stimuli

Inspiration stimuli (such as images, objects, or abstract concepts) serve as external inputs that spark and support creative thinking during the design process. Studies have explored the effects of different types of stimuli on design creativity. For instance, Hou[17] investigated the impact of design inspirations from near, medium, and far domains, finding that far-domain inspirations enhanced the novelty of the solutions generated by designers (Figure 2.10). These stimuli are often classified based on their form and analogy distance [18][19](Table 2.1). Kosa Goucher-Lambert and colleagues examined the role of stimuli in creativity, using latent semantic analysis to identify adaptive stimuli and proposing real-time design monitoring measures [20]. Blandino et al. systematically reviewed the influence of stimuli and other factors on idea generation in conceptual design processes [18].

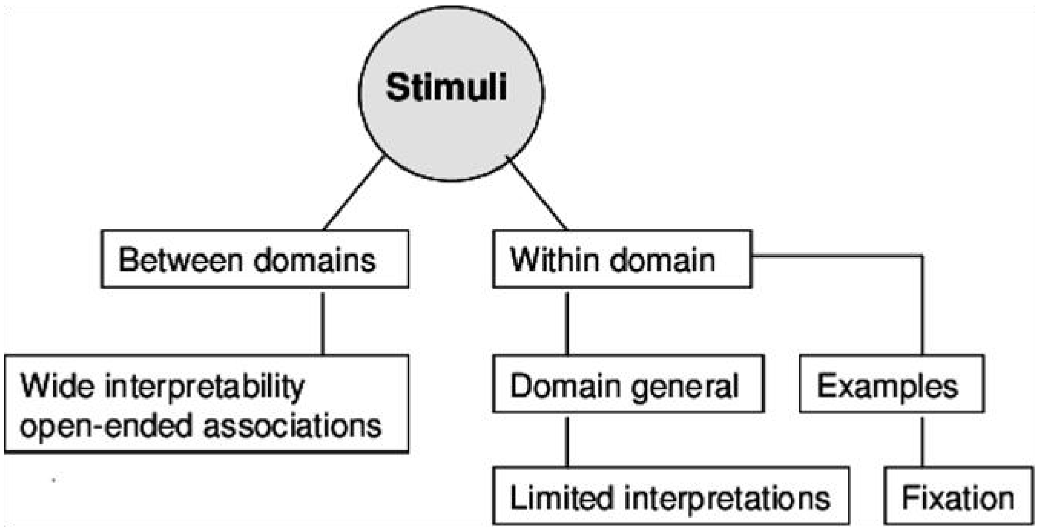

Figure 2.10 Stimuli types and their effects on designing

(Jia, L., Becattini, N., Cascini, G., & Tan, R. 2020)

Although designers typically prefer visual stimuli [21][22], other forms such as sketches and text-based stimuli can also affect creativity, sometimes facilitating or hindering the creative process [23][24]. Existing literature emphasizes the significant role of inspiration stimuli in design ideation and creativity [25][26][27][28].

Table 2.1. Comparative Review of Protocol Analyses on Stimuli Features: Source, Analogical Distance, and Form of Representation[18]

			Protocol Analyses
Stimuli Features	Source	Internal	Self-generated sketches suggest new ways to correct initial ideas (Suwa and Tversky, 1997) and to generate creative solutions (Goldschmidt and Smolkov, 2006). They do not affect the quality of experienced architects' ideas (Bilda *et al.*, 2006). Summarizing ideas through keywords improves the generated solutions (Doboli *et al.*, 2014); Physical models help designers generate ideas with a higher level of quality (Viswanathan and Linsey, 2012).
		External	Information comes randomly to the designer or through an active process where information is searched voluntarily by the designer through different sources (Gonçalves *et al.*, 2011) Their effect depends on their features.
	Analogical distance	Near	Near stimuli support the generation of more solutions at a higher level of quality than far stimuli (Srinivasan *et al.*, 2018); Near stimuli support the generation of the most creative ideas (Chan *et al.*, 2015).
		Medium	At the midpoint distance, participants demonstrated "peak inspiration" (Gonçalves *et al.*, 2014)
		Far	More distant stimuli are difficult to interpret (Gonçalves *et al.*, 2014); They support generating ideas with greater novelty (Chan *et al.*, 2011).
	Form/modality of representation	Visual	Visual stimuli are positively correlated with the creative solutions generated by participants (Goldschmidt and Smolkov, 2006); Visual stimuli can have different levels of the richness of details (Vasconcelos and Crilly, 2016).
		Textual	Textual stimuli require more effort than visual during for their interpretation (Gonçalves *et al.*, 2016); Textual stimuli have a negative effect on the number of ideas (Chan *et al.*, 2011).
		Other	The combination of stimuli enhances the creative potential of designers (Malaga, 2000; Borgianni *et al.*, 2020); Technical representations enhance the variety of ideas (Cascini *et al.*, 2020); Biology analogies can influence the design process, sometimes preventing designers from adequately exploring the solution space (Helms *et al.*, 2009).

Beyond visual stimuli, verbal and semantic stimuli are also recognized as important influences on creative output. Semantics refers to the meaning of words expressed through separable features, which together form the complete meaning of a word. The fundamental purpose of semantic stimuli is to expand cognitive boundaries, break habitual thinking patterns, and serve as tools for fostering divergent thinking across different groups. Earlier theories described word meanings through feature lists and compiled feature sets for concrete and abstract words, although such sets might not capture all relevant meanings. Vigliocco et al.[29] emphasized the importance of gathering feature information from multiple speakers to assess significance. Zahner et al.[30] studied the effects of concrete (domain-specific) and abstract (domain-general) stimuli on idea generation, finding that abstraction could stimulate novel ideas during the divergent phase but might reduce their practicality during the convergent phase. This suggests that abstract stimuli can generate new ideas, their practical applicability needs to be reassessed.

Georgiev[31] explored the use of dynamic semantic networks to investigate creative thinking, demonstrating that semantic measurement can effectively assess and enhance creativity in design education. This highlights the potential of linguistic elements as catalysts for creative thinking within design environments. Kivisaari et al.[32] conducted a cross-method and cross-linguistic comparison of semantic feature norms, again stressing the importance of collecting feature information from multiple speakers. Wise and Kenett[33] showed that automatically generated word suggestions could encourage creativity, emphasizing the role of semantic associations as metacognitive cues. Moreover, Wang et al.[34] found through EEG studies that participants exhibited significantly enhanced brain activity during design ideation tasks after receiving semantic feedback, indicating that semantic feedback can boost students' cognitive engagement and creative thinking abilities.

These findings highlight the key role of semantic stimuli in fostering creativity. In art education, the challenge lies in selecting suitable semantic words and effectively using them to enhance students' creative potential and expand their creative pathways.

2.3.2 Creativity Evaluation Metrics

In recent years, the assessment of design creativity has received widespread attention. Building on earlier work that identified novelty, diversity, quality, and quantity as key metrics, Vasconcelos & Crilly[35] further emphasized originality and relevance. Runco pointed out that structure and function address issues of usability and practicality, aesthetics focus on emotional and visual engagement, and originality reflects the assessment of novelty and innovation[36]. Blandino et al.[18](Table 2.2) conducted a systematic review on the role of stimuli in idea generation, highlighting the importance of introducing metrics such as novelty, diversity, quality, and quantity to evaluate participants' performance. These metrics are crucial for assessing the effectiveness of stimuli in enhancing creativity during the design process. Additionally, Owen and Roberts[37] proposed the Rowen Test for visualizing design creativity, focusing on four metrics: quantity, correctness, novelty, and feasibility. This test aims to provide a structured method for evaluating creativity in visual design, promoting objective assessment and fostering innovation.

Table 2.2. Comparative Review of Stimuli Effects on Idea Generation by Design Discipline and Creativity Metrics[18]

Other factors		Metrics: Novelty	Originality	Variety	Quality	Quantity	Fixation
Architecture	*Novice*		↑[a]Near analogies (Ozkan and Dogan, 2013)	↑Pictures (Purcell and Gero, 1992)	↑Pictures (Casakin, 2010)		↑Source examples (Ozkan and Dogan, 2013) ↑Pictures (Purcell and Gero, 1992)
	Expert				↑Pictures (Casakin, 2010)		↓[b]Far analogies (Ozkan and Dogan, 2013)
Industrial Design	*Novice*		↑Pictures & far Analogies (Yao *et al.*, 2017)		↑List of questions (Royo *et al.*, 2021) ↑Sketches of internal ideas (Sun *et al.*, 2013)	↑Keywords & near stimuli (Goucher-Lambert *et al.*, 2019) ↑Questions (Royo *et al.*, 2021) ↑Descriptions of internal ideas (Sun *et al.*, 2013)	↑Initial internal ideas (Leahy *et al.*, 2020) ↓Pictures & Far analogies (Yao *et al.*, 2017)
	Expert		↑Pictures & far analogies (Yao *et al.*, 2017)		↑Sketches of internal ideas (Sun *et al.*, 2013)		↓Pictures & far analogies (Yao *et al.*, 2017)
Engineering Design	*Novice*	↑Pictorial line-drawing of existing design solutions & far analogies (Cardoso and Badke-Schaub, 2011) ↓Sketch of solution example (Hernandez *et al.*, 2010) ↓Sketch of examples & before problem-solving (Perttula and Liikkanen, 2006) ↑List of words & far stimuli & After problem-solving (Tseng *et al.*, 2008) ↑List of words & near stimuli & Before problem-solving (Tseng *et al.*, 2008)	↓Pictorial line-drawing or photograph of existing design solutions (Cardoso *et al.*, 2009)	↑Sketch of solution example (Hernandez *et al.*, 2010) ↑List of words & far stimuli & After problem-solving (Tseng *et al.*, 2008) ↑List of words & Near stimuli & before problem-solving (Tseng *et al.*, 2008)	↓Pictorial line-drawing or photograph of existing design solutions (Cardoso *et al.*, 2009) ↓Sketch of solution example (Hernandez *et al.*, 2010) ↑Textual keywords & near stimuli (Goucher-Lambert *et al.*, 2019)	↑Pictorial line-drawing or photograph of existing design solutions (Cardoso *et al.*, 2009) ↑Sketch of solution example (Hernandez *et al.*, 2010) ↑Sketch of examples & after problem-solving (Perttula and Liikkanen, 2006) ↑List of words & far stimuli & after problem-solving (Tseng *et al.*, 2008) ↑List of words & near stimuli & before problem-solving (Tseng *et al.*, 2008)	↑Pictorial line-drawing or photograph of existing design solutions (Cardoso *et al.*, 2009) ↑Sketch of examples (Perttula and Liikkanen, 2006)
	Expert	↑Sketches of internal ideas (Viswanathan and Linsey, 2013)		↑Sketches of internal ideas (Viswanathan and Linsey, 2013)		↑Sketch of example solution (Viswanathan and Linsey, 2011)	↑3D and physical models of internal ideas (Viswanathan and Linsey, 2013) ↓List of words & description of the task (Viswanathan and Linsey, 2011) ↑Example solutions (Viswanathan and Linsey, 2011)

[a] ↑ Stimuli associated with this symbol have a positive effect on the performance metric.

[b] ↓ Stimuli associated with this symbol have a negative effect on the performance metric.

Traditional creativity evaluation has mostly focused on outcome-based approaches, emphasizing objective metrics such as the novelty, practicality, and refinement of works(Figure 2.11). However, in recent years, researchers have begun to emphasize the role of evaluating the creative process itself. Jiang Zhuqing et al.[38] mentioned in their study that methods for assessing creative thinking have gradually shifted from traditional outcome orientation to a focus on the design process.

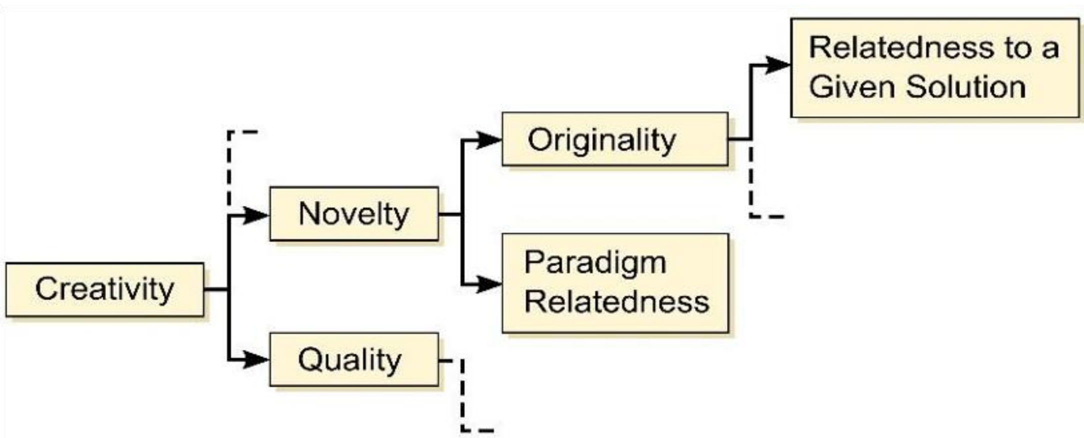

Figure 2.11 The metrics for evaluation of creativity, (Georgiev, Georgi, et al. 2016)

These studies collectively highlight the evolving methods and metrics used to assess and enhance creativity, emphasizing the importance of structured assessment tools and the integration of various metrics to promote innovative outcomes. However, no research has yet directly applied creativity evaluation metrics proactively to guide initial thinking in order to stimulate students' idea generation in the early conceptual design phase.

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2.3.3 Other Factors Influencing Participants' Creativity

In experimental studies on idea generation, Blandino et al. pointed out that several factors influence participants' performance, including background, expertise, experience, and gender [18](Table 2.3). Referring to this study, we propose, for students in art and design fields, to investigate the impact of semantic stimuli on creativity by using variables such as academic background, educational level, practical experience, and gender.

Table 2.3. Comparative Review of Other Factors in Stimulus: Participant Characteristics, Time, and Supporting References[18]

Other Factors		References
Participant's characteristics	*Background*	• Goldschmidt and Smolkov (2006) • Goucher-Lambert *et al.* (2019) • Royo *et al.* (2021) • Todoroff *et al.* (2021) • Vieira *et al.* (2019) • Vieira *et al.* (2020)
	Expertise	• Casakin (2010) • Chai *et al.* (2015) • Cross (2004) • Gonçalves *et al.* (2011) • Goucher-Lambert *et al.* (2019) • Kavakli and Gero (2001) • Hu *et al.* (2021) • Majdic *et al.* (2017) • Nelius *et al.* (2020) • Ozkan and Dogan (2013) • Sun *et al.* (2013) • Suwa and Tversky (1997) • Viswanathan and Linsey (2013) • Yao *et al.* (2017)
	Experience	• Hu and Reid (2018) • Sun *et al.* (2014)
Time	*Timing of Stimulation*	• Perttula and Liikkanen (2006) • Tseng *et al.* (2008)
	Time available	• Liikkanen and Perttula (2010)

In this study, “Academic background” refers to the different disciplines or majors of the participants. Recent research indicates that interdisciplinary collaboration in design education can enhance creativity and problem-solving abilities. For example, Fleischmann, K.[39] discussed the integration of unrelated disciplines into design classrooms, highlighting both the benefits and challenges of this approach. Zheng et al.[40] analyzed a large number of scientific publications and patents, concluding that teams with diverse expertise can produce more original and longer-lasting works. Similarly, Ou et al.[41] found that binary teams composed of designers and non-designers generated more original and useful design ideas compared to homogeneous teams. Todoroff et al.[42] compared the design thinking traits between samples of civil engineering and architecture students across various institutions in the United States. Differences in perceived design thinking suggest diverse academic backgrounds can enhance creativity in design education.

In this study “Educational level” refers to whether participants are graduate students or undergraduates. An study by CHEUNG et al.,[43] investigated the effects of students' majors and years of study on creativity. The study found that level of study (diploma vs. degree) and prior academic performance were significant predictors of divergent thinking abilities. This suggests that the educational process and academic background influence creativity. A longitudinal study by Kim, J. Y., at a Korean engineering university examined the relationship between students’ creative potential and academic performance[44]. The results indicated that creative potential improved over four years, particularly in aspects such as fluency and originality. This shows that higher education can enhance certain aspects of creativity over time. These studies suggest that educational level can influence creativity through factors such as duration of study.

In this study, "Practical experience" is represented by the length of time participants have been engaged in design practice. Phothong et al.[45] observed that students with design experience exhibited a more developed design thinking mindset after participating in design-based learning activities. Samaniego et al.[46] conducted a systematic review emphasizing the role of experiential learning in fostering creative thinking in art and design education. Their study highlighted that hands-on learning environments help cultivate core creativity. These findings suggest that the duration and intensity of participation in design practice projects are positively correlated with the enhancement of creativity.

"Gender" studies have shown varying results regarding gender differences in design creativity. Research by Luo et al. [47] indicated that gender stereotypes in creativity might hinder female students' development of creative self-efficacy in visual arts education. Conversely, other studies suggest that female students may excel in certain aspects of design thinking. For instance, a study by Cañizares[48] found that, compared to male students, female students had more positive impressions and perceptions regarding methods for participating in idea generation.

Although the studies mentioned above have validated the influence of these four participant factors on creativity, in the context of art and design education, further exploration is needed on how to appropriately define participant factors and investigate their impact on the stimulation of creativity through semantic stimuli.

In summary, Chapter 2 is structured to establish a coherent theoretical and literature foundation for the MRO and to clarify how each section supports the MRQ, SRQ, and the Study. Section 2.1 reviews research developments in knowledge transformation within design education, addressing the MRO by examining how design knowledge is generated, internalized, and transformed through learning processes, while identifying limitations in existing models regarding operational mechanisms. Building on this foundation, Section 2.2 synthesizes studies on creative thinking in design education, further supporting the MRO by clarifying the cognitive characteristics, pedagogical strategies, and evaluation approaches associated with creativity development, and highlighting the need to better integrate knowledge transformation with creative cognition. Focusing on SRQ and Study, Section 2.3 reviews empirical and theoretical research on semantic stimulus mechanisms and their effects on creative thinking, emphasizing different stimulus types, creativity evaluation metrics, and influencing factors, while identifying gaps in systematic and pedagogically grounded applications within design education. Collectively, these sections demonstrate how existing literature informs and constrains current understanding, justify the research gaps addressed by the two studies, and position the thesis's integrated approach to knowledge transformation, semantic stimulation as a coherent response to the MRQ, thereby preparing the conceptual and methodological groundwork for the subsequent Research Design and Methodology chapter.

2.4 Gaps in Existing Research and the Focus of the Present Study

The previous review and bibliometric analysis highlight the increasing prominence of Knowledge Transformation and Creative Thinking as key themes in contemporary design education research. However, despite this growing interest, there remain several critical gaps in understanding how these two concepts interrelate, particularly in the context of design education.

In relation to Knowledge Transformation research, findings from the CiteSpace analysis reveal a consistent growth in related studies since 2018, underscoring the academic community ’ s sustained interest in the interplay between knowledge and creativity in design education. These studies highlight how learners' design knowledge evolves through processes like socialization, externalization, combination, and internalization, with a particular focus on how tacit knowledge is articulated and reshaped. While these investigations emphasize the motivational roles of reflective learning, flipped classrooms, and scaffolded teaching approaches, several systemic limitations persist. Current research predominantly addresses specific educational settings such as higher design education, workshops, or professional training programs. However, there is still a lack of comprehensive frameworks that integrate knowledge transformation as a dynamic process that fosters both learning and creativity.

In relation to Creative Thinking research, the literature similarly demonstrates a marked upward trajectory, with a primary focus on classroom practices and the cognitive dimensions of creativity development. Studies frequently analyze the thinking characteristics of design learners through dimensions such as fluency, flexibility, originality, and elaboration, while also considering the impacts of technological enhancement and cultural adaptation. However, the body of research remains fragmented and lacks comprehensive integration. In particular, there is insufficient exploration into the systematic incorporation of creative cognition within instructional frameworks. While the importance of creative thinking in design education is widely recognized, the development of structured pathways for fostering creativity and robust evaluation systems still requires substantial attention.

Thorough analysis reveals several gaps in current research, which can be categorized as follows:

Gap 1: Integration of Knowledge Transformation and Creative Thinking

Current research often treats knowledge transformation and creative thinking as separate domains without sufficiently exploring their dynamic relationship. There is a noticeable gap in understanding how these two processes interact in the context of design education. Specifically, the ways in which knowledge transformation catalyzes creative thinking, and vice versa, remain underexplored. A comprehensive framework that links these two processes systematically and emphasizes their reciprocal influence is sorely lacking. This gap limits the development of pedagogical models that can enhance both learners' knowledge and their creative capabilities simultaneously.

Gap 2: Application of Semantic Stimulation in Design Education

The application of semantic stimulation within design education—particularly in fields such as graphic visual design—remains under-researched. While some studies have explored the effects of semantic cues on learners' creative processes, there is a significant lack of clear pedagogical methodologies that systematically incorporate semantic stimuli into the learning process. This limitation is especially pronounced in the context of design education, where semantic stimulation could play a crucial role in promoting creativity. Additionally, research has not sufficiently examined how semantic stimulation mechanisms can be integrated into knowledge transformation frameworks to enhance the learning experience in design education. In particular, the alignment of semantic stimulation with creative cognition in the context of visual design education remains a critical issue that warrants further exploration.

Gap 3: Lack of Systematic Integration of Semantic Stimulation with Creative Thinking and Knowledge Transformation

While some studies have examined the impact of semantic cues on cognitive and creative processes, there is a lack of comprehensive integration of semantic stimulation within broader educational frameworks for knowledge transformation and creative thinking. A structured approach to semantic stimulation, one that addresses different forms of semantic cues (e.g., expert commentary, abstract and concrete terminology, evaluative language), and its systematic use within teaching practices, is sorely needed. Current studies have not sufficiently explored how different types of semantic stimuli activate creative cognition in learners or how they facilitate the transition from tacit to explicit knowledge. Moreover, how individual learner characteristics influence the effectiveness of semantic stimulation mechanisms in the design process remains an understudied area. The absence of an integrated pedagogical framework that combines semantic stimulation, creative thinking, and knowledge transformation limits the potential for designing educational strategies that can effectively enhance both creative and cognitive growth in design learners.

This research proposes a framework that explores the relationship between knowledge transformation and creative thinking in design education. It examines how semantic stimulation mechanisms — such as expert commentary, terminology variation, and evaluative language — facilitate both processes, aiming to develop a pedagogical model that integrates them.

The research introduces an iterative model where learners acquire tacit knowledge through experience, externalize ideas into design language, and engage in creative innovation. Semantic stimulation plays a key role in activating creative cognition and guiding learners through idea development and knowledge restructuring.

By integrating semantic and cognitive perspectives, the study clarifies how semantic cues foster creativity and knowledge transformation, helping learners apply knowledge more meaningfully. Ultimately, this research offers a sustainable mechanism for continuous development of knowledge and creative skills in design education. It contributes to teaching practices across diverse settings, suggesting that semantic stimulation supports flexible thinking, fostering an environment conducive to both knowledge transformation and creativity.

In conclusion, the study shows how semantic stimulation mediates the relationship between knowledge transformation and creative thinking, helping learners transition from tacit to explicit knowledge and generate innovative design solutions. The research contributes to developing more effective design pedagogies, enhancing cognitive and creative capabilities in design learners.

3

Empirical research

Chapter 3 examines the function of semantic stimulation mechanisms within design education as a means to enhance creative thinking. It investigates the influence of descriptive terms, extracted by specialists, on stimulating students' creativity. The chapter further analyzes the effects of various semantic categories, potential biases in evaluation metrics, and individual differences on idea generation. Additionally, it considers semantic stimulation as a potent mechanism for knowledge transformation and offers pedagogical recommendations that incorporate innovation processes and multi-phase cognitive transformation.

Chapter 3 Study：The Role of Semantic Stimulation in Enhancing Creative Thinking in Design Education (*for SRO*)

3.1 Research Design: Practical Objectives and Core Issues

Building on the identified gaps in the literature on semantic stimulation mechanism in design education, Chapter 3, Study empirically investigates how different types of semantic stimuli, creativity evaluation metrics, and individual differences influence the stimulation of creative thinking in design, offering insights for their application in design pedagogy.

Specifically, it addresses three areas: (1) Analyzing the differential effects of abstract and concrete stimuli; (2) Developing creativity guidance based on various evaluation metrics at the early design stages; (3) Investigating how academic background and education influence the effectiveness of semantic stimuli, aiming to provide targeted semantic guidance strategies for design education **(Figure 3.1).**

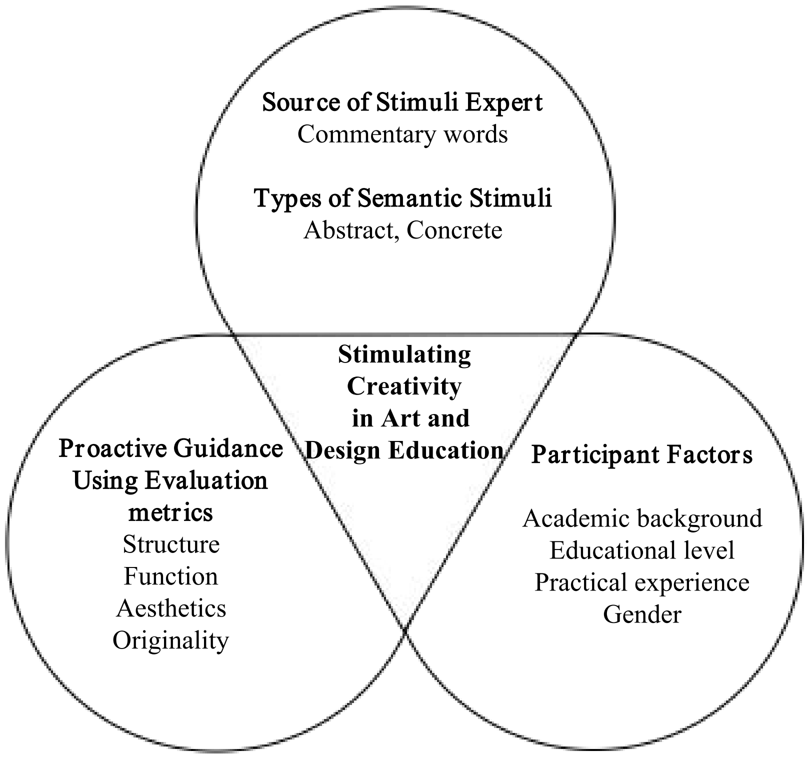

Figure 3.1.　Diagram of Research Content

3.2 Methods and Materials: Empirical Testing of Semantic Stimuli

To differentiate from previous studies that generally selected semantic stimuli, this study used expert commentary words as semantic stimuli. These were classified based on semantic types and creativity evaluation tendencies and applied during the initial phase of the design process to guide thinking. The study explored the effect of semantic stimuli on enhancing creative thinking in art and design education. The goal was to evaluate the role of semantic stimulus types (concrete, abstract), creativity evaluation orientations (structure, function, aesthetics, originality), and other participant factors (academic background, education level, practical experience, gender) in stimulating creativity among students majoring in art and design.

To achieve this objective, we followed three steps:

(1) Experts extracted commentary words based on the visual stimuli of award-winning works from world-class competitions.

(2) Commentary words were classified and validated based on semantic type and creativity evaluation orientation.

(3) Chi-square tests were conducted on semantic stimuli, creativity evaluation orientations, and participant factors.

3.2.1 Step One: Extracting Commentary Words from Visual Stimuli of Award-Winning Works by Experts

Sample Selection: This study used award-winning designs from the '2020 WorldStar Global Packaging Awards' as visual stimuli. This award (https://worldstar.org), organized by the World Packaging Organization (WPO), represents the highest recognition for outstanding packaging designs worldwide and indicates trends in packaging design development. These award-winning designs were selected because their creativity and innovation had been recognized, ensuring high-quality examples of design principles. According to WorldStar statistics, in recent years, the packaging competition has received over 300 entries annually from more than 34 countries around the world, a total of 212 works won awards. The awarded works serve as effective triggers for new ideas, representing a diverse range of creative excellence.

Data Collection: We invited 7 experts (six males and one female) with over 20 years of design experience, all of whom had served as design judges at various design workshops. The task for the expert judges was to evaluate each provided award-winning design (visual stimulus) and write a brief response (a word or short phrase, i.e., commentary word) under each design, commenting on why they believed the design had won an award. Each expert was required to provide twenty or more words or phrases. Figure 3.2 shows an example of our visual stimuli set along with the commentary words provided by one of the experts.

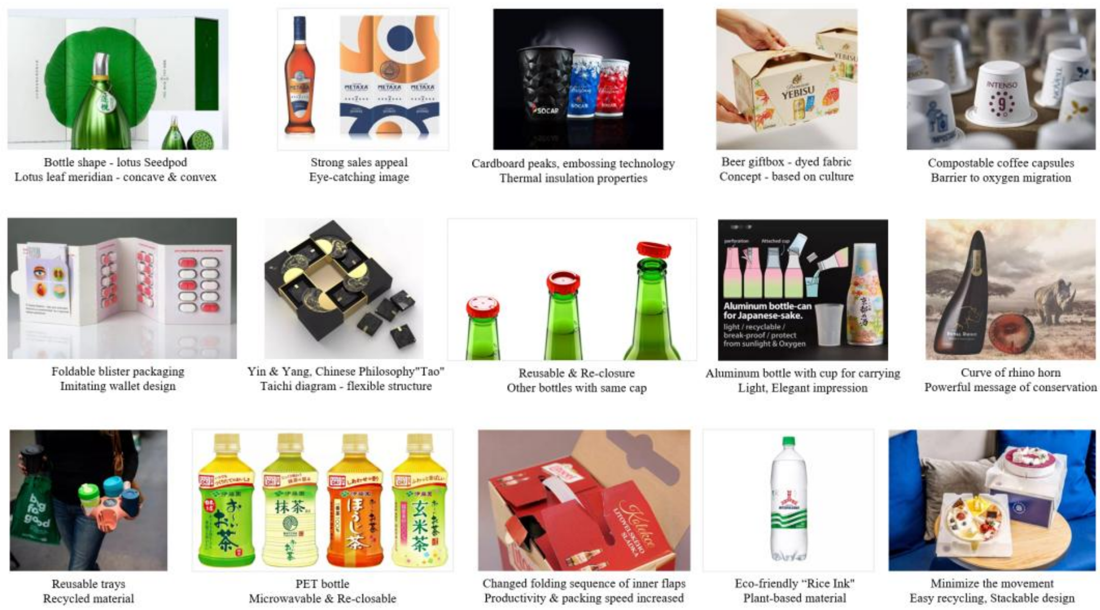

Figure 3.2. Example: Expert commentary on selected award-winning works

3.2.2 Step Two:Classification and Validation of Commentary Words Based on Semantic Types and Creativity Evaluation Orientations

1 Classification of Semantic Types and Creativity Evaluation Orientations of Commentary Words

We provided a set of commentary words obtained from expert opinions to 51 design faculty members with extensive design experience. These faculty members were asked to classify each word according to two semantic types and four creativity evaluation orientations: that is, ‘abstract or concrete’ semantic types, and ‘structure, function, aesthetics, originality’ orientations. This step ensured that the final word set represented different semantic attributes.

Commentary words were selected as semantic stimulation because they provide a verbal, controllable, and cognitively integrative form of input that can be standardized across learners and deliberately manipulated in relation to semantic type and evaluative orientation. In the target study, unlike generic lexical prompts, commentary words were extracted from experts' critiques of award-winning design works; therefore, they carried stronger disciplinary relevance and a clearer evaluative orientation, allowing students to attend not only to "what a design is" but also to "why it is considered creative." In this sense, commentary words function as condensed carriers of professional judgment. They translate the discourse of critique into stimulus material that can be introduced at the ideation stage, thereby moving evaluation criteria from a purely post hoc role to a formative and proactive one. This choice is also consistent with recent research showing that the form of stimuli affects idea generation, that textual stimuli can be adjusted according to design phase and task demands, and that word-based prompts can trigger new associations in semantic memory, especially when designers encounter fixation or impasse. For design education, commentary words are therefore not merely verbal cues; they are pedagogically meaningful semantic triggers that connect expert knowledge, evaluative language, and creative concept generation in a more structured way.

This study selected abstract and concrete as the semantic classification dimensions for the following reasons: First, the cognitive manner in which semantic stimuli are processed directly affects the outcomes of idea generation. Abstract and concrete representations each have unique advantages in activating thought processes and together can meet the full-spectrum needs of design thinking, from conceptual exploration to practical implementation. Second, these categories may align with the staged characteristics of design education and the differentiated needs of various design disciplines regarding the abstract–concrete dimension.

This study chose structure, function, aesthetics, and originality as the classification dimensions for creativity evaluation tendencies based on the following considerations: Creativity assessment must balance practicality and aesthetic innovation. In the field of design education, design competitions are often used as key measures of teaching effectiveness, and their evaluation metrics typically encompass multiple dimensions, such as structural rationality, functional performance, aesthetic expression, and conceptual originality. Unlike previous studies, this study innovatively expanded the application of these metrics in two ways: First, as a basis for classifying the semantic stimuli; Second, by transforming them into thinking guidance tools during the early design stages to systematically stimulate creative potential through proactive dimension setting. This dual application not only maintains the educational relevance of traditional evaluation standards but also overcomes the limitation of their use solely as post assessment tools.

The classification of expert opinions served two purposes: First, this process enabled a systematic assessment of the impact of different types of stimuli on creativity, providing a method for evaluating how semantic words align with design thinking. Second, It helped establish clearer links between specific stimuli and creativity evaluation tendencies, aiding the conceptual design process through semantic word classification.

To enhance consistency in classification, a preparatory coordination session was conducted with all 51 faculty members prior to the formal classification. During this session, representative sample words were used to calibrate understanding of the semantic types (“abstract” vs. “concrete”) and creativity evaluation orientations (“structure,” “function,” “aesthetics,” and “originality”). Faculty members discussed edge cases and clarified ambiguous terms to ensure a shared conceptual understanding. All data processing operations were subsequently carried out by two independent researchers with expertise in design and semantic analysis, who followed a predefined coding protocol to categorize the words. Preliminary trial coding ensured consistency, and in cases of disagreement, coders engaged in structured discussion with a third reviewer to justify and align their judgments based on shared metrics and contextual usage in design discourse. The classification of words as "abstract" or "concrete" was grounded in both linguistic definitions and design cognition principles: abstract words were defined as those referring to intangible qualities, emotions, or conceptual constructs (e.g., “balance,” “innovation”), while concrete words referred to physical forms, sensory experiences, or tangible phenomena (e.g., “texture,” “curve”). These definitions were informed by cognitive linguistics literature and refined through the faculty discussion process.

2 Survey on the Effectiveness of Commentary Words in Stimulating Creativity

Participants

We recruited 409 students from China, studying at two schools: the School of Art and Design and the School of International Education. The questionnaires was sent via online survey app. A total of 409 questionnaires were distributed, and 345 valid responses were collected.The effective rate of the questionnaire was 84.4%. Participants joined voluntarily via the university's online platform. Their demographic information is as follows: 107 males and 238 females; 178 students majoring in Visual Communication Design, and 167 students majoring in other design fields (such as Product Design, Fashion Design, Digital Media, etc.); 307 undergraduate students and 38 graduate students. Among them, 47 students had more than three year of design experience, while 298 had less than three year of experience. Participants received participation credits for their involvement. Before the experiment, researchers explained the study's purpose and procedures to participants in detail. Each participant gave informed consent and provided demographic information through a questionnaire. They were informed that all data would be used solely for research purposes, and they retained the right to withdraw or terminate participation at any time.

The division of participants by education level (undergraduate vs. graduate) followed the official enrollment status provided by their academic programs. Major categories were defined based on institutional curriculum tracks, with Visual Communication Design treated as a separate focus due to its relatively high enrollment and distinctive pedagogical characteristics. Although the sample sizes of the groups were not numerically balanced, the distribution reflects typical proportions found in comprehensive design schools in China. Therefore, the composition of the sample was deemed appropriate for exploratory analysis and aligned with common demographic patterns in art and design education.

Procedure

First, a quantitative survey was conducted via an online questionnaire distributed through the internet platform (https://www.wjx.cn/). The questionnaire description read: "We are interested in exploring how effectively semantic words can stimulate creativity in design students. A list of semantic words selected by experts is provided. Please rate the effectiveness of each word in inspiring creativity on a 5-point Likert scale, from 1 (low effectiveness) to 5 (high effectiveness). Your choices are subjective and individual—there are no right or wrong answers." Participants had 5–10 minutes to complete this task. Secondly, 9 participants were randomly selected for interviews to conduct a qualitative survey on the effectiveness of the comment-based semantic words in stimulating creativity.The selection of 9 participants is based on the following considerations: Firstly, our focus is on generating detailed insights through in-depth conversations—such conversations typically require dedicated time (about 45–60 minutes per participant). Secondly, we also need to consider selecting representative participants of different types, including those with varying design expertise and creative preferences identified in the quantitative survey.

3.2.3 Step Three: Chi-Square Tests on Semantic Stimuli, Creativity Evaluation metrics, and Participant Factors

First, a correlation analysis was performed between abstract and concrete semantic words. Then, correlation analyses were conducted between the two types of semantic stimuli (abstract, concrete), the four creativity evaluation metrics(structure, function, aesthetics, originality), and participant factors (academic background, education level, practical experience, gender). The aim was to identify potential differences in how various semantic stimuli affected the target group, thus enabling more tailored educational interventions for different types of students.

3.3 Results

3.3.1 Results of High-Frequency Semantic Words Extracted and Integrated from Expert Comments

In Step One, 150 unique words reflecting design attributes and creative features were extracted from expert reviews of design works, as shown in Figure 3.3. In the word cloud, larger font size indicates higher frequency of mention. After consolidating semantically similar terms and merging synonyms (e.g., “ergonomic” and “user-friendly”), the 30 most frequently mentioned words achieving the highest consensus among the 7 experts were selected and ranked by mention frequency, providing a basis for semantic stimuli in the following research (Table3.1).

Figure 3.3. Word Cloud of Comment-Based Semantic Words

Table3.1 Top 30 Most Frequently Mentioned Words with the Highest Consensus

Words	Retro	Fusion	Fun	Integration	Technology	Recycled	Efficient	Texture	Material	Compostable
Frequency	7	7	7	7	6	6	6	6	6	6
Words	Symbol	TaiJi YinYang	Eye-catching	Portable	Magic	Culture	Humorous	Fresh	Deliverable	Tactile
Frequency	6	5	5	5	5	5	5	4	4	4
Words	Conservation	Manual	ECo-friendly	Foldable	Metaphor	Elegant	Care	Interaction	Stackable	Classic
Frequency	4	4	3	3	3	3	3	2	2	2

3.3.2 Results of Effectiveness of Classifying Semantic Word Types and Preceding Evaluation metrics in Stimulating Inspiration

1 **Classification Results of Semantic Word Types and Creativity Evaluation metrics**

The classification results based on semantic types and creativity evaluation metrics are shown in Figures 3.4 and 3.5. The number before each word indicates its ranking among the 30 most mentioned words.

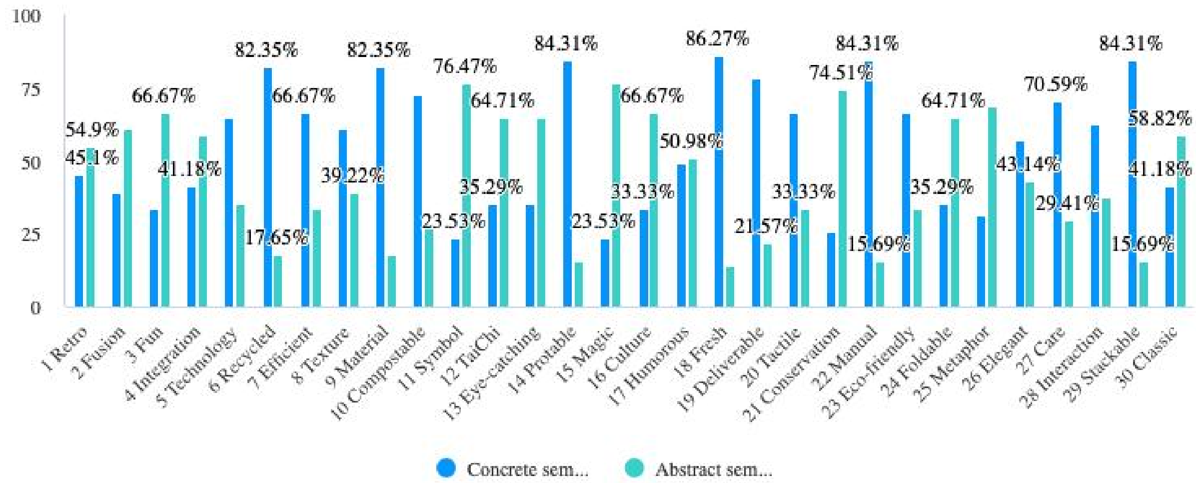

Figure 3.4. Classification of Semantic Word Stimuli
Based on Abstract and Concrete Features

Figure 3.4 shows the classification of the 30 comment words based on abstract and concrete semantic features. The higher the blue line percentage, the stronger the recognition of the word as having concrete features; the higher the green line percentage, the stronger the recognition of the word as having abstract features.

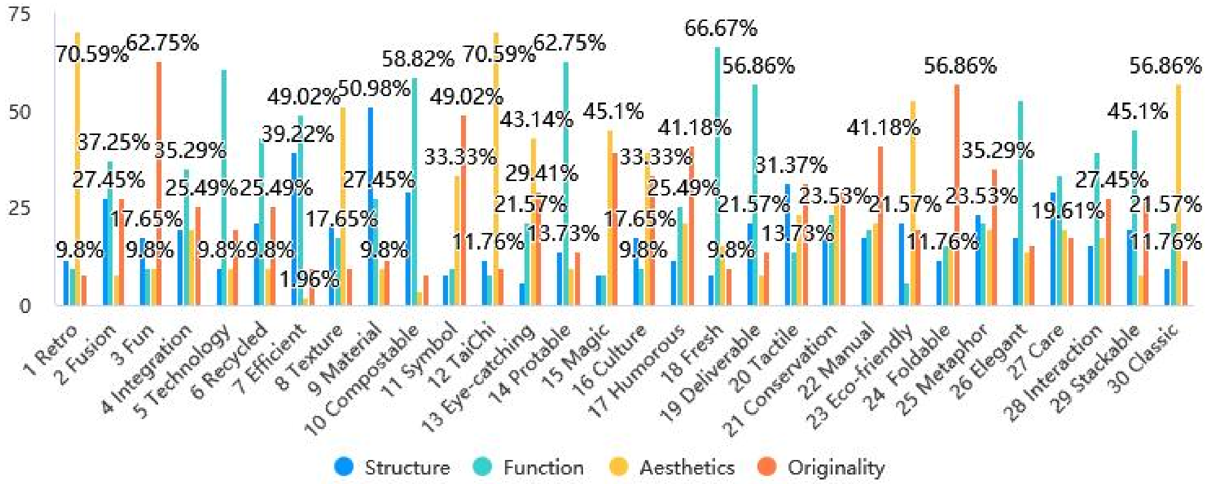

Figure 3.5. Classification of Semantic Word Stimuli
Based on Creativity Evaluation metrics

Figure 3.5 shows the classification results of the 30 comment words according to the four creativity evaluation metrics. The higher the blue line percentage, the stronger the recognition of the word's structural attributes; the higher the green line percentage, the stronger the recognition of functional attributes; the higher the yellow line percentage, the stronger the recognition of aesthetic attributes; and the higher the orange line percentage, the stronger the recognition of originality attributes.

2 Results of the Survey on the Effectiveness of Comment-Based Semantic Words in Stimulating Creativity

Result 1: Based on the results of Figure 3.4 and 3.5 and the following criteria, we removed five words with unclear feature tendencies. Semantic ambiguity: Items showing a small difference between Concrete and Abstract classifications were considered semantically less distinctive. Lack of clear dominance in creativity dimensions: Items with no clearly dominant category across Structure, Function, Aesthetics, and Originality were considered insufficiently discriminate.

"1 Retro" and "17 Humorous" can be removed because the difference between "Concrete" and "Abstract" is small (less than 10%). "27 Care" can also be removed because the difference between the values for "Structure" and "Function" is small (2) (see Appendix D). Although "4

Integration" and "30 Classic" show a difference between Abstract and Concrete semantics (41.18% vs. 58.82%), both terms were ultimately removed for the following reasons. In the creativity evaluation results, neither term demonstrates a clearly dominant dimension. For "4 Integration," the counts are distributed across Function (18), Originality (13), and both Structure and Aesthetics (10 each), indicating a dispersed evaluative profile rather than a single salient attribute. Similarly, "30 Classic" shows a concentration in Aesthetics (29), but its scores in Structure (5), Function (11), and Originality (6) are relatively low and dispersed. This indicates that, while it conveys a general aesthetic impression, it does not provide sufficient discriminate information across multiple dimensions of design evaluation. In contrast, the retained items show both clearer semantic orientation and more balanced or distinctive representation across the four creativity dimensions, making them more informative for analysis. "20 Tactile," was retained because it showed a clear majority (66.67% concrete) in semantic classification, reflecting a shared, perceptually grounded understanding among participants—even though its creativity ratings were moderately distributed, and it contributes meaningful information in the context of other terms and represents a distinct tactile aspect of design not captured by other retained items. Its retention ensures that the final set remains balanced and representative across both semantic and creativity dimensions.

The 25 most relevant words were selected for the effectiveness survey(Table3.2). Figure3.6 presents the quantitative assessment of the effectiveness of these 25 words (excluding invalid questionnaires). On the X-axis are the semantic words ranked by frequency of mention. The Y-axis shows the percentage of participants who rated the effectiveness of each word in inspiring creativity, using the Likert scale. Low proportions of blue indicate low effectiveness, cyan indicates relatively low effectiveness, yellow indicates moderate effectiveness, orange indicates relatively high effectiveness, and high proportions of green indicate high effectiveness. From the quantitative results in Figure 3.6, it can be seen that for the 25 unclassified semantic words, the proportion of participants who selected 'high effectiveness' and 'relatively high effectiveness' was much higher than those who selected 'low effectiveness' or 'relatively low effectiveness'.

Table3.2 25 Relevant Words for Effectiveness Survey (Excluding 5 with Unclear Features)

1st	Retro	Fusion	Fun	Integration	Technology	Recycled	Efficient	Texture	Material	Compostable
2nd	☒	☑	☑	☒	☑	☑	☑	☑	☑	☑
1st	Symbol	TaiJi (YinYang)	Eye-catching	Portable	Magic	Culture	Humorous	Fresh	Deliverable	Tactile
2nd	☑	☑	☑	☑	☑	☑	☒	☑	☑	☑
1st	Conservation	Manual	Eco-friendly	Foldable	Metaphor	Elegant	Care	Interaction	Stackable	Classic
2nd	☑	☑	☑	☑	☑	☑	☒	☑	☑	☒

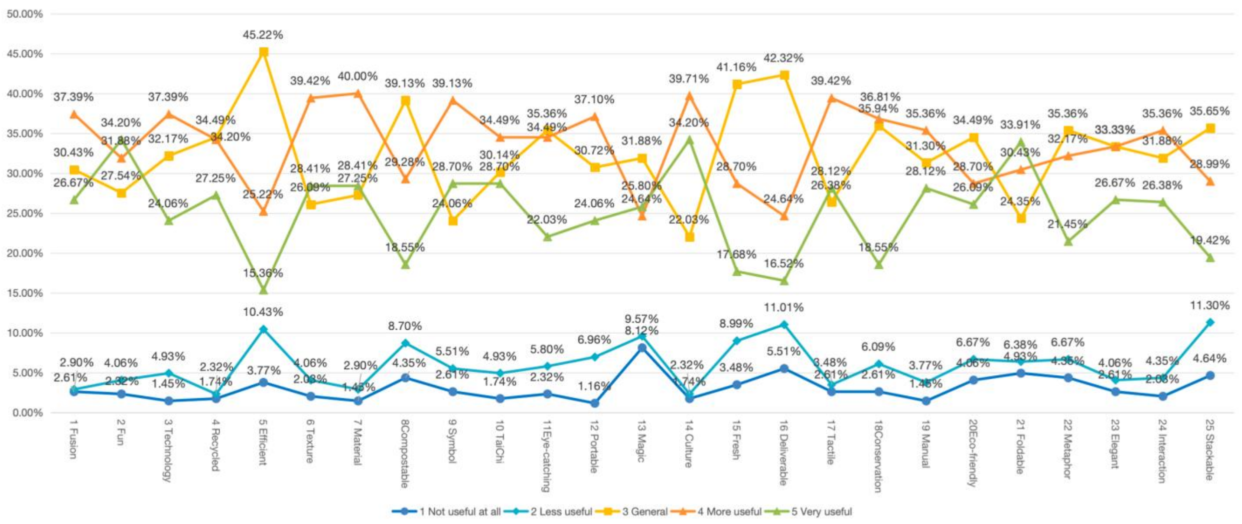

Figure 3.6. Proportion of Participants Evaluating the Effectiveness of Unclassified Semantic Words in Stimulating Inspiration

Similarly, the qualitative interviews confirmed these findings (Table3.3): Among the nine interviewees, eight reported that they found it easy to draw inspiration from the high-rated words, for example, participant ID P9 mentioned,“「Elegance」inspired designs featuring natural forms and organic patterns. 「Magic」 triggered narrative-driven design ideas, both offering abstract inspiration.”While only one reported difficulty in deriving concrete design ideas from them, for example, participant ID P3 noted, “「Culture」 made me think more about user emotions and humanistic factors, offering broader considerations beyond a single focus. However, it wasn’t particularly strong in inspiring specific design ideas.”

Table 3.3. Excerpts from Qualitative Interviews with Some Participants

ID	Gender	Education	Major	Semantic Tendency	Word Choices	Excerpts from Interview Results
P1	Female	Undergraduate	Visual Communication	Abstract	Fusion, Magic, Conservation, Symbol	"Fusion" made me think of combining sustainable concepts with traditional weaving techniques. "Magic" inspired surreal compositions, leading to a poster idea combining paper-cutting with AR technology. "Symbol" prompted me to reconstruct a brand using Oracle bone script.
P2	Male	Undergraduate	Visual Communication	Concrete	Foldable, Ink	"Foldable" sparked ideas for portable display booklets. These words made me associate with printed media and installation art, aiding design expression and presentation.
P3	Female	Undergraduate	Digital Media	Both Abstract and Concrete	Culture, Care	"Culture" made me think more about user emotions and humanistic factors, offering broader considerations beyond a single focus. However, it wasn't particularly strong in inspiring specific design ideas.
P4	Male	Graduate	Digital Media	Abstract	Fusion, Technology, Metaphor	"Fusion" inspired me to incorporate ink-style comic elements into UI animations. "Technology" made me abandon skeuomorphic design and explore network visualization interactions. "Metaphor" led me to think about using visual symbols to guide user behavior.
P5	Female	Undergraduate	Fashion Design	Concrete	Material, Tactility, Culture	"Material" made me think about real materials and their application contexts. "Tactility" inspired me to

						consider thermosensitive fabrics; combining it with “Culture” helped me create a transformable Hanfu sleeve design, improving my project score.
P6	Female	Undergraduate	Visual Communication	Abstract	Culture, Tai Chi (Yin Yang)	“Culture” guided me back to the roots, such as using embroidery elements to create modern handbags. Abstract words helped prompt deeper cultural expressions.
P7	Female	Graduate	Visual Communication	Both Abstract and Concrete	Deliverable, Technology	I liked “Deliverable” because it pushed me to imagine how textual information could be visualized. “Technology” encouraged me to consider different technical expression methods.
P8	Male	Graduate	Product Design	Concrete	Portability, Compostable, Stackable, Interaction	“Portability” inspired me to design bottles with handles, considering ease of use. “Compostable” stimulated modular product joints using mortise-and-tenon structures with biodegradable plastics. “Stackable” helped me design better packaging structures. “Interaction” led me to add tactile feedback devices in children's dining chairs, which I wouldn't have considered during undergraduate studies.
P9	Female	Graduate	Visual Communication	Abstract	Elegance, Magic	“Elegance” inspired designs featuring natural forms and organic patterns. “Magic” triggered narrative-driven design ideas, both offering abstract inspiration.

These quantitative and qualitative results were derived from an investigation of expert review words that had not yet been classified by semantic types or creativity evaluation metrics. Result 1 indicates that using unclassified expert review words as semantic stimuli is both feasible and effective. For example, words such as "Elegance" and "Magic", though not yet categorized into specific semantic groups, were frequently cited by participants as effective in triggering creative ideas.

This also demonstrates that, regardless of whether the data were obtained through quantitative or qualitative methods, all unclassified semantic words had a significant impact on stimulating creativity. For instance, in the qualitative interviews, participants mentioned that "Elegance" inspired designs featuring natural forms and organic patterns, while "Magic" sparked narrative-driven, imaginative concepts—both offering abstract inspiration that contributed to ideation processes..

Result 2: Based on the 5-point Likert scale ratings, Table3.4 presents the aggregated statistical data of the average effectiveness scores of words after classification by semantic type and creativity evaluation metrics. From the table, it can be seen that for each semantic word—whether it belongs to the abstract or concrete type—the average effectiveness score is above the median value of 3. The four creativity metrics—structure, function, aesthetics, and originality—also show the same trend. This suggests that the classified expert review words remain reasonable and effective when used as semantic stimuli.

Table 3.4. Effectiveness Scores of Classified Semantic Words for Effectiveness in Stimulating Inspiration

Concrete Semantic	**Abstract Semantic**
Technology 3.78	Fusion 3.83
Recycled 3.83	Fun 3.92
Efficient 3.38	Symbol 3.86
Texture 3.88	Tai Ji (Yin Yang) 3.83
Material 3.91	Eye-catching 3.68
Compostable 3.49	Magic 3.50
Portable 3.76	Culture 4.02
Fresh 3.48	Conservation 3.63
Deliverable 3.36	Metaphor 3.60
Tactile 3.87	Elegant 3.77
Manual 3.85	
Eco-friendly 3.66	
Foldable 3.82	
Interaction 3.80	
Stackable 3.47	
Mean	Mean
3.69	3.76

Structure	**Function**	**Aesthetics**	**originality**
Material 3.91	Fusion 3.83	Texture 3.88	Fun 3.92
Portable 3.76	Technology 3.78	Tai Ji (Yin Yang) 3.83	Symbol 3.86
Fresh 3.48	Recycled 3.83	Eye-catching 3.68	Conservation 3.63
Deliverable 3.36	Efficient 3.38	Elegant 3.77	Manual 3.85
Tactile 3.87	Compostable 3.49	Culture 4.02	Magic 3.50
Foldable 3.82	Interaction 3.80	Eco-friendly 3.66	Metaphor 3.60
	Stackable 3.47		
Mean	Mean	Mean	Mean
3.70	3.65	3.81	3.73

Result 3: Differences exist among the classified groups shown in Table3.4. In terms of effectiveness in stimulating creativity, abstract semantic words (3.76) scored higher than concrete semantic words (3.69). Words related to aesthetics (3.81) and originality (3.73) scored higher than those related to structure (3.70) and function (3.65). Moreover, abstract semantic words associated with aesthetics and originality showed higher consistency, while concrete semantic words associated with structure and function exhibited higher consistency.

Similarly, in the qualitative study (Table 3.3), two participants expressed their feelings about the expert review words during interviews: One participant chose the abstract word ‘elegance’ and responded that she believed the word would inspire designs featuring natural forms and organic patterns. This indicates that abstract words, through user cognition, become concretized in natural organic forms, forming metaphorical links from aesthetics to emotions, thereby guiding the visual expression of creative designs. Another participant, when discussing the concrete word ‘portability’, emphasized that when designing a ‘bottle with a handle’, it naturally led to associations with ease of use and comfort. This illustrates that concrete elements can enhance the cognitive clarity and functional linkage of abstract concepts. These findings are consistent with the quantitative results shown in Table3.4. The participants’ qualitative evaluations further support the reliability of the results presented in Table 3.4. However, it should also be noted that participants might have been aware that the focus of the study was on creativity and thus tended to give more positive evaluations to these words. This may have influenced the distribution of responses.

3.3.3 Results of Chi-Square Tests on Semantic Stimuli, Creativity Evaluation metrics, and Participant Factors

In Experimental Step Three, data were analyzed using IBM SPSS version 25.0. Chi-square tests were applied to categorical variables with a two-tailed test, and the significance threshold was set at $P < 0.05$. Basic demographic information of the student participants in this test is shown in Table3.5.

Table 3.5. Basic Demographics of Student Participants

Attributes		Frequency	Proportion
Gender	Male	107	31.01%
	Female	238	68.99%
Education	Undergraduate	307	88.98%
	Postgraduate	38	11.02%
Major	Visual Communication Design	178	51.59%
	Non-Visual Communication Design	167	48.41%
Years of design work	Less than 3 years	298	86.37%
	More than 3 years	47	13.63%

The chi-square test revealed no significant differences between practical experience and gender in relation to preferences for semantic stimuli and creativity evaluation metrics ($P > 0.05$), indicating no correlation among these variables. However, four results were statistically significant:

Chi-square Test Result 1: As shown in Table3.6, the two-tailed significance value between abstract and concrete semantic words ($p = 0.001$) is less than 0.05, indicating that these two types of semantic stimuli exhibit different triggering characteristics in guiding creative thinking. Combined with the overall performance of effectiveness scores, both abstract and concrete semantic types demonstrated strong potential in different task contexts, suggesting that while both are advantageous for stimulating creativity, they may do so through different mechanisms.

Table3.6. Chi-square test result of abstract semantic feature VS concrete semantic feature

	Value	degree of freedom	progressive significance
Pearson Chi-square	3086.247[a]	1364	**.001**
Likelihood ratio	1035.779	1364	1.000
Linear correlation	235.031	1	.000
Number of valid cases	345		

Chi-square Test Result 2: There is a significant difference between the use of abstract semantic words and education level. As mentioned earlier, in this study "Educational level" refers to whether participants are graduate students or undergraduates. As shown in Table3.7, participants of different education levels exhibited significant differences in the use of abstract semantic words (*p* = 0.027 < 0.05), indicating a correlation. This suggests that education level may influence preferences for semantic stimuli. Based on interview results and effectiveness scores, the postgraduate group was relatively more active in using abstract semantic words, demonstrating greater sensitivity and receptiveness to handling abstract concepts and conceptual generation.

Table 3.7. Chi-square test results of abstract semantic feature VS education level

	Value	degree of freedom	progressive significance
Pearson Chi-square	47.932[a]	31	**.027**
Likelihood ratio	39.346	31	.144
Linear correlation	9.325	1	.002
Number of valid cases	345		

Chi-square Test Result 3: A significant difference also exists between the use of originality-related semantic words and education level. As shown in Table3.8, students of different education levels showed significant differences in the use of originality-related semantic words (*p* = 0.004 < 0.05). Combined with interview responses and effectiveness scores, the postgraduate group had a higher tendency to choose originality-related semantic words than undergraduates, suggesting that higher education levels may enhance individuals' originality tendencies in creative design. Considering the emphasis on innovative thinking in graduate education, it is speculated that postgraduate students may be more inclined to use originality-related semantic cues in the creative process compared to undergraduates.

Table 3.8. Chi-square test result of originality metrics VS education level

	Value	degree of freedom	progressive significance
Pearson Chi-square	40.395[a]	20	**.004**
Likelihood ratio	36.657	20	.013
Linear correlation	8.405	1	.004
Number of valid cases	345		

Chi-square Test Result 4: There is also a significant difference between the use of functional semantic words and participants' academic major. As shown in Table3.9, students from different majors showed significant differences in their use of function-related semantic words (*p* = 0.023 < 0.05), indicating a correlation. Interview responses and effectiveness ratings suggest that academic background may influence preferences for semantic stimuli. Given that functional design emphasizes practicality and engineering thinking, students from non-visual communication majors such as product design, fashion design, and digital media may be more inclined to use function-related semantic words to align with their training, which prioritizes functionality and utility.

Table 3.9. Chi-square test result of functional metrics VS major

	Value	degree of freedom	progressive significance
Pearson Chi-square	38.499[a]	23	**.023**
Likelihood ratio	41.818	23	.010
Linear correlation	8.400	1	.004
Number of valid cases	345		

The chi-square test results indicate that there is a statistically significant difference between the types of abstract and concrete semantic words and their effectiveness in stimulating creativity. Abstract semantic words may be more effective in terms of originality and aesthetics, whereas concrete semantic words may be more effective for structure and functionality.

These findings carry important implications for the refinement of teaching strategies in art and design education. First, the differentiated effects of abstract and concrete semantic stimuli highlight the need for educators to purposefully select stimulus types based on specific design tasks and learning objectives. For instance, when aiming to foster conceptual innovation and aesthetic exploration, abstract semantic words may serve as more effective triggers in the early conceptual design phase. In contrast, concrete stimuli may be better suited for tasks emphasizing structural problem-solving or functional detailing. Second, the confirmed influence of creativity evaluation orientations suggests that integrating evaluative language into the ideation phase—rather than reserving it solely for post-hoc assessment—can provide students with clearer mental frameworks for ideation. Finally, the observed differences across academic backgrounds indicate the importance of tailoring semantic prompts to match students' prior knowledge and cognitive preferences. In sum, the results offer actionable insights for aligning semantic stimulus design with pedagogical intent, potentially increasing the efficacy and inclusiveness of creativity instruction.

4
Discussion

This chapter aims to provide a comprehensive analysis and discussion of the findings from the previously mentioned studies, focusing on the mechanisms of semantic stimulation in fostering creative cognition within design education. It also examines the practical implications of knowledge transformation and its impact on educational practice. Based on the interpretation of these research findings, this chapter further proposes innovation strategies and multi-phase cognitive transformation teaching approaches, offering concrete recommendations to enhance teaching methods and learning outcomes in design education.

Chapter 4 Discussion

4.1 Analysis of Research Findings: Interpretation of the Semantic Stimulation

Based on chapter 3 results, Study demonstrates the feasibility of using expert commentary words as semantic stimuli. Both abstract and concrete semantic words showed potential in stimulating creativity, with abstract words proving more promising than concrete ones. Abstract semantic words were more effective in stimulating originality and aesthetics, while concrete words were more suited to tasks emphasizing structure and functionality. We found that applying the tendencies of creativity evaluation metricsas semantic stimuli during the initial stages of design had a positive guiding effect on students' idea generation. Additionally, chi-square tests confirmed that individual differences such as participants' education level and professional background influenced their preferences for semantic stimuli and their creative performance.

In the experiment involving students majoring in art and design, the use of expert commentary words as semantic stimuli shows promise as both feasible and effective. The quantitative results for semantic types revealed an insightful trend: regardless of whether the semantic words were abstract or concrete, their average usefulness scores were above the median, indicating that both types of semantic stimuli had a positive effect on promoting creativity. However, a deeper comparison of their effectiveness in stimulating creativity revealed that abstract words were significantly more effective in enhancing students' creative performance, particularly in the dimensions of aesthetic perception and original expression. This may be related to the broader associative and conceptual transfer abilities evoked by abstract vocabulary. In contrast, concrete words were more helpful in supporting creative performance related to structural clarity and functional implementation, reflecting their role in aiding task clarity during actual design work. Thus, different types of semantic stimuli have distinct strengths in triggering specific dimensions of creativity, suggesting that in design education, semantic guidance strategies should be flexibly applied based on task requirements to maximize students' creative potential. Furthermore, qualitative interview results also revealed clear differences in how different types of words stimulated students' creative thinking. Abstract words such as "fusion" or "culture" tended to guide students toward conceptual construction and symbolic meaning, triggering philosophically and culturally imaginative creative responses. Concrete words such as “portable” or “material” more often evoked considerations of practical function, operability, and material use, stimulating a mindset focused on implementation and practicality. This phenomenon confirms that different sources and types of semantic stimuli have a distinct impact on students’ creativity in art and design education, with these effects exhibiting divergence in both levels and directions of thinking.

Creativity evaluation metricsare traditionally used to assess the final outcomes of a completed design. However, in this study, we proposed using the tendencies of creativity metricsto classify expert commentary words and applying them as semantic stimuli during the early stages of idea generation. The study found that vocabulary related to the aesthetic and originality dimensions was significantly more effective than words related to structure and functionality. This reflects that creativity metricsare not only useful for later evaluation but can also serve as effective tools for guiding students' creative thinking from the beginning of the design process. Specifically, when students encountered symbolic and open-ended words like “magic” or “suggestion,” their ideas tended to be more novel and diverse; when faced with concrete, function-oriented words like “logistics” or “preservation,” students were more likely to generate highly operable and practical design solutions. These results support that introducing creativity indicator tendencies at the idea generation stage can positively influence design students’ thinking and expression pathways, thereby expanding both the depth and breadth of their application in educational contexts.

The results showed that participants’ education level and professional background did indeed have an effect on the creative generation process. Compared to undergraduates, graduate students were more inclined to select abstract semantic words during the early stages of idea development, especially showing stronger abstract thinking and symbolic association in the conceptual divergence phase. This difference may be attributed to their richer knowledge structures and more advanced cognitive training. At the same time, professional background also exhibited differentiated trends: students from non-visual communication design fields showed greater emphasis on functional and structural dimensions in their word choices, suggesting that different professional training shapes the focus of design attention. These findings collectively confirm that individual background factors such as education and major exert a positive moderating and guiding influence on the paths and preferences of idea generation. This indicates that design education should adopt differentiated instruction approaches, paying close attention to background differences among students in order to better support their creative development.

In summary, the findings from these research questions offer valuable insights into the use of semantic stimulation strategies within design education and practice. Specifically, the differentiated functions of abstract and concrete semantic words in the creative process can inform the phased structuring of teaching. For instance, in heuristic learning scenarios such as creative workshops, the introduction of abstract words like “fusion” can effectively spark innovative thinking and conceptual divergence among students. In contrast, during prototyping and testing stages, the use of concrete terms such as “durable” can help students focus on details and feasibility, strengthening their practical design execution. This semantic stratification is also applicable in professional practice settings. Project teams focused on sustainability can stimulate systemic and forward-thinking design ideas using abstract words like “renewability.” Conversely, product development teams that prioritize functionality can benefit from concrete terms like “adjustable,” which enhance the precision and efficiency of functional design.

Based on the analysis of participant characteristics, the study further proposes tiered teaching strategies using semantic stimulation. For undergraduate students, it is advisable to prioritize concrete and specific semantic stimuli during brainstorming and conceptual development stages to help build clear design frameworks and execution plans. For graduate students, abstract and conceptual stimuli can be introduced during later stages such as prototyping and iteration to enhance critical thinking and imaginative expression. This pedagogical approach, grounded in differences in cognitive development and learning stages, helps improve the adaptability and specificity of design education.

In addition, to better balance universality and individual differences, the study recommends a hybrid approach to semantic stimulation. On the one hand, general semantic cues can be used to broaden students’ creative thinking boundaries; on the other, personalized and differentiated strategies can gradually be introduced to increase the contextual relevance and learning effectiveness of the stimuli. However, it's important to note that excessive customization might reduce students' adaptability to diverse design tasks. Therefore, an appropriate balance between guidance and openness should be sought to cultivate creativity with both depth and flexibility.

Moreover, drawing from recent studies on creativity[49], future pedagogical models might consider integrating a combinatory use of semantic stimuli tailored to individual learners' cognitive styles and disciplinary needs. While this study focused on verbal semantic stimuli, especially semantic words, other formats such as visual metaphors, ambient soundscapes, or narrative memory cues may activate complementary aspects of creativity (e.g., intuitive, emotional, or associative thinking). A combinatory use of semantic stimuli may therefore enhance inclusivity and responsiveness in design education, offering differentiated entry points for diverse learners. This direction warrants systematic investigation in future work.

4.2 Research Insights: The Semantic Stimulation in the Transformation of Design Knowledge and the Cultivation of Creative Thinking

Drawing on these findings, the study establishes an educational framework driven by linguistic processes to facilitate the transformation of design knowledge (Figure 4.1).

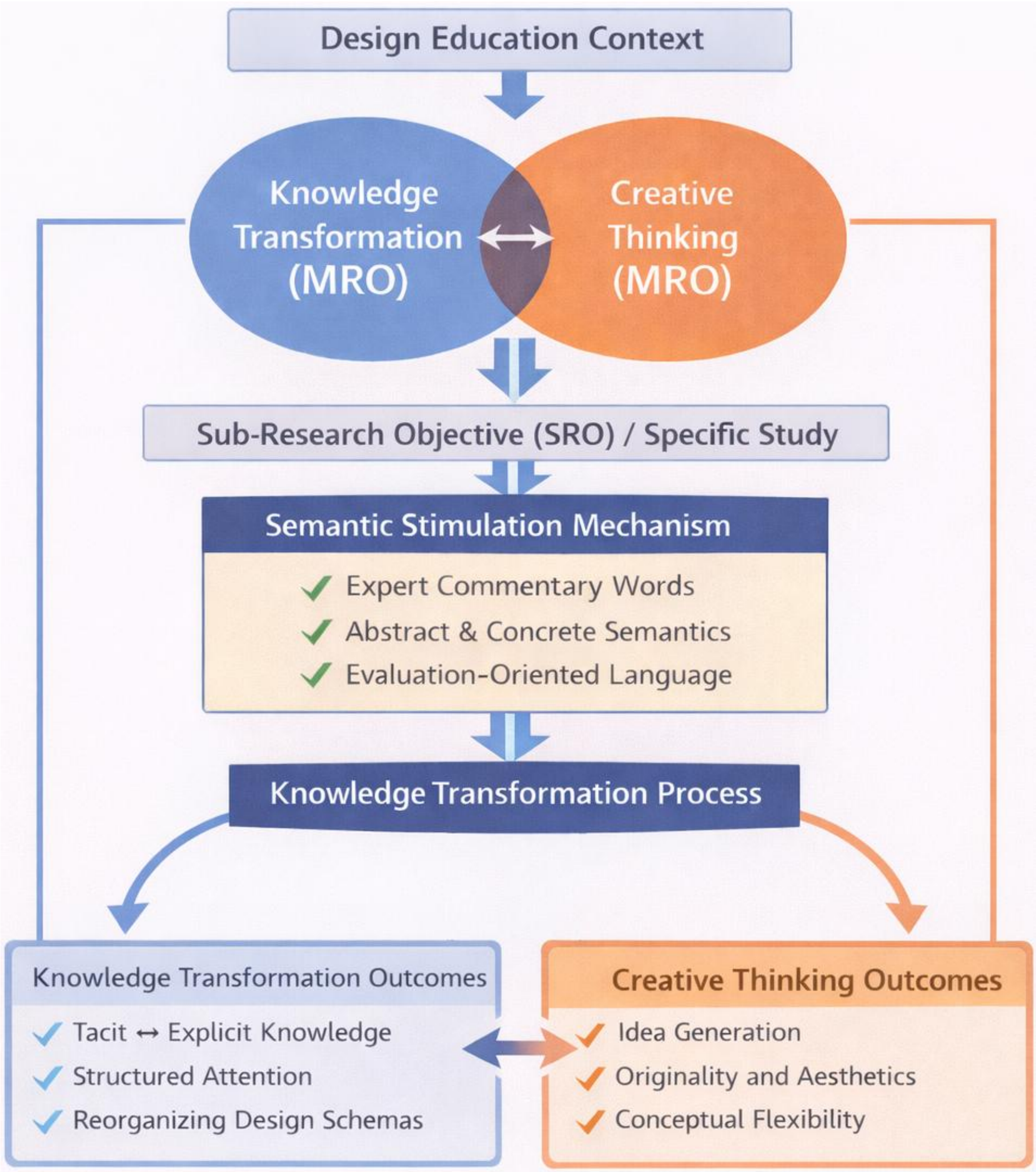

Figure 4.1 Theoretical Model

This research is structured around two Main Research Objectives (MRO) — knowledge transformation and creative thinking — situated within the context of design education. These objectives are understood as interrelated and mutually reinforcing processes that together explain how knowledge and creativity develop in design learning environments. Knowledge transformation concerns how design knowledge changes form during learning, particularly how learners move between tacit and explicit knowledge, while creative thinking focuses on how learners generate novel, original, and meaningful design ideas. Creative thinking in design education emerges through continuous knowledge transformation, where each process reshapes and deepens understanding via cycles of interpretation, expression, and application.

Within this conceptual framework, the study's main research objectives (MROs) focus on clarifying how knowledge transformation and creative thinking are dynamically connected. The role of semantic stimuli in enhancing creativity in design education serves as a Specific Sub-Objective (SRO) of the dissertation. By examining semantic stimuli as a concrete pedagogical and cognitive mechanism, the study bridges and operationalizes the Main Research Objectives (MROs). Semantic stimuli, including expert commentary words, abstract and concrete terms, and evaluation-oriented language, are treated as active instructional interventions rather than passive instructional content.

The relationship between the SRO and the MRO is therefore mediating and instrumental. On the one hand, semantic stimuli enable knowledge transformation by guiding learners' attention, shaping their interpretation of design problems, and supporting movement between tacit and explicit forms of design knowledge. On the other hand, these same stimuli promote creative thinking by expanding semantic associations, reducing cognitive fixation, and supporting diverse and original idea generation. Through this mediating mechanism, the study demonstrates how linguistic guidance structures learners' cognitive processes and facilitates the emergence of creativity within design education. The research focuses on design education, where knowledge is shaped through semantic interpretation, experiential judgment, and iterative meaning-making in studio settings, with critique, dialogue, and reflection-in-action playing key roles.

From the perspective of knowledge transformation, the findings indicate that design knowledge is not simply transmitted or accumulated, but continuously restructured through learners' engagement with semantic stimuli during ideation in the early conceptual design phase. By introducing semantic cues aligned with creativity-related dimensions such as originality, aesthetics, structure, and function, learners are encouraged to externalize implicit ideas, reorganize explicit information, and internalize new design understandings. Knowledge transformation thus occurs through iterative interpretation, articulation, and application, rather than through direct instruction alone.

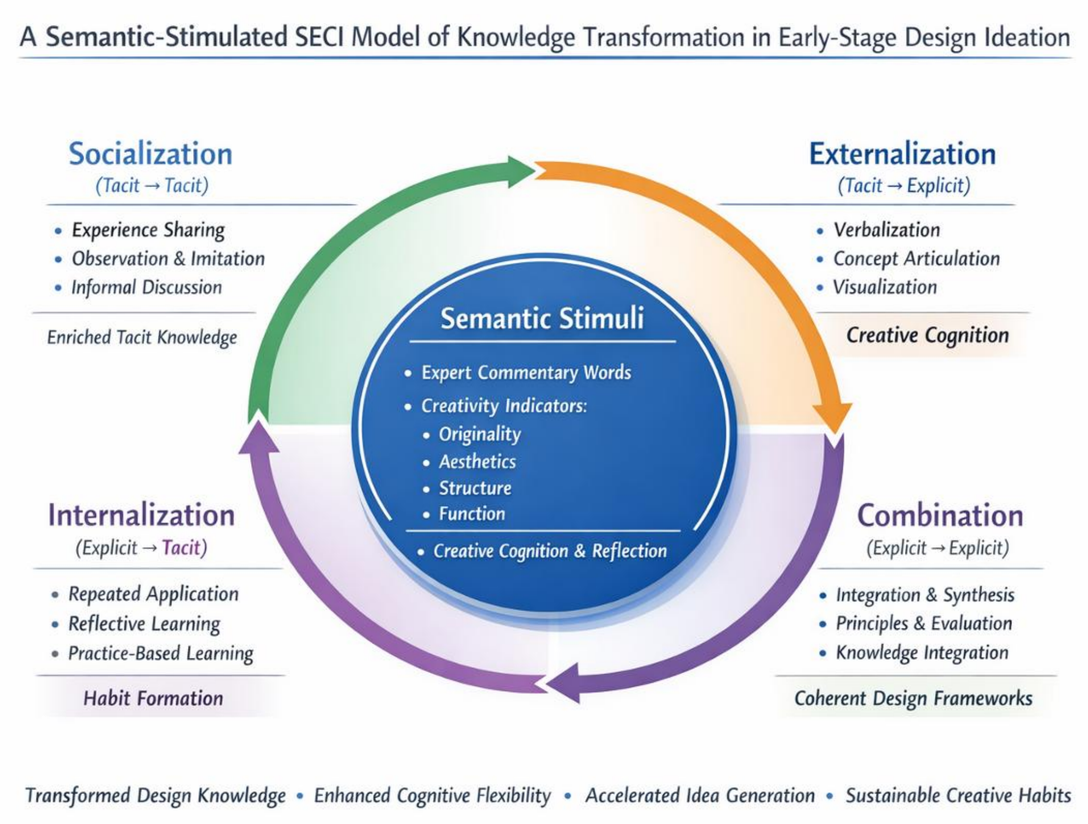

Figure 4.2 The New SECI Model for Knowledge Transformation in Design Learning

This transformation process is theoretically articulated through the new SECI model (Figure 4.2). Through socialization, learners move from experience-based tacit knowledge toward enriched design sensibilities under the influence of expert commentary and shared semantic cues. Externalization occurs as learners verbalize and visualize implicit ideas through abstract and concrete semantic stimuli, making creative intuitions explicit. During combination, learners integrate semantic stimuli with design principles and evaluation metrics, reorganizing fragmented explicit knowledge into coherent design frameworks. Finally, through internalization, repeated application and reflection embed explicit knowledge into learners' cognitive repertoires, forming new tacit capabilities and stable creative thinking habits.

In terms of creative thinking, semantic stimuli function as cognitive triggers that shape how learners explore and construct ideas throughout the design process. Abstract semantic stimuli support conceptual expansion, symbolic association, and originality, while concrete semantic stimuli facilitate clarity, feasibility, and functional reasoning. When applied proactively at different stages of design activity, these stimuli guide thinking pathways, stimulate divergent exploration, and ensure that creative outcomes are both innovative and practically viable. Creative thinking therefore emerges as a systematic and learnable capability grounded in structured semantic guidance, rather than an innate or spontaneous talent (Figure 4.3).

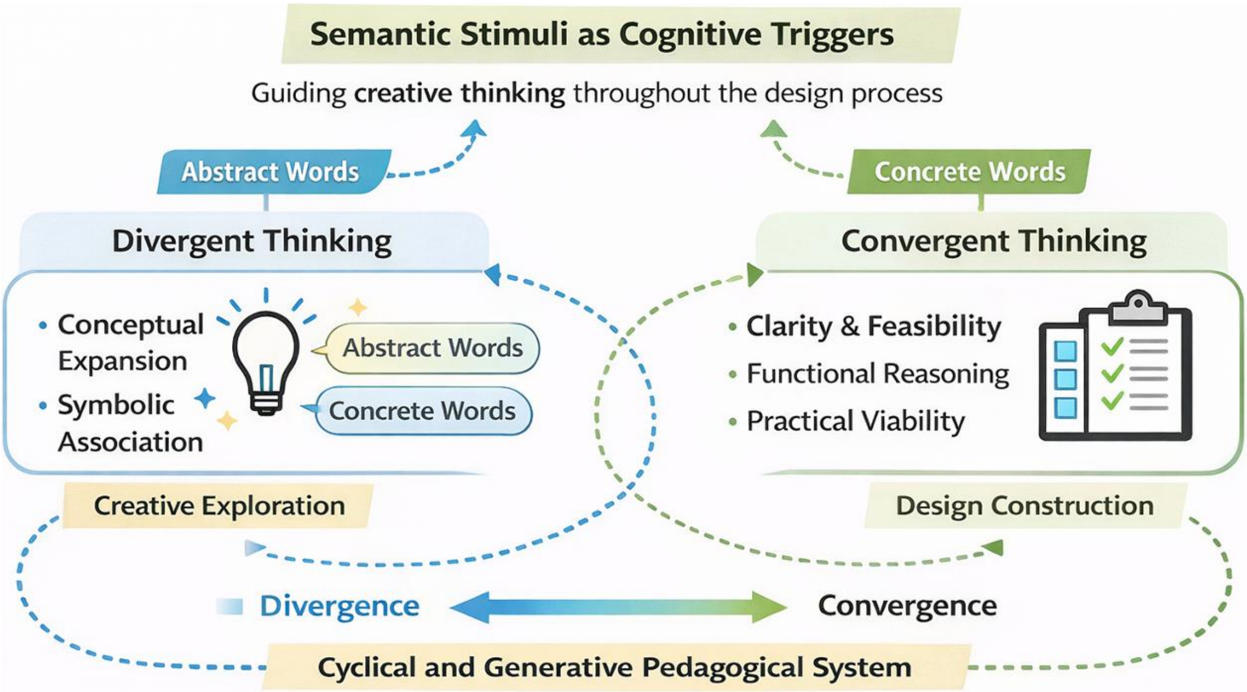

Figure 4.3 Semantic Stimuli – Guided Creative Thinking in the Design Process

This framework methodically guides learners through multiple stages of cognitive transformation, forming a cyclical and generative pedagogical system. It prioritizes conceptual divergence and creative interpretation while supporting the progressive construction of a cognitive continuum from abstract concepts to tangible design execution, enabling balanced development of both knowledge and skills.

5

Conclusion

Chapter 5 provides a comprehensive summary of the theoretical and practical contributions of this research to the fields of knowledge transformation and creative thinking within design education. It introduces a knowledge transformation framework focused on semantic stimulation, advancing design education theory while offering actionable strategies for classroom instruction and cultural innovation. Additionally, the chapter critically examines the research limitations and highlights prospective avenues for future studies, aiming to further improve the systematization, scientific rigor, and practical applicability of design education.

Chapter 5 Conclusion

5.1 Conclusion of the study

This study aimed to explore how semantic words can stimulate creative thinking in design students at the early stages of the design process.The key innovations of the research lie in two aspects: first, the introduction of expert commentary words as semantic stimulation materials, verifying their specificity and effectiveness in educational contexts; and second, unlike traditional uses of creativity evaluation metricsat the end of the design process, this study innovatively frontloads these metricsby categorizing expert commentary words and transforming them into semantic stimuli to influence students' conceptual development pathways from the outset. We examined the distinct impacts of abstract and concrete semantic words on creative thinking. Results showed that both types can effectively stimulate student creativity. originality more than undergraduates. On the other hand, function-oriented semantic stimuli were more strongly preferred by students from non-visual communication design fields (such as product design, fashion design, and digital media), indicating a link between professional background and semantic preference in creative thinking.

In terms of educational impact, this study contributes to a shift in design teaching from a traditional experience-based model to an empirically grounded, rationally guided approach. By introducing customizable semantic stimuli, educators are better equipped to target and stimulate students' creative thinking, improving both the adaptability and effectiveness of instruction. For design practice, the study provides a scientific foundation for the conceptual generation phase, helping design teams overcome cognitive inertia, improve efficiency, and accelerate the transformation of ideas into outcomes. Theoretically, this study offers a new explanatory framework for understanding the mechanisms that stimulate creative thinking in design education and fills a gap in existing literature regarding the role of semantic stimulation in the early stages of design. Practically, it provides systematic cognitive support tools for educators and design teams during the concept development stage.In conclusion, this study systematically explored the role of semantic stimulation in enhancing creativity in design education, offering new theoretical support and practical value for both design education and professional practice.

5.2 Contribution to the science of knowledge

This study contributes to knowledge science, an interdisciplinary field that integrates methods from design studies, cognitive sciences, social sciences, and information sciences to generate novel knowledge and practical solutions. Specifically, this research explores knowledge transformation and creative thinking in design education, with a particular focus on the role of semantic stimulation. These two Main Research Objectives (MRO)—knowledge transformation and creative thinking—are central to the study' s exploration, with a Specific Sub-Objective (SRO) focusing on how semantic stimuli bridge the two MROs to enhance creative thinking and facilitate knowledge transfer. The contributions of this study can be grouped into three key dimensions: advancing theoretical understanding, enriching design pedagogy, and offering practical methodologies for applying knowledge transformation in professional design practice.

1. Advancing Theoretical Understanding of Knowledge Transformation

This research advances the theoretical understanding of knowledge transformation within design education by demonstrating how semantic stimuli—such as expert commentary words and creativity evaluation metrics—act as active agents in reshaping design knowledge. This study proposed a dynamic, cyclical model where knowledge evolves through continuous reinterpretation and reorganization, guided by semantic cues. These cues do not simply aid in articulating ideas; they play a role in externalizing tacit knowledge, expanding conceptual thinking, and integrating new design principles. In the early stages of design thinking, semantic stimuli facilitate creative cognition by prompting conceptual exploration, ensuring that creativity and innovation drive the transformation process. Additionally, during the combination phase, these stimuli help learners synthesize new knowledge with established design frameworks, ensuring the practical application of abstract concepts. Overall, this research positions semantic stimulation as a key mechanism for facilitating both knowledge transfer and creative thinking, presenting a iterative framework for understanding knowledge transformation in design education.

2. Enriching Design Education and Creative Pedagogy

This study proposes a pedagogical approach that integrates semantic stimulation into design curricula, offering a concrete method for fostering creativity in design education. By utilizing techniques such as scaffolding, guided exploration, and multi-dimensional evaluation, students are encouraged to generate novel and original design solutions. This approach aligns with the mission of knowledge science, emphasizing interdisciplinary knowledge creation and bridging the gap between cognitive science and design practice. Through this pedagogical model, educators can systematically foster creative expression and cognitive flexibility in design students, making semantic stimulation a key tool in promoting creative thinking and knowledge transformation in design education.

3. Practical Methodologies for Knowledge Transformation in Design

Beyond its theoretical and pedagogical contributions, this study offers practical methodologies for applying knowledge transformation in professional design practice. By demonstrating how semantic stimuli can enhance creative cognition from the outset of the design process, the research provides actionable insights for both educators and design practitioners. The use of customizable semantic stimuli allows educators to target specific cognitive pathways, fostering more informed and intentional approaches to idea generation and problem-solving. The practical application of this framework helps design teams overcome cognitive inertia, accelerating idea transformation in collaborative settings and bridging the gap between theory and practice.

In conclusion, this thesis contributes to knowledge science by advancing the understanding of how semantic stimulation facilitates knowledge transformation and creative thinking in design education. It develops a dynamic framework in which semantic cues actively drive the cyclical transformation of design knowledge, linking tacit knowledge, creative generation, and practical application. Through this, the study provides concrete pedagogical strategies for fostering creativity, enabling educators to apply structured semantic guidance that enhances students' cognitive flexibility and creative expression. Additionally, the research offers practical methodologies for applying knowledge transformation in professional design practice, demonstrating how semantic stimuli can drive creative cognition and accelerate idea generation in real-world settings. By bridging design science and cognitive science, this research highlights the value of interdisciplinary approaches in optimizing creative thinking, ultimately contributing to the development of educational models that support transformative knowledge creation and enhance creativity across diverse contexts.

5.3 Research Limitations and Future Directions

5.3.1 Limitations Concerning Sample Composition, Timeliness, and Applicability Scope

This research offering novel theoretical and practical perspectives for understanding the interplay between knowledge transformation and creative thinking within design education. Nonetheless, certain limitations persist regarding the sample composition, timeliness, and the breadth of methodological applicability.

Firstly, the sample size and representativeness of the research are relatively limited. Participants were predominantly drawn from specific institutions and design disciplines, exhibiting relatively homogeneous educational backgrounds, professional experience, and cultural contexts. This homogeneity may limit the generalizability of the findings across diverse institutions, academic fields, and cultural settings. Notably, students from varied cultural backgrounds may interpret semantic stimulation and cultural elements differently, potentially impacting the universal applicability of the conclusions related to creative performance.

Secondly, regarding semantic stimulation interventions, they were primarily implemented in traditional classroom and research laboratory environments, without a comprehensive assessment of their effectiveness in remote education, blended learning, or digital platforms. In digital learning contexts, learner interaction patterns, real-time feedback mechanisms, and individualized needs may influence the cognitive activation effects of semantic stimulation—an aspect not thoroughly examined in this research. The interventions focused predominantly on verbal vocabulary, without systematically exploring the potential creative stimulation afforded by multimodal stimuli such as visual symbols, soundscapes, and narrative cues. This limitation may constrain a holistic understanding of the complex cognitive processes involved.

In conclusion, the semantic stimulation approaches encounter challenges in practical application, including sample limitations, restricted methodological extensibility, limited cross-cultural relevance, and insufficient integration with digitalization and automation. These constraints underscore the necessity for future research to broaden theoretical frameworks, innovate methodological approaches, and enhance practical implementations to improve the universality, scientific rigor, and operability of the findings.

5.3.2 Future Directions for Multidimensional Integration, Deepening, and Knowledge Expansion Research

To overcome the limitations previously identified, future research should focus on the following dimensions.Firstly, it is imperative to expand the sample size to encompass learners from diverse institutions, disciplines, years of study, and cultural backgrounds. This expansion will strengthen the external validity of research outcomes and broaden their applicability across varied contexts.

Secondly, with respect to the semantic stimulation, investigating the integration of semantic stimulation with digital education platforms, interactive learning modules, and learning analytics systems can offer dynamic, personalized learning support. Such integration would enable real-time guidance and sustained stimulation of students' creative thinking, thereby enhancing instructional flexibility both within and beyond the classroom environment. Additionally, this approach provides empirically grounded intervention strategies suitable for remote and hybrid design education settings. Further inquiry should examine the differential application of semantic stimulation across distinct design disciplines and developmental stages. For instance, research might explore its cognitive guidance effects during concept generation, prototype development, and implementation phases within product design, interaction design, environmental design, or cross-media design. It is also essential to consider individual difference variables (including learners' cognitive styles, design experience, and cultural backgrounds) and their moderating influence on creative thinking trajectories. Such analysis will support the development of more targeted and adaptable pedagogical models, thereby furnishing a scientific foundation for personalized instruction and interdisciplinary education.

In summary, forthcoming research should particular emphasis on sample diversity, interdisciplinary applicability, digital and intelligent integration, and longitudinal application assessment. Future research should also explore the effectiveness of this framework across different countries to verify its cross-cultural applicability and global educational value. These endeavors will enhance theoretical rigor, methodological robustness, and practical utility, thereby delivering systematic, scientifically grounded, and scalable solutions for design education and design industries.

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A
Appendix

Appendix A

List of publication, presentations, award

-Papers publish in journals

Yang Yu, and Yukari Nagai. "The Role of Semantic Stimuli in Enhancing Creativity in Art and Design Education." Frontiers in Education, In Print, vol. 10, p.1624324. 08 September 2025

Yang Yu, Jiaji Gao, and Nagai Yukari. "Analysis on the Correspondence between Sustainable Social Service Design and Humanistic Aesthetic Design and Cognitive Psychological Utility." Journal of Environmental and Public Health, PUBLISHED, no. 1 (2022): 7309888. 2022

-Books

Yang Yu. Intelligent Creativity and Innovative Design Research. Jilin Fine Arts Press, China, 2022. ISBN 978-7-5731-2612-2. PUBLISHED

- International conference proceedings

Yang Yu, Eunyoung Kim, Yukari Nagai, Fei Fei, Jie Jiang, A Study of Cognitive Thinking in Visual Design: The Utility of Words of Different Semantic Types to Inspire Creative Thinking, International Conference on Knowledge, Information and Creativity Support System(KICSS), PUBLISHED, P10, November 2020, Japan

Yang Yu, Cognitive-Based Visual Element Semantics, 2019 International Conference on Art Design, Music and Culture(ADMC 2019), PUBLISHED, October 2019, P105-107, Prague, Czechia

Yang Yu, Symbolic Analysis in the Field of Visual Design in the Digital Age, 2019 International Conference on Art Design, Music and Culture(ADMC 2019), PUBLISHED, October 2019, P148-150, Prague, Czechia

Yang Yu, Nagai Yukari, Jiang Jie, Li Ruixuan, Changing of Innovative Education System in the Graphic Design of Universities, The 41st International Conference of Japan Creativity Society. PUBLISHED, September 2019, P 7-10, Japan

- Award

Excellent Paper Award. International Conference on Knowledge, Information and Creativity Support System(KICSS), November 2020, Japan

Appendix B

CORE BIBLIOMETRIC DATA ON "KNOWLEDGE TRANSFORMATION" AND "DESIGN EDUCATION" RETRIEVED VIA CITESPACE

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Appendix D

Semantic Classification of Commentary Words by 51 Design Faculty Members（1）

Options	Concrete semantics	Abstract semantics
1 Retro	23(45.10%)	28(54.90%)
2 Fusion	20(39.22%)	31(60.78%)
3 Fun	17(33.33%)	34(66.67%)
4 Integration	21(41.18%)	30(58.82%)
5 Technology	33(64.71%)	18(35.29%)
6 Recycled	42(82.35%)	9(17.65%)
7 Efficient	34(66.67%)	17(33.33%)
8 Texture	31(60.78%)	20(39.22%)
9 Material	42(82.35%)	9(17.65%)
10 Compostable	37(72.55%)	14(27.45%)
11 Symbol	12(23.53%)	39(76.47%)
12 TaiChi	18(35.29%)	33(64.71%)
13 Eye-catching	18(35.29%)	33(64.71%)
14 Portable	43(84.31%)	8(15.69%)
15 Magic	12(23.53%)	39(76.47%)
16 Culture	17(33.33%)	34(66.67%)
17 Humorous	25(49.02%)	26(50.98%)
18 Fresh	44(86.27%)	7(13.73%)
19 Deliverable	40(78.43%)	11(21.57%)
20 Tactile	34(66.67%)	17(33.33%)
21 Conservation	13(25.49%)	38(74.51%)
22 Manual	43(84.31%)	8(15.69%)
23 Eco-friendly	34(66.67%)	17(33.33%)
24 Foldable	18(35.29%)	33(64.71%)
25 Metaphor	16(31.37%)	35(68.63%)
26 Elegant	29(56.86%)	22(43.14%)
27 Care	36(70.59%)	15(29.41%)
28 Interaction	32(62.75%)	19(37.25%)
29 Stackable	43(84.31%)	8(15.69%)
30 Classic	21(41.18%)	30(58.82%)

Four Creativity Evaluation Classification of Commentary Words by 51 Design Faculty Members (2)

Options	Structure	Function	Aesthetics	Originality
1 Retro	6	5	36	4
2 Fusion	14	19	4	14
3 Fun	9	5	5	32
4 Integration	10	18	10	13
5 Technology	5	31	5	10
6 Recycled	11	22	5	13
7 Efficient	20	25	1	5
8 Texture	11	9	26	5
9 Material	26	14	5	6
10 Compostable	15	30	2	4
11 Symbol	4	5	17	25
12 TaiChi	6	4	36	5
13 Eye-catching	3	11	22	15
14 Portable	7	32	5	7
15 Magic	4	4	23	20
16 Culture	9	5	20	17
17 Humorous	6	13	11	21
18 Fresh	4	34	8	5
19 Deliverable	11	29	4	7
20 Tactile	16	7	12	16
21 Conservation	10	12	14	15
22 Manual	9	10	11	21
23 Eco-friendly	11	3	27	10
24 Foldable	6	8	8	29
25 Metaphor	12	11	10	18
26 Elegant	9	27	7	8
27 Care	15	17	10	9
28 Interaction	8	20	9	14
29 Stackable	10	23	4	14
30 Classic	5	11	29	6

Proportion of Participants Evaluating the Effectiveness of Unclassified Semantic Words in Stimulating Inspiration（3）

Options	1 Not useful at all	2 Less useful	3 General	4 More useful	5 Very useful
1 Fusion	2.61%	2.90%	30.43%	37.39%	26.67%
2 Fun	2.32%	4.06%	27.54%	31.88%	34.20%
3 Technology	1.45%	4.93%	32.17%	37.39%	24.06%
4 Recycled	1.74%	2.32%	34.49%	34.20%	27.25%
5 Efficient	3.77%	10.43%	45.22%	25.22%	15.36%
6 Texture	2.03%	4.06%	26.09%	39.42%	28.41%
7 Material	1.45%	2.90%	27.25%	40.00%	28.41%
8Compostable	4.35%	8.70%	39.13%	29.28%	18.55%
9 Symbol	2.61%	5.51%	24.06%	39.13%	28.70%
10 TaiChi	1.74%	4.93%	30.14%	34.49%	28.70%
11Eye-catching	2.32%	5.80%	35.36%	34.49%	22.03%
12 Portable	1.16%	6.96%	30.72%	37.10%	24.06%
13 Magic	8.12%	9.57%	31.88%	24.64%	25.80%
14 Culture	1.74%	2.32%	22.03%	39.71%	34.20%
15 Fresh	3.48%	8.99%	41.16%	28.70%	17.68%
16 Deliverable	5.51%	11.01%	42.32%	24.64%	16.52%
17 Tactile	2.61%	3.48%	26.38%	39.42%	28.12%
18Conservation	2.61%	6.09%	35.94%	36.81%	18.55%
19 Manual	1.45%	3.77%	31.30%	35.36%	28.12%
20Eco-friendly	4.06%	6.67%	34.49%	28.70%	26.09%
21 Foldable	4.93%	6.38%	24.35%	30.43%	33.91%
22 Metaphor	4.35%	6.67%	35.36%	32.17%	21.45%
23 Elegant	2.61%	4.06%	33.33%	33.33%	26.67%
24 Interaction	2.03%	4.35%	31.88%	35.36%	26.38%
25 Stackable	4.64%	11.30%	35.65%	28.99%	19.42%