DESIGN AND VALIDATION OF A VERSATILE SCALE FOR ASSESSING DESIGN THINKING CAPABILITY ACROSS CONTEXTS

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Design and Validation of a Versatile Scale for Assessing Design Thinking Capability Across Contexts

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CERTIFICATE OF ORIGINALITY

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WANG XIAO

Abstract

In an era where innovation and creativity are highly valued, having strong design thinking competencies is seen as the key to success across diverse disciplines. However, although its importance has been widely recognized, the current research on design thinking remains in the theoretical stage, lacking a reliable way to measure and assess an individual's design thinking skills. This study addresses this critical gap by proposing and rigorously validating the Design Thinking Capability Scale (DTCS), a comprehensive tool for assessing design thinking capabilities in a variety of educational and professional settings that provides a reference for individuals or organizations, offering a standardized reference point that supports the objective analysis and enhancement of design thinking aptitudes.

The development of the Design Thinking Capability Scale (DTCS) began with a thorough review of relevant literature leading to a nuanced analysis and synthesis of existing design thinking models. The development process involved the careful formulation of design evaluation items by drawing parallels content from existing measurements. The next steps involved creating and improving items through ongoing testing and analysis to ensure they accurately capture the nuances of design thinking. In pursuit of empirical validation, the preliminary scale went through a series of rigorous testing phases. These items have been refined to ensure the subtlety and complexity inherent in design thinking. This iterative validation process ensures that DTCS not only reflects theoretical structures but can accurately and reliably capture the essence of design thinking under scrutiny of actual, real-world applications.

The outcome highlighted important aspects of design thinking, such as empathy and user Together, these elements form the comprehensive structure of the DTCS, enabling a thorough evaluation of design thinking capabilities. Following the establishment of the scale items, the validity was substantiated through preliminary pilot testing. The robustness of the DTCS was further confirmed when the scale was subjected to expanded trials involving a larger and more diverse pool of participants, which consistently reaffirmed the tool's precision and practical utility. The research revealed notable disparities in design thinking capabilities among the participants. It delved into the variances in design thinking skills between individuals with and without formal design education, as well as among those occupying various roles within the organization. By conducting a detailed case study, the paper scrutinizes the contrast in design thinking proficiencies between students of diverse academic disciplines and professionals from different hierarchical levels, thereby uncovering the fundamental nature of design thinking.

This investigation not only validates the significance of the DTCS but also enriches the comprehension of the variations in design thinking competencies across individuals with a range of educational and occupational backgrounds. The DTCS emerges as a valuable instrument for the appraisal and cultivation of design thinking abilities, presenting a systematic methodology to direct the enhancement of these critical skills. The implications of this research are profound, offering a substantial base for the progress of design thinking pedagogy and the stimulation of innovation in multiple sectors.

Keywords: *Design Thinking Capability, Measurement, Self-assessment, Educational and Professional Development*

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Chapter One

Introduction

1.1 Background of Study

In the rapidly globalizing landscape of the 21st century, the integration of the global economy has resulted in heightened consumer demand characterized by increased diversification and complexity (Lechner & Boli, 2005; Urdea et al., 2021; Schmitt & Zarantonello, 2013; Ramaswamy, 2004; Kumar et al., 2018). This phenomenon is particularly evident in contemporary product markets, where consumers exhibit a pronounced preference for regular updates, enhancements, and a wide array of offerings. The rise of digital technology and e-commerce platforms has further amplified this demand, enabling consumers to access an expansive range of products at their fingertips. As economic conditions have evolved, consumer preferences have shifted from a primary focus on functionality to an increased emphasis on aesthetic appeal (Fiore, 1996; Hassenzahl, 2003; Luchs et al., 2012), emotional connection, and experiential value (Norman, 2004). This change reflects a broader societal trend where consumers seek products that not only serve practical purposes but also resonate with their personal identities and lifestyles (Piccinini, 2015; Kim et al., 2014; Melumad et al., 2020; Fahmy, 2020). Furthermore, the advent of Industry 5.0—characterized by the collaboration between humans and intelligent systems—highlights the need for design that enhances user agency and promotes sustainable practices (Nahavandi, 2019; Tiwari et al., 2022; Verma, 2024). Such shifts necessitate a critical reevaluation of the role and significance of design, asserting that effective design not only enhances user engagement but also

aligns closely with the dynamic needs and desires of consumers (Mourtzis et al., 2022; Grosse et al., 2023), ultimately contributing to brand loyalty and competitive advantage in the marketplace (Leng et al., 2022; Ghobakhloo et al., 2023).

Moreover, the evolution of design transcends mere aesthetics (Vogel , 2009; Eisenman, 2013); it plays a pivotal role in creating seamless and intuitive user experiences that address both emotional and psychological satisfaction (Gonen, 2020). In today's fast-paced and highly competitive environment, organizations are increasingly recognizing that a user-centered approach is essential for success (Sward, 2007). In response to the complexities of modern markets, engineers and organizations have increasingly recognized the necessity of embedding design thinking within technological processes (Venturi et al., 2006; Lárusdóttir et al., 2014; Carvajal et al., 2023). This integration ensures that products are not only technologically advanced but also user-centric, thereby fostering innovation that blends form and function (Kumar, 2012; Magues et al., 2016).

The principles of Industry 5.0 further emphasize the importance of human-centric design (Ivanov, 2022), where technology serves to enhance human capabilities rather than replace them (Longo et al, 2020; Alves et al., 2023). By prioritizing user feedback and iterative design processes (Fronemann & Peissner, 2014), companies can create solutions that truly meet consumer needs. Consequently, contemporary product design emphasizes a holistic approach that prioritizes user needs and experiences, marking a significant evolution in product conceptualization (Chong et al., 2009; Veryzer & Mozota, 2005). This shift underscores the importance of design thinking as a

fundamental driver of innovation (Meinel et al., 2020; Rösch et al., 2023), where understanding user journeys and integrating design principles become crucial for developing products that enhance quality of life and foster meaningful interactions (Battarbee & Mattelmäki, 2002; Veryzer & Mozota, 2005; Saucken & Gómez, 2014; van de Grift & Kroeze, 2016; Fronemann et al., 2021; Mayıs, 2021).

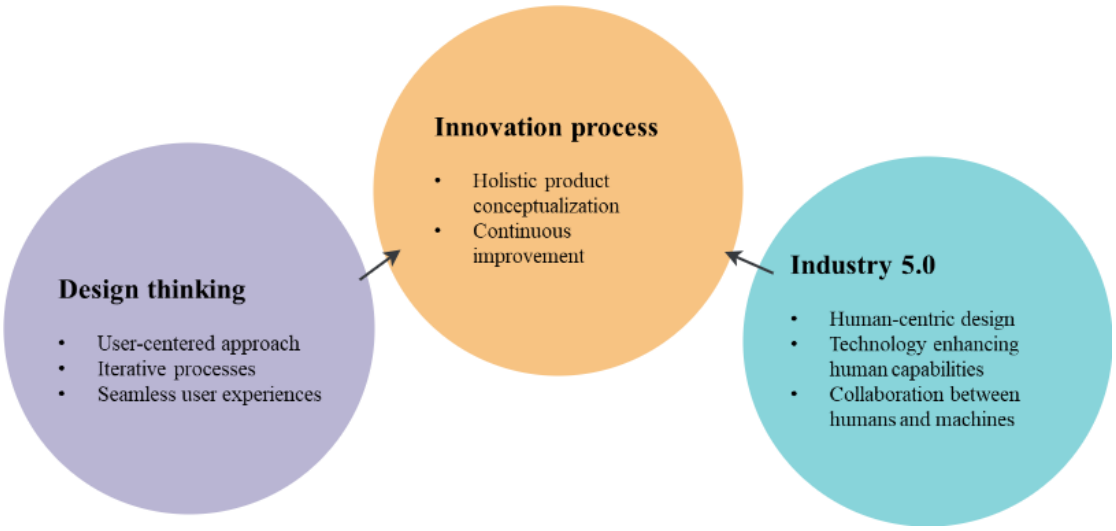


Figure 1-1 Design thinking and industry 5.0 in the innovation process

As a human-centered approach, design thinking significantly enhances the development of solutions for unfamiliar scenarios and complex challenges across various fields, including healthcare, engineering, and education (Razzouk & Shute, 2012; Lor, 2017; Thienen et al., 2017; McLaughlin et al., 2019; Luka, 2020). Design thinking helps reframe the problem in a human-centric way and focuses on users' needs (Buchannan, 1992). By promising to overcome the above existing issues through the dynamic, iterative process from the user-oriented perspective to achieve solutions, an innovative

design has made itself a preferred methodology for tackling complex challenges (Carlgren et al., 2014).

Grounded in comprehending the needs and desires of users, design thinking enables the creation of innovative and practical solutions. It empowers teams to explore multiple perspectives and uncover unique insights by encouraging collaboration, experimentation, and iteration (Clark & Smith, 2008; Chasanidou et al., 2015; Liedtka, 2018). Thus, design thinking has evolved into a component for organizations and industries in fostering significant innovation (Beckman & Barry, 2007; Plattner et al., 2014; Chasanidou et al., 2014). The broad acceptance underscores its effectiveness and ability to foster creativity and enhance user experiences.

Design thinking represents a contemporary methodology that employs a flexible and iterative process to generate solutions grounded in a human-centered perspective (Luchs et al., 2015), effectively addressing contemporary challenges (Foster, 2019). This approach has significantly influenced a diverse range of sectors, including the public sector, healthcare, pharmaceuticals, education, retail, social innovation, and entertainment. (Kimbell, 2011; Lockwood, 2010; Kolko, 2015; Melles, 2011; Howlett, 2014; Luka, 2014; Koh et al., 2015; Mulgan, 2006; Fabrica, 2022).

The application of design thinking across various fields has drawn considerable attention from researchers in this area. This interdisciplinary approach not only fosters innovation but also enhances problem-solving by centering on user needs (Bazzano et al., 2017; Kimberly et al., 2018; Beckman, 2020; Mardiah et al., 2023). As

organizations increasingly adopt design thinking, its methodologies and implications merit further investigation. In the corporate sector, design thinking focuses on putting the customer at the center of the development strategy (Knight et al., 2020). This strategy helps companies meet customer needs effectively, leading to rapid and ongoing enhancements and new ideas (Chen & Meira, 2019; Kwon et al., 2021). The influence of design thinking also extends into education and learning (Orthel, 2015). It enables students to connect theoretical knowledge with practical application, encourages cross-disciplinary teamwork, and supports the open and ethical pursuit of innovation (Scheer et al., 2012; Lor, 2017). By positively influencing education and learning by encouraging students to think about the construction of a theory-to-practice framework in interdisciplinary collaboration and education to explore innovation in a more open, ethical way (Chon & Sim, 2019; Beligatamulla et al., 2019; Carroll et al., 2010). In the engineering sector, design thinking is essential for thoroughly grasping user requirements and stimulating interdisciplinary cooperation (Altringer & Habbal, 2015; McKilligan et al., 2017). It also aids in coordinating team members with diverse roles (Chasanidou et al., 2014; Durantin, et al., 2017).

Therefore, the exploration of design thinking research primarily focuses on two aspects. First, it examines the processes of design thinking through case studies of successful problem-solving. In this context, design thinking is utilized to systematically deconstruct the motivations and methodologies at each stage of the design process, including discovery, definition, development, and delivery (Fleury et al., 2016; Adikari et al., 2013). Second, it applies the essential processes of design thinking to address practical issues. This application enables teams to examine problems from diverse perspectives, conduct in-depth analyses of user needs, stimulate innovative thinking,

and promote interdisciplinary collaboration (Plattner et al., 2010; Kwon et al., 2021; Tushar et al., 2020). By leveraging collective insights and iterating on solutions in practice, this dual focus both enhances the theoretical framework surrounding design thinking and provides actionable insights for practitioners seeking to implement these principles in real-world contexts.

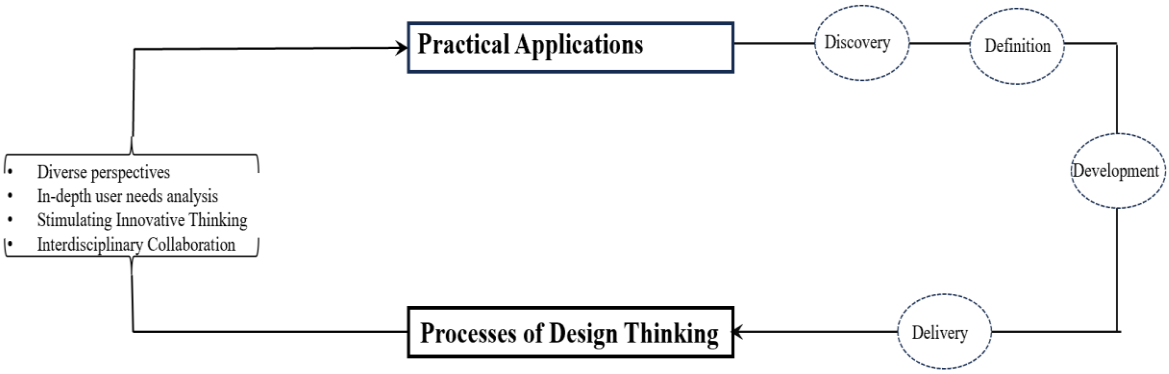


Figure 1-2 Main focus of current design thinking research

Recent research on design thinking has expanded beyond methodologies to explore organizational implementation and cultural impacts. Chen and Venkatesh (2013) identified four key schemes for implementing design thinking in organizations, including user profiles and organic structures. Plattner et al. (2014) focused on understanding the innovation process and the people behind it, emphasizing factors like empathy and creativity. Elsbach and Stigliani (2018) examined the relationship between design thinking tools and organizational culture, finding that their experiential nature allows them to support each other. They proposed a framework for future research in this area. Kernbach et al. (2022) highlighted the challenges of long-term implementation of design thinking in organizations, providing an overview of enablers

and barriers at both organizational and individual levels. These studies collectively demonstrate a shift towards understanding the human and cultural aspects of design thinking implementation in organizational contexts.

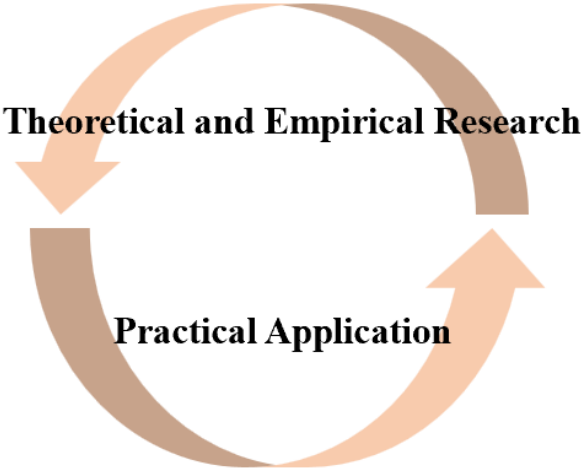


Figure 1-3 Mainstream research methods in design thinking

Currently, the mainstream research on design thinking predominantly emphasizes methodologies and processes, often overlooking the individuals who implement these methods (Faridizad et al., 2023). The successful application of design thinking relies heavily on individuals with the capability to think creatively and strategically (Rauth et al., 2010; Razzouk & Shute, 2012). This raises pertinent questions: Is this capability innate, or can it be acquired through training and experience? If the latter is true, what specific skills and competencies should be cultivated to enhance an individual's design thinking capabilities?

By exploring these questions, this research diverges from existing literature, shifting the focus from the methods themselves to the development of the individuals who utilize them. This paradigm shift emphasizes the importance of understanding the underlying factors that contribute to design thinking capabilities, thereby enriching the theoretical framework surrounding this field. Understanding the underlying factors that contribute to design thinking abilities not only enriches the theoretical framework but also provides practical implications for educational programs and professional development, educators and practitioners can tailor curricula and training programs to better cultivate these skills. This approach aims to bridge the gap between theory and practice, ultimately fostering a more comprehensive understanding of how design thinking can be effectively applied across diverse contexts. Ultimately, by focusing on the individual's development within the design thinking process, this research contributes to a more holistic perspective on fostering innovation and creativity in problem-solving, ensuring that the implementation of design thinking is both effective and sustainable in real-world applications.

1.2 The Exploration of Design Thinking

In response to the growing demand for design thinking across various domains, organizations and individuals from different fields are exploring the secrets to maintaining the effectiveness of this problem-solving approach and enhancing competitiveness (Quaiser & Pandey, 2023). The strong demand for design thinking capabilities underscores the importance of expanding researchers' knowledge in this area. As user needs continue to evolve, the application of design thinking is undergoing a trend of diversification and stratification, characterized by frequent updates,

continuous optimization, and an increasing variety of products (Liedtka, 2018, Combelles et al., 2020). The complex requirements arising from these dynamic changes necessitate that individuals, teams, and companies urgently establish standardized and appropriate operational processes (Wrigley et al., 2020). The design of such solutions often requires the development of innovative technologies and interdisciplinary collaboration (Boger et al., 2017; Bednarik et al., 2022; Iles & Mulvihill, 2012).

However, two challenges arise in the design of these solutions. On one hand, the dynamic and complex nature of developments makes it difficult to gain accurate insights into core needs through traditional analysis (Quesenbery, 2014; Bordin & Angeli, 2016; Mink et al., 2018). This complexity often results in a misalignment between user expectations and the solutions being developed (Benbya & McKelvey, 2006), leading to inefficiencies and potential failures in addressing real-world problems (Hyysalo, 2003; Maunder et al., 2007). On the other hand,cooperation and technological innovation across disciplines often lack systematic guidance (Newman, 2023), which can significantly hinder effective collaboration and the seamless integration of diverse perspectives (Hund et al., 2021). This absence of structured frameworks can lead to misunderstandings and fragmented efforts, ultimately stifling the potential for innovative solutions that draw on the strengths of each discipline (Rogers et al., 2005; Stange, 2009).

These challenges highlight the limitations of conventional problem-solving approaches and the necessity for more adaptive and integrative methodologies. Consequently, design thinking is emerging as a transformative method for problem-solving and

innovation (Carlgren et al., 2016; Pusca & Northwood, 2018; Eisenbart et al., 2022). By fostering a user-centered approach and encouraging iterative development, design thinking addresses these challenges by enabling teams to remain responsive to evolving needs and facilitating cross-disciplinary collaboration (Plattner et al., 2010; Gonera & Pabst, 2019). However, without attention to the long-term development of design thinking skills, this highly effective problem-solving approach may struggle to achieve sustainability or scalability (Baldassarre et al., 2024; Macagno et al., 2024), ultimately limiting its impact in various contexts.

To ensure the sustained effectiveness of design thinking as a problem-solving methodology, it is crucial to prioritize the long-term development of design thinking skills among individuals and teams (Plattner et al., 2014; Royalty et al., 2015). This involves not only initial training but also ongoing professional development that reinforces key principles and practices (Panke, 2019). Educational programs should be designed to cultivate a deep understanding of the design thinking process, enabling participants to navigate its complexities and apply it effectively in diverse settings (Lor, 2017). Moreover, fostering a culture of continuous learning and experimentation within organizations can facilitate the integration of design thinking into everyday practices (Reine, 2017). By encouraging teams to engage in regular reflection and iterative cycles of feedback, organizations can enhance their adaptive capability and innovation potential (Elsbach & Stigliani, 2018; Björklund et al., 2020).

When individuals or organizations set out to learn the design thinking methodology without prior knowledge, they typically embark on a structured educational path. They

derive a foundational text through in-depth observation and analysis of successful design thinking implementation cases, such as Brown's “Change by Design” (Brown, 2009) which demonstrates how design thinking can be leveraged to propel organizational innovation and growth, or “The Art of Innovation” (Kelley & Littman, 2001) which offers an insider’s perspective on how IDEO, a global design firm, has used design thinking to create breakthrough products and services. From these narratives and analyses, learners extrapolate core principles and methodologies, constructing their comprehensive models. These models detail the various phases of the design thinking process, starting with cultivating empathy for the user, generating a plethora of ideas (ideation), and then rapidly prototyping potential solutions (Kim & Ryu, 2014). Throughout these phases, the emphasis remains on a human-centric approach that is pivotal to design thinking (Fleury et al., 2016; Morey, 2024). Insights derived from user needs and experiences serve as the driving forces behind innovative solutions, ensuring that the outcomes are not only functional but also resonate with the target audience (Brown & Katz, 2009).

Therefore, it is imperative to conduct further investigation into the long-term development and cultivation of design thinking capabilities (Carlgren et al., 2014; Liedtka, 2020). As Cross (2011) aptly states, “Everyone can—and does—design,” highlighting the inherent potential within individuals to engage in design thinking. To become proficient design thinkers, it is essential to attain a deeper understanding of the specific capabilities that characterize effective practitioners in this domain (Brown & Katz, 2011; Luchs, 2016; Desert & Rizzo, 2014; Elsbach & Stigliani, 2018; Kimbell, 2011). Current research on design thinking should extend beyond theoretical frameworks (Kimbell, 2017); it must also explore the historical origins and practical

applications of these methodologies (Carlgren et al., 2016). Such a broader exploration is crucial for a comprehensive understanding of the developmental processes, sociocultural contexts, and key factors that facilitate effective implementation in real-world settings (Powers et al., 2015; Moullin et al., 2019; Moullin et al., 2020; Hickey et al., 2020). By integrating theoretical insights with practical experiences, researchers can illuminate the pathways necessary for nurturing design thinking skills (Kurtmollaiev et al., 2018; Chon & Sim, 2019), ultimately enhancing their relevance and applicability across various fields (Plattner et al., 2010; Park & Lee, 2021). This holistic approach will not only contribute to the academic discourse but also provide actionable strategies for educators and practitioners aiming to foster design thinking in diverse contexts.

Design thinking has traditionally been regarded as a systematic and iterative method for solving complex problems (Fleury et al., 2016; Baker & Moukhliss, 2020; Verganti et al., 2021), and it has been the focus of academic and professional study for decades. This approach emphasizes a human-centered methodology aimed at fostering innovation and addressing challenges across various domains, including business, education, and healthcare (Holeman & Kane, 2019). By prioritizing user needs and experiences, design thinking facilitates the creation of solutions that are both innovative and contextually relevant.

Recently, the focus has shifted from the methodology itself to the individuals who embody design thinking—known as design thinkers (Cross, 2007; Plattner et al., 2014; Corrales-Estrada, 2019). This shift underscores the need to understand the qualities and

skills that enable these individuals to effectively apply design thinking principles in practice (Howard, 2015). Characterized by empathy, integrative thinking, optimism, experimentalism, and collaboration (Brown, 2009), design thinkers can effectively manage complicated processes, spanning activities from understanding user needs to prototyping and evaluating solutions (Kim & Ryu, 2014; Schweitzer et al., 2016), the increasing acknowledgment of the design thinker's role underscores a wider appreciation that the success of design thinking depends not merely on following a prescribed series of steps, but also on the individual's mindset and cognitive approaches to problem-solving (Liedtka, 2015; Carlgren et al., 2016; Dijksterhuis & Silvius, 2017).

As organizations seek to foster innovation, individuals who can apply design thinking with agility and creativity are increasingly valued (Glen et al., 2014; Reine, 2017), as they not only contribute to the generation of novel ideas but also enhance the organization's ability to adapt to rapidly changing market conditions and user needs (Buehring & Moore, 2018; Wolniak, 2023). Educational institutions have responded by integrating design thinking curricula that focus not just on the method, but also on cultivating the dispositions and cognitive styles of design thinkers (Razzouk & Shute, 2012; Retna, 2016; Lor, 2017; McKilligan et al., 2017). This holistic approach to teaching design thinking ensures that the next generation of innovators can apply these methods dynamically and empathetically in diverse contexts.

Nevertheless, while design thinking is often regarded as a transformative tool for innovation (Eisenbart et al., 2022; Rösch et al., 2023), its efficacy is frequently limited among certain context. The potential for creatively solving problems and instigating

meaningful change is significantly underutilized in these contexts. Therefore, it is imperative to identify and cultivate specific individuals as design thinkers within these groups to accelerate positive societal advancements. By empowering these individuals with the necessary skills and resources, the capability could be enhanced to leverage design thinking principles effectively, ultimately fostering a more inclusive and impactful approach to problem-solving that addresses the unique challenges faced by marginalized populations (Slavova et al., 2013; Frisk & Holm, 2022). This targeted investment not only promotes social equity but also harnesses the diverse perspectives and insights that are crucial for generating innovative solutions to complex issues.

1.3 Research Problem and Knowledge Gap

Brown (2015) posits that although it is suggested that everyone can engage in design thinking and adopt a designer's mindset, this notion may appear far-fetched if not substantiated by practical examples that illustrate its applicability across various contexts. Design thinking encompasses a range of diverse skills that elicit different reactions depending on the specific circumstances, making it essential to provide concrete demonstrations of its effectiveness (Hassi & Laakso, 2011; Carlgren, et al., 2016). Without sufficient clarity and concrete examples, the concept's potential impact remains obscured, preventing individuals and organizations from fully harnessing the transformative power of design thinking in addressing complex challenges (Elsbach & Stigliani, 2018; Wrigley et al., 2020).

Although design thinking has been widely adopted and individuals who have mastered its principles are highly valued by large corporations (Liedtka, 2015; Kwon et al., 2021). It remains an intangible "golden key" in the hands of a few (Martínez-Vergara & Valls-Pasola, 2020). Most people can only observe its effects without truly understanding its essence. Despite the abundance of design thinking training programs on the market, there is no standard tool to assess one's skills or the effectiveness of these programs (Schmiedgen et al., 2016). This lack of a common measure makes it difficult to improve and utilize these skills in schools and workplaces. It also hinders individuals from evaluating and comprehending their abilities.

Through the creation of such tools, it is possible not only to enhance the effectiveness of design thinking training but also to offer individuals and organizations a more defined insight into their abilities and capacity for innovation. Furthermore, a standardized measure of design thinking capabilities could facilitate research in this area, aiding in the enhancement of educational approaches and the development of design thinking as an academic discipline. Razzouk and Shute (2012) emphasize the need for such instruments by identifying strengths and areas for enhancement. Facilitating more focused and effective growth. Scheer et al. (2012) argue that standardized evaluation tools are crucial for integrating design thinking into broader educational programs. Those attempts broaden the reach of this essential skill set across diverse demographics.

The traditional approach to design thinking research typically begins with successful case studies, analyzes the design thinking process, and concludes by outlining the

prerequisites for its effective implementation. In contrast, this research adopts a more foundational perspective, positing that the ability to think like a designer is rooted in specific cognitive and behavioral traits. Rather than solely relying on formal methodologies, it seeks to uncover the innate talents that enable certain individuals to excel in design thinking (Martin, 2009).

By identifying and exploring these essential traits, the study aims to provide a more nuanced understanding of how design thinking skills manifest across diverse individuals and environments. This approach not only highlights the significance of inherent abilities in the design thinking process but also encourages a reevaluation of how educational and professional development programs can be structured to nurture these attributes. Ultimately, this research aspires to contribute to a more holistic framework for understanding design thinking, emphasizing the interplay between individual characteristics and contextual factors in fostering innovative problem-solving.

1.4 Objectives of the Study

The primary goal of this study is to shift the focus away from the basic understanding of design thinking as a process and instead look into the personal abilities that align closely with its core principles. The research suggests that design thinking skills are essential, not just additional. It aims to delve into the abilities that naturally enable some individuals to be adept at design thinking, even without formal training in design disciplines. It intends to identify and explore the cognitive patterns, mental models, and

characteristics that define proficiency in design thinking. Furthermore, the study will investigate how these traits work in tandem with traditional design thinking approaches. Through a comparative analysis of individuals from diverse backgrounds and experiences, the research seeks to unveil the cognitive mechanisms and problem-solving tactics characteristic of design thinking and evaluate how these inherent skills can be cultivated and enhanced to foster greater innovation and creativity.

This study aims to develop a comprehensive scale for assessing an individual's design thinking capabilities, thereby contributing to the expanding body of research in this critical area. By creating a robust measurement tool, this research intends to facilitate the evaluation of the multifaceted nature of design thinking capabilities, which are essential for effective problem-solving and innovation across a variety of contexts. The establishment of such a scale not only enhances our understanding of design thinking capabilities but also provides valuable insights for educational and professional development initiatives.

The specific aims of this study are articulated as follows:

1. To systematically review and synthesize existing design thinking models from the literature, identifying core capabilities that are widely recognized as essential to the design thinking process. This comprehensive analysis will provide a foundational understanding of the key elements that underpin effective design thinking.

2. To develop and rigorously validate a psychometric scale designed to assess the identified design thinking capabilities, ensuring that the instrument demonstrates both reliability and validity. This step is crucial for establishing the scale as a credible tool for measuring design thinking competencies.

3. To empirically evaluate the utility of the developed scale through a case study, thereby assessing its practical applicability and robustness in real-world scenarios. This evaluation will provide insights into how well the scale functions in diverse contexts and its effectiveness in capturing design thinking capabilities.

4. To enhance existing theoretical frameworks related to design thinking by integrating empirical evidence derived from the scale application and the case study. This integration aims to contribute to a more nuanced understanding of design thinking and its implications for practice, ultimately enriching the academic discourse surrounding the subject.

1.5 Research Questions

1. What are the constituent items of a valid and reliable scale that can measure design thinking capabilities, and how can this scale be methodologically developed?

2. What characteristics define individuals with high design thinking abilities, and how do these abilities correlate with their educational background and experiences?

3. Given that design thinking is referred to as the "designerly way of thinking" (Cross, 1982), do individuals lacking a design-related background hold the competencies required for effective design thinking?

4. What are the practical implications of the research findings for implementing design thinking across various organizational contexts, and what can the scale aid this implementation?

1.6 Significance of the Study

The significance of this study extends far beyond just academic exploration of design thinking. It has the potential to revolutionize how design thinking is perceived, taught, and applied across various sectors. By uncovering the essence of design thinking within the intrinsic problem-solving approaches of individuals, the research could lead to a more accessible and scalable model of design thinking education. Such insights stand to democratize design thinking, transforming it from a niche skillset into a universally adoptable mindset that can foster innovation and drive problem-solving in numerous contexts—from corporate strategy and public policy to education and social entrepreneurship. The consequences of this research are manifold: It has the potential to transform talent acquisition by identifying new markers of inherent design thinking capabilities, reform educational strategies to include a broader demographic and

encourage the integration of design thinking principles across various disciplines to address complex issues. Ultimately, this study seeks to foster a worldwide culture of collaborative, empathetic, and strategic problem-solving, thus unleashing a vast pool of underutilized creative potential within the global community.

1.7 Scope of the Study

The scope of this study focuses on college students as the primary demographic target. This choice introduces certain limitations, as the findings may be influenced by the specific characteristics of this population. Therefore, the validity of the results is contingent upon the diversity of the sample; a more varied participant group could enhance the generalizability of the findings.

Moreover, design thinking is inherently a multi-faceted construct, and this research may not fully encapsulate all dimensions of it. The complex and nuanced nature of design thinking suggests that the scope of this study may not adequately address how design thinking abilities develop over time or how they are influenced by training, experience, or other forms of learning. Additionally, the cross-sectional design of this research limits the ability to determine whether design thinking skills are primarily innate or significantly shaped by individuals' life experiences and educational backgrounds.

These limitations underscore the necessity for future longitudinal studies that explore the evolution of design thinking competencies and the various factors that contribute to their development. Such research could provide deeper insights into the interplay

between inherent traits and experiential influences, thereby enriching our understanding of design thinking as a holistic and adaptive skill set.

1.8 Methodological Overview

In this thesis, a mixed-method research strategy is employed to comprehensively investigate design thinking capabilities. The methodology begins with an extensive review of existing literature, encompassing scholarly articles, books, and conference papers. This thorough examination enables the identification of critical elements that constitute design thinking proficiency within both educational and professional contexts. By synthesizing diverse perspectives and findings, the literature review enriches the understanding of this complex construct and serves as a foundational basis for the subsequent development of a measurement instrument.

Building upon the theoretical insights gained from the literature, a measurement scale is constructed to evaluate individuals' design thinking abilities. This scale undergoes a rigorous development process, incorporating iterative rounds of expert feedback and pilot testing to ensure its content validity. Quantitative methods are utilized to validate the scale, enhancing its reliability and applicability. Additionally, a case study is conducted to provide qualitative insights into the practical application of the scale in real-world scenarios, thereby enriching the findings with contextual depth.

The outcomes of these methodological approaches not only confirm the accuracy and dependability of the measurement tool but also highlight deficiencies in current training

programs by revealing variations in design thinking skills among professionals from diverse backgrounds. This comprehensive methodological framework aims to contribute a validated tool to the field of design thinking research, offering a more nuanced understanding of competencies that are relevant across both educational settings and industry environments. Ultimately, this research aspires to advance the discourse on design thinking and inform future educational and professional development initiatives.

Chapter Two

Literature Review

2.1 Introduction

A literature review serves as the foundational element of any research project. It achieves several critical objectives: positioning the research within the existing body of knowledge, pinpointing areas of agreement and contention within the field, highlighting innovations that current research seeks to contribute, and justifying the research methodology (Randolph, 2009). For this thesis, the literature review established the foundation for creating a new scale to assess design thinking skills.

The objective of this literature review is dual. Firstly, it seeks to categorize and synthesize the different models of design thinking that have been proposed and analyzed in scholarly articles. Such a synthesis would enable the identification of core competencies related to design thinking, as recognized by different frameworks (Johansson-Sköldberg, Woodilla, & Çetinkaya, 2013). Second, the review examines existing methods for measuring these competencies, focusing on the psychometric properties that these measures must have in order to be considered reliable and valid (Nunnally & Bernstein, 1994).

This literature review thoroughly analyzes the current body of research on design thinking to pinpoint the essential components that constitute design thinking capability and the various attempts at its measurement.

2.2 Deep Insights into Design Thinking

Design thinking has emerged as a formidable strategy for innovation and problem-solving, transcending the traditional boundaries of design. Originally rooted in industrial design practices (Kimbell, 2011; Luka, 2020; McCarthy, 2022), it has evolved into a comprehensive methodology embraced by businesses, educators, and policymakers alike (Brown, 2008; Martin, 2009). Central to design thinking is a user-centric approach that compels organizations to prioritize the needs and experiences of the individuals they serve (Petrovic & Siegmann, 2011; Vagal et al., 2019; Luca & Ulyannikova, 2020). This focus not only leads to enhanced products and services but also fosters improved processes that resonate with users, ultimately driving greater satisfaction and engagement.

The significance of design thinking gained considerable momentum in the 1990s, as influential leaders such as David Kelley of IDEO and the Stanford d.school formalized its application, extending its reach beyond industrial design to tackle a diverse array of business and social challenges (Kelley & Kelley, 2013; Meinel, Leifer, & Plattner, 2011). This expansion marked a pivotal shift in how organizations approach problem-solving, viewing design thinking as a vital tool for fostering creativity and innovation.

One of the hallmark features of design thinking is its iterative process (Plattner et al., 2010; Glen et al., 2014; Koca & Koç, 2020), characterized by five key stages: empathy, definition, ideation, prototyping, and testing (Anand et al., 2015). While these stages are not strictly sequential, they suggest a cyclical framework that emphasizes ongoing

refinement and continuous innovation (Gonen, 2020). This iterative nature allows teams to embrace uncertainty and adapt their solutions based on user feedback, fostering a culture of experimentation and collaborative learning (Elsbach & Stigliani, 2018). As such, design thinking not only enhances problem-solving capabilities but also cultivates a mindset that embraces change and values the insights gleaned from real-world application (Chasanidou et al., 2015; Schweitzer et al., 2016).

At the foundation of design thinking lies empathy, where designers immerse themselves in the users' experiences (Brown, 2008). After gaining this profound understanding, the steps of defining the problem, ideating solutions, developing prototypes, and thoroughly testing them in real-world scenarios follow. This iterative approach is innovation-centric, challenging assumptions, exploring possibilities, and fostering user-centric creation (Brown, 2009). Prominent leaders like Tim Brown from IDEO have advocated for design thinking, defining it as a discipline that merges user needs with technological feasibility and viable business strategy to generate value and market opportunities (Brown, 2008). Likewise, Roger Martin has highlighted the importance of design thinking in balancing analytical and intuitive thinking, thus fostering a union of art and science in decision-making processes (Martin, 2009).

The scholarly discussion surrounding design thinking has broadened its theoretical and practical relevance across multiple disciplines. Brown's investigation into its theoretical foundations brings together ideas from various fields, underscoring its revolutionary effect in education, where it is progressively applied to enhance instructional methods and promote critical thinking and creativity (Carlgren, Rauth, & Elmquist, 2016).

Despite its growing popularity, the conceptualization and practical application of design thinking continue to be subjects of intense academic discussion. Johansson-Sköldberg et al. (2013) discuss the varied definitions and intellectual foundations of design thinking, which both enrich and complicate its comprehension However, this discussion emphasizes the adaptable nature of the discipline (Kolko, 2015). Design thinking has a far-reaching impact outside of academia, as industries worldwide use it to drive innovation and tackle complex problems (Liedtka & Ogilvie, 2011). Its widespread application demonstrates its flexibility and reflects a broader trend toward creating value that is empathetic and user-centered (Brown, 2008).

Many real-life examples show how design thinking can effectively generate innovative solutions and foster a culture of continuous improvement and learning within organizations (King et al., 2013; Liedtka, 2014; Elsbach & Stigliani, 2018; Cousins, 2018). The approach, which emphasizes empathy, defining problems, generating ideas, creating prototypes, and testing, has proven particularly successful in business settings, leading to the development of products and services that deeply resonate with consumers (Brown, 2009; Liedtka & Ogilvie, 2011). Evolving from a specialized method in product design to a comprehensive problem-solving strategy, design thinking is known for its focus on the user, creativity, and ongoing learning through iteration (Cooper et al., 2009; Razzouk & Shute, 2012; Fleury et al., 2016; Verganti et al., 2021). It offers a solid framework for addressing the complexities of the modern world, enabling teams to develop solutions that meet user needs.

In essence, design thinking represents a significant shift in problem-solving approaches. It embraces a mindset that rethinks challenges, prioritizing human values and a collaborative, iterative approach to innovation (Brown & Katz, 2009). This philosophy harnesses collective intelligence, incorporates new technologies, and aligns with strategic objectives to create lasting value (Sytnik et al., 2022). Its adaptability and emphasis on human aspects make design thinking a crucial tool for contemporary organizations (Jahnke, 2009; Chasanidou et al., 2015; Cousins, 2018; Elsbach & Stigliani, 2018), fostering an atmosphere of innovation and continuous learning.

2.3 Design Thinking Models

Design thinking resides at the intersection of creativity and practicality, a dynamic field shaped by various strategic frameworks. The exploration of these frameworks goes beyond academic interest, it is a pursuit to capture the essence of design thinking and explore the potential to drive innovation and enhance problem-solving across diverse disciplines and professional contexts. By analyzing the structure of these models, the common foundational elements can be identified while also recognizing the distinct nuances and adaptations that each contributes.

Various influential models are explored in this field, ranging from well-known designs by IDEO to educational structures promoted by Stanford's d.school. With the ideas put forth by other leading thinkers, this research will begin to understand the essential elements of individual design thinking skills. This journey grasps the significant impact of design thinking models. There is a passage to see how empathy and innovation come

together, and how ideas evolve into action. Lastly, practitioners can use this powerful method to create solutions that are both impactful and enlightening.

The Human-Centered Design Model (HCD) is a framework centered on understanding human needs. It integrates principles that have been pivotal in design discourse since the 1980s, and emerge from fields such as industrial engineering and human-computer interaction (IDEO, 2015; Boy, 2017). Characterized by its foundation in empathetic research, collaborative ideation, and iterative prototyping, aimed at developing products, services, or systems that effectively address user challenges and enhance experiences (Chung & Kong, 2016; Eberhart et al., 2019; Nijagal, 2021). It encompasses three phases (Bui et al., 2024): (i) Inspiration, where insights are gathered through user observations, interviews, and feedback to thoroughly understand user needs; (ii) Ideation, which fosters creativity and the generation of innovative ideas within a freely explorative environment; and (iii) Implementation, where ideas are actualized, tested, and refined. This approach has been notably effective in healthcare, optimizing patient care by prioritizing safety and efficiency (Wymer et al., 2023). By merging with implementation science, the practical application of this user-centric research method has been effectively realized (Chen et al., 2021). In alignment with the model's ethos, Chatti et al. (2020) developed a Human-Centered Indicator Design (HCID) for learning analytics at the University of Duisburg-Essen, demonstrating the model's practicality through course structure and selection analyses. The methodology is supported by a dual focus: balancing user observation with actual design practice, and integrating comprehensive user observations that account for both physical and emotional needs. Van der Bijl-Brouwer and Dorst (2017) expanded upon this model by

developing a four-tier framework addressing human needs and desires, while Leary et al. (2022) synthesized the essential stages identified in the pertinent literature.

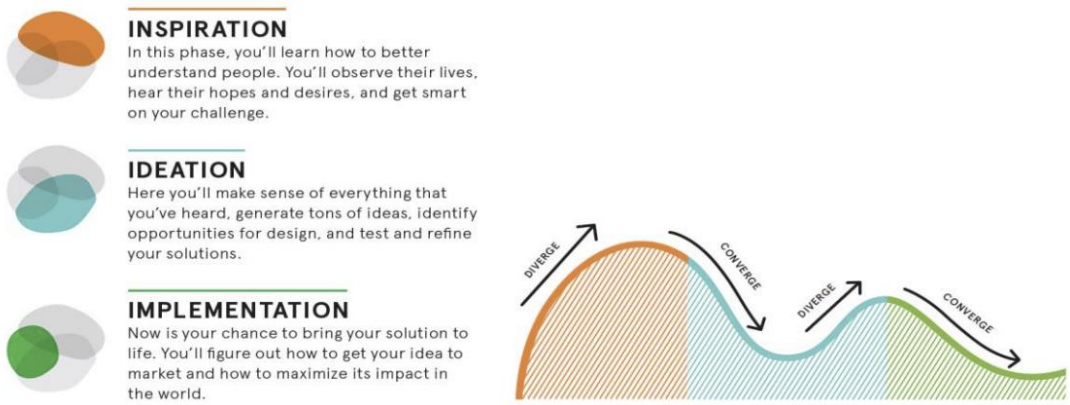


Figure 2-1 Human-centered design model (HCD) (IDEO, 2015)

However, there are difficulties when applying HCD. Sometimes, focusing on user needs too much can cause important factors like market trends, technical feasibility, and the long-term success of solutions to be overlooked. Designs that prioritize users may not always align with an organization's overall goals or lead to competitive products. Some solutions that initially please users may not last or make money in the long run. HCD's emphasis on immediate user preferences can limit the introduction of groundbreaking ideas, preferring small improvements instead. Relying too much on current user feedback can hinder forward-thinking and innovation for future needs. The time-consuming nature of the iterative design process can be a major challenge, especially for smaller businesses. Investing time, money, and people in designing, testing, and refining may be difficult if effective solutions are not quickly found. Overcoming these challenges necessitates a sophisticated strategy that blends insights from users with a well-defined strategic direction, a willingness to embrace disruptive innovations, and a

realistic evaluation of how resources are utilized. Practitioners must be mindful of these limitations and customize the HCD framework to align with the specific objectives and context of their projects.

IDEO's Design Thinking Model (IDEO): As a leading international design consultancy, IDEO applies this methodology across a variety of business scenarios (Rau, 2020; Tschimmel, 2012). One of IDEO's initial projects, the creation of the first Apple mouse, demonstrated their dedication to principles of user-centered design. IDEO's design thinking philosophy has been disseminated through publications, educational programs, and partnerships with a variety of industries (Grönman & Lindfors, 2021). The core activities of the IDEO model include three parts: (i) Inspiration: The entire design process begins with understanding the problem, followed by brainstorming a solution framework, and then observing and analyzing the problem (Leal Filho et al., 2021; Waidelich et al., 2018); (ii) Ideation: after obtaining in-depth recognition of faced challenges, insights and thinking from a diverse and integrated team will be collected to seek creativity and solutions in this collision (Leal Filho et al., 2021); (iii) Implementation: attempts for materializing adopted idea will be conducted by testing, iteration and advancement of design ideas and solutions through the means of prototyping (Kim & Park, 2021).

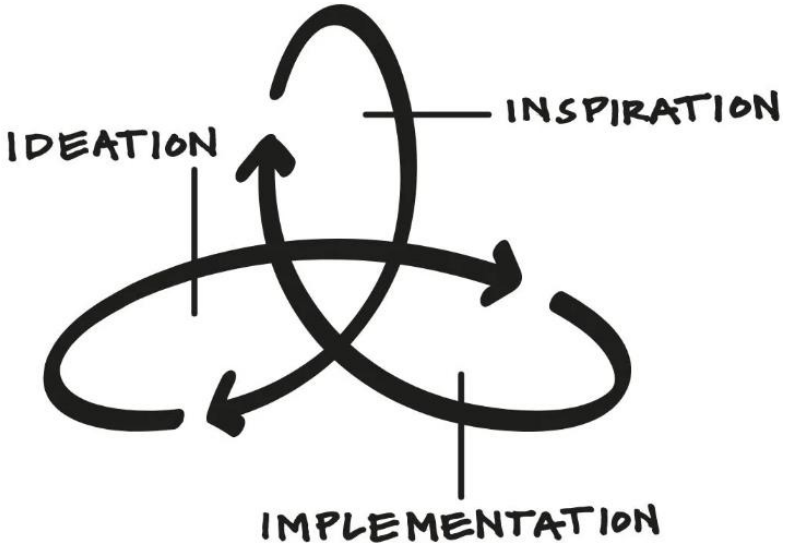


Figure 2-2 IDEO's design thinking model (Interaction design foundation, 2016)

Scholars have engaged with the model, optimizing and enriching it through various studies. Mahmoud-Jouini et al. (2019) examined successful cases of IDEO practice in a large multi-department organization, identifying five key elements that contribute to design success. Additionally, Glen et al. (2015) expanded the model for business curriculum education to include six distinct stages, offering a detailed framework that helps students and teachers effectively navigate the design process with defined objectives, feedback, and guidance. Roberts et al. (2016) illustrated the application of the IDEO design thinking framework in transforming processes within an emergency department, which resulted in enhanced patient satisfaction and shorter waiting periods. Additionally, the Nueva School in California implemented this method to create an interdisciplinary curriculum that emphasizes the significance of critical thinking and problem-solving skills.

Mahmoud-Jouini et al. (2019) identified many obstacles when trying to use the three-stage process in businesses, like mental limits and conflicts between new and old ways of doing things, as well as other conflicting factors. Shapira et al. (2017) noted that while their adaptation of design thinking within the framework of strategic sustainable development (FSSD) presented a structured five-stage process, it fell short of preparing for sustainability adequately. The IDEO design thinking approach, though it encourages innovation, may prioritize creativity too heavily, sometimes resulting in ideas that are not practically or economically feasible. Its focus on a user-centric methodology might overlook important technical or business aspects, thereby confining solutions to a limited user perspective. In industries that are strict or highly regulated, the iterative and prototype-focused techniques of the model may be unsuitable. Moreover, the vague nature of design thinking can lead to confusion and stress, especially in educational environments, highlighting the need for clearer instructions to alleviate these issues.

The Hasso Plattner Institute design thinking model (HPI) was developed through a collaboration between Professor Hasso Plattner and Stanford University's School of Design. This model is based on design principles that focus on people and uses a methodical, step-by-step approach to solving problems (Wölbling et al., 2012; Muhtaseb & Burqan, 2021; Carlgren et al., 2016; Okai-Mensah et al., 2021; Traifeh et al., 2019). This model is grounded in human-centered design principles and utilizes a systematic approach to problem-solving. It encourages designers to continually revisit and refine the stages as necessary (Tham, 2022; Bongiovanni & Louis, 2021). As well as promoting enhancement and ensuring solutions to meet user requirements. It comprises five stages (Sakama et al., 2018): (i) Empathize: Designers engage with the environment and experiences with stakeholders to gather insights and understand their

needs. (ii) Define: This stage involves condensing the gathered insights into a clear problem statement that acts as a compass for all design activities. (iii) Ideate: Designers brainstorm a broad spectrum of ideas and potential solutions to the articulated problem. In using techniques like mind mapping and rapid prototyping to explore innovative concepts. (iv) Prototype: Designers create tangible representations of their ideas through prototypes or mock-ups, which are essential for testing and refining the concepts through iterative cycles. (v) Test: The final stage testing the prototypes with users to collect feedback. This feedback is crucial for assessing the viability of the solutions and making necessary adjustments before final deployment.

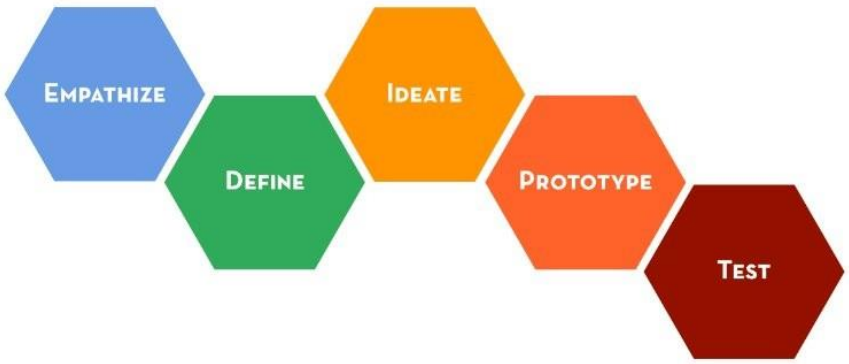


Figure 2-3 The design yhinking model of the Hasso-Plattner-Institute (HPI) (Plattner et al., 2010)

The HPI model is a strong framework that boosts creativity in different industries. In a business context, Bertão et al. (2023) studied how LG Company's HR department in South Korea incorporated design thinking training. Meanwhile, Pata et al. (2021) investigated how agile and lean methodologies are combined with design thinking in

the field of engineering. Additionally, Thienen et al. (2022) developed a neural design using the HPI model as a foundation but expanded it to include six phases: understanding, experience, point of view, ideate, test prototypes, and bring home.

While the HPI design thinking model is a strong tool for fostering innovation, it encounters some criticisms and challenges, especially when applied to complex real-world scenarios or in contexts that demand tangible outcomes and definitive guidance. Meinel and Leifer (2011) contend that rigidly structured processes may restrict the creative freedom necessary for designers to explore and generate ideas effectively. The model struggles with complicated problems where its linear approach might reduce complexities to oversimplified solutions. Which potentially leads to superficial outcomes (Razzouk & Shute, 2012). In practical applications, the cooperative aspect of the HPI model may face difficulties. Lindberg, Noweski, and Meinel (2010) have studied how group dynamics and the existing organizational culture can affect the effectiveness of collaborative design thinking efforts. Additionally, the model's inherent ambiguity can be confusing, particularly for students who find themselves struggling in educational settings (Johansson-Sköldberg et al., 2013).

The Double Diamond Design Thinking Model is a strategic design approach that guides the process of design, which was developed in 2005 by the UK Design Council. The model blends divergent and convergent thinking, striving to address problems by fostering empathy and iterative processes. (Schmidt & von der Oelsnitz, 2020; Peng & Kueh, 2022). It is typically structured in four phases (Buhl et al., 2019; Kwon et al., 2021) (i) Discover: the divergent thinking of exploring the problem situation, collecting

user needs, and obtaining information; (ii) Define: this is the first convergence thinking that analyzes, filters, integrates, filters all the information, to construct design solutions and refine problem statements after synthesizing information; (iii) Develop: this is the divergent thinking of diverse teams conceiving and exploring solutions, often using visual representations, prototypes, etc., to develop, test, and iterate; (iv) Deliver: this is the convergent thinking of the designer to practice the solution selected after refactoring and adjusting. This phase also typically includes solution testing, elaboration, and practical preparation.

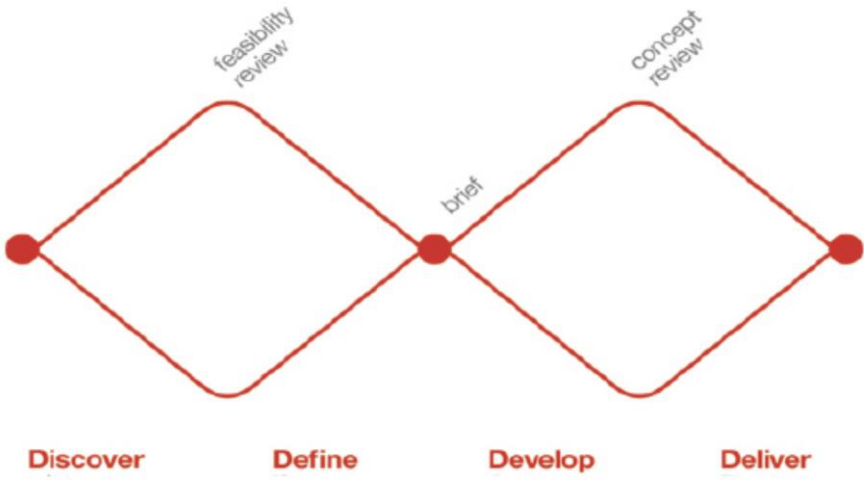


Figure 2-4 Double diamond design thinking model ((Design Council UK, 2005)

It serves as a structured guide within the methodology, offering a visual representation of divergent and convergent stages critical to innovative problem-solving (Grönman & Lindfors, 2021; Hassenzahl, 2013). Its adaptability and versatility have facilitated its integration into various industries and disciplines. The significance of the two-drill model (Kochanowska & Gagliardi, 2022) is presented through design engineering visualization and the establishment of practical ways for designers and users to

cooperate. In addition, the framework and principles for evaluation are provided in cases where the uncertainty of the outcome exists. Wang et al. (2023) utilized the double diamond model in addressing design issues related to aging. Pyykkö et al. (2021) investigated the use of the same four stages in supply chain management. The authors summarized four strategies under this model, which are co-creating change, pushing change, bringing about change, and forcing change. Huang and Hands (2022) explored the application in business. They summarized the methodology "the Three Gears of Business Design", which contributed more attention to the end users and reduced the emphasis on strategic development.

Although widely recognized for clarity in representing the design process. However, the double diamond model still has several limitations. The neat, linear, sequential process depicted in the model may oversimplify the complexity and non-linearity of actual design work (Roberts et al., 2016; Stigliani and Fayard, 2017). Besides, the model does not clearly define the complex dynamics of stakeholder relationships and negotiations, which are often crucial in design projects. (Sangiorgi, 2011). By funneling the process into divergent and convergent thinking stages, there is a risk that designers may become fixated on certain ideas too early. Youmans (2011) discusses how design fixation can limit creativity, a potential byproduct of strictly adhering to the structured phases of this model.

IBM Design Thinking Model: The framework is one of the newly developed (Okai-Mensah et al., 2021). The beginning motivation was the establishment of a design process to understand consumer needs and implement empathy. IBM’s guidelines have

three parts (Marcus & Rosenzweig, 2020; Micheli et al., 2019): a focus on user outcomes (understanding the real needs of users and establishing results metrics), restless reinvention (constantly developing existing prototypes and products for changing environments, markets, and users), and diverse empowered teams (diverse teams achieve differentiated results and decisions) (Nedeltcheva & Shoikova, 2018). The IBM model is typically a loop of three stages: (i) Observe: rely on empathy to observe and understand the real needs of users and the environment; (ii) Reflect: diverse teams work together to flexibly integrate requirements and produce innovative solutions; (iii) Make: develop, test, and deliver prototypes to users and timely adjustment and reconstruction based on feedback.

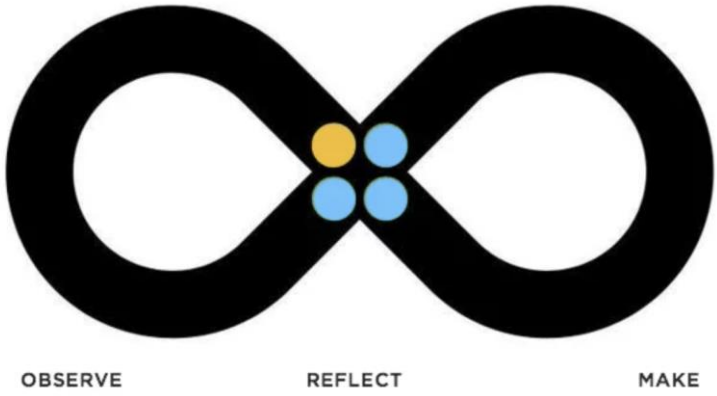


Figure 2-5 IBM design thinking model (Justinmind, 2019)

Realistic cases employing this model have been widely presented. Chebabi and von Atzingen Amaralet (2019) worked with the human resources department in Brazil to complete the first stage through interviews and online surveys. Guided by this model, users can integrate with teams to find imperceptible problems accompanied by exquisite

solutions in a funny way. In software development, Lucena et al. (2017) used IBM frameworks to extend the principles in meeting users' needs for rapid development as well as capture at scale. While widely adopted for its user-centric and agile approach, the IBM design thinking model also faces several limitations: The adoption of this design thinking method can sometimes clash with the established procedures and culture in organizations, leading to resistance. This issue is discussed in the literature that examines how companies integrate new methodologies and the challenges they face in doing so (Bucolo and Matthews, 2011). Scaling the design thinking approach across larger and more complex organizations can be a significant challenge. Liedtka (2015) discusses the potential scalability issues of design thinking within large organizational settings, noting that while design thinking offers a promise for innovation, its application can be problematic on a larger scale.

Jeanne Liedtka Design Thinking Model: is a "design thinking for business innovation" model developed by Jeanne Liedtka in collaboration with Tim Ogilvie (2011). Based on the various types of models mentioned above, they make adaptive adjustments for business and management, reflecting the construction and application of this model in business behavior which established four phases: (i) 'What is?' phase: This means an accurate assessment of the situation and an empathetic analysis to define scope and goals, during which designers need to put aside personal empiricism and stand in the context of the current understanding. It is also a reference point for subsequent changes. Four common methods are visualization, journey mapping, value chain analysis, and mind mapping. (ii) 'What if?' phase: This stage is the embodiment of creativity and generation, during which designers are required to brainstorm ideas and then visualize proposed ideas based on existing data and information to think more creatively about

future scenarios. This stage encourages breaking out of existing limitations by organizing and combining ideas. Two practicable methods are brainstorming and concept development tools. (iii) ‘What wows?’ phase: After getting luxuriant ideas for the future, designers need to find amazing ideas that make users ‘wow’. This requires the system development evaluation test process. The prototype obtained through experimental testing also needs to be delivered to users for feedback. Methods including assumption testing and rapid prototyping provide effective identification of core parts of the hypothesis. (iv) ‘What works?’ phase: Commercial value for the prototype test results obtained in the first three stages needs to be recognized, which means positive recognition from the market. Reconstructs and iterates existing prototypes and solutions through user and market feedback to continuously overcome the impact of high uncertainty. Finally, the commercialization of the product and the feasibility of the program can be realized. The appropriate methods for this phase are customer co-creation and learning launch.

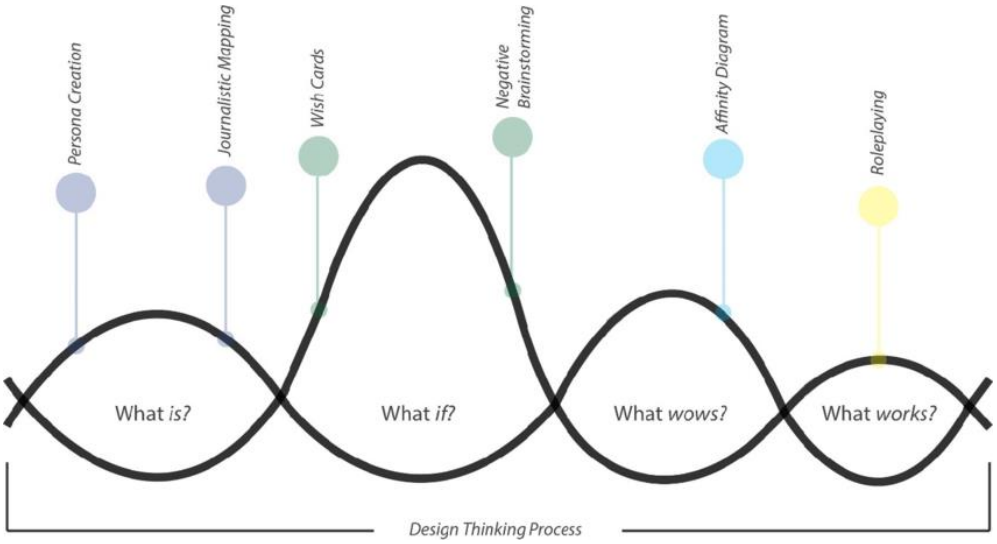


Figure 2-6 Jeanne Liedtka design thinking model (Liedtka & Ogilvie, 2011)

Jeanne Liedtka's Design Thinking Model is still influential in the field of business innovation. The model has been implemented in a variety of organizations that seek to integrate design thinking into their strategic planning and decision-making processes. While the details of its application may vary, the enduring relevance of the model demonstrates its effectiveness in fostering a design thinking mindset in a business environment (Liedtka, 2014). While not a direct critique, the complexity and multitude of tools in Liedtka's model could potentially create hurdles in practice. For insights into the issue of complexity in design thinking tools (Micheli, 2019）. Besides, the strategic alignment emphasized in Liedtka's model is double-edged; it can streamline innovation to fit business goals but may also neglect valuable creative opportunities. To ensure the thoroughness of this thesis, a detailed comparative analysis of design thinking models is included in Appendix 1 (WANG et al., 2024, see Appendix 1).

Model	IDEO	HPI	HCD	Double Diamond	IBM	Liedtka
Stage	Inspiration	Empathise	Inspiration	Discover	Observe	What is
		Define		Define		What if
	Ideation	Ideate	Ideation	Develop	Reflect	What wows
	Implementation	Prototype	Implementation	Deliver	Make	What works
		Test				

Table 2-1 List of design thinking models

2.4 Assessing Current Design Thinking Capability

To ascertain the state of design thinking capability measurement, this research undertook an exhaustive literature survey. The review's boundaries were delineated to include scholarly works concentrated on the quantification, evaluation, as well as conceptualization of design thinking capabilities. A strategic search, employing keywords such as "design thinking" in conjunction with "measurement," "scale," "assessment," "test," and "capability," was performed across several leading academic databases, such as Web of Science, Google Scholar, and Scopus. Despite a considerable volume of literature, exceeding 300 relevant journal articles, a scant number were found to be directly pertinent to the measurement of design thinking capabilities, highlighting a gap in current research and an opportunity for significant contributions.

Dosi (2018): Dosi's meticulous research synthesized the literature to extract the core elements of design thinking. An 84-item questionnaire emerged from a review designed to highlight the cognitive facets and the essential competencies required for its effective application. This comprehensive questionnaire is intended to measure individuals' grasp and expertise in design thinking. However, the method of selecting elements based on their frequency in the literature may have introduced a bias, potentially overlooking less prevalent yet critical aspects of design thinking.

Tsai (2018): Tsai's study offered a lucid delineation and examination of design thinking, distilling the concept into three overarching stages: identification, generation, and actualization. While the study offered a framework for grasping design thinking

processes, it did not fully grasp problem framing. It served as a crucial stage that demands a more thorough analytical examination.

Vignoli, Dosi, and Balboni (2023) delved deeper into how design thinking is used in different areas. They used quizzes and expert opinions to assess design thinking skills, pinpointing 10 key components and developing 34 detailed questions. However, the limited number of questions for each component suggests a more comprehensive approach may be needed to fully grasp the complexities.

Existing measurements of DT capability			
Author	• **Content**	• **Target**	
Chesson (2017)	• 78 items under 11 elements • English	• People **with experience** in the DT approach • > 35mins	• Selected elements based on their frequency in the literature may have introduced a bias, potentially overlooking less prevalent yet critical aspects of design thinking.
Tsai (2018)	• 16 items under 4 elements • Chinese	• Undergraduate **design students** taking DT training course • ~10mins	• Outlined design thinking theory but abruptly transitions to the questionnaire, lacking robust evidence for the origins of the questions. This gap undermines the validity of the questionnaire, as it lacks a solid theoretical foundation.
Dosi, Rosati, and Vignoli (2023)	• 34 items under 10 elements • English	• People **with experience** in the DT approach • ~20mins	• Identified 10 key elements of design thinking based on expert opinions, the limited number of questions for each component indicates that a more comprehensive approach is necessary leads to a narrow perspective and limits the breadth of the findings.

Table 2-2 Existing measurements of design thinking capability

Thus assessing design thinking capabilities is a developing area within academic research. The studies mentioned previously contribute to the knowledge and quantification of design thinking. However, it also highlights the necessity for measurement tools that are more detailed, strong, and all-encompassing. Given this nascent stage, the present research aims to fill the scholarly void by identifying core

components of design thinking capability and seeking to establish a consensus among existing frameworks.

The next steps involve the development of a new, psychometrically validated scale designed to capture the multifaceted nature of design thinking. This scale will not only consider cognitive elements but also incorporate affective and behavioral dimensions. It will seek to address the limitations unveiled in prior research by ensuring that the construct's multifaceted nature is fully represented, thereby facilitating a more accurate and holistic evaluation of design thinking capabilities. The subsequent chapters will focus on constructing a psychometrically sound scale that encompasses the breadth and the complexity, informed by both the gaps and the strengths of existing research.

2.5 Capability in the Context of Design Thinking

With organizations keen to cultivate a creative culture and lead to innovative solutions, the evaluation and enhancement of design thinking capability have become essential. Nevertheless, an agreement on the definition and measurement of design thinking capability has remained unsolved. Within the scope of design thinking, the capability may be described as the cognitive aptitude and collective skills that individuals or teams apply in issue resolution, innovation, and the overall procedure (Paula et al., 2018).

Design thinking capability refers to the ability to effectively apply design thinking principles to solve complex problems and create significant innovations. Research

frequently focuses on its implementation in organizational management, highlighting the strategic and practical use of design strategies to foster innovation (Paula et al., 2018). Academics stress the critical role of the designer in the creative process, advocating for a more in-depth investigation of design thinking capabilities that move beyond mere aesthetic considerations to a focus on user-centric approaches (Buchanan, 1992; Razzouk & Shute, 2012; Owen, 2007).

Design thinkers are recognized for their creative and intuitive abilities, effectiveness, communication prowess, determination, and focused approach (Buchanan & Margolin, 1995). And known for their dynamic mindset (Brown, 2008; Liedtka, 2000) and the capability to toggle between creative and analytical modes of thinking (Owen, 2005). This study portrays the design thinker as an active and accountable person, equipped with the necessary skills for inventive problem-solving. Design thinking requires a diverse set of mindsets, behaviors, and personality traits from its practitioners.

Design involves more than just thinking processes; it also combines different ways of thinking based on reasoning and problem-solving. It requires careful analysis and deduction to determine if design solutions are feasible (Dorst, 2011). The importance of evaluating design thinking skills has become more apparent as it becomes more significant (Haskamp, 2021). Evaluating this capability is crucial for comprehending the origins, development, and synergistic interactions inherent in the design thinking process. This capability represents a framework that emphasizes understanding and improving the ability of individuals and organizations to engage in design thinking practices. This perspective extends beyond simple skill acquisition or asserts to

methodologies, encompassing broader elements such as knowledge, skills, attitudes, mindsets, and resources that together facilitate effective participation in the process.

Efforts have been made to explore the core skills of design thinking (Groeger & Schweitzer, 2020), enhancing the understanding of the necessary abilities and competencies. Design thinking as a process of developing capabilities "includes fostering a collaborative attitude toward global issues, an open and inquisitive mindset, creative strength, and a moral framework" (Panke, 2019). Designers often integrate these skills into specific situations and design challenges to create innovative, user-focused solutions (Micheli et al., 2019). However, accurately measuring design thinking capabilities is crucial and involves precise measurement and evaluation. Studies on design thinking capabilities sometimes face challenges related to content duplication, especially in the construction of questionnaires. Excessive questions can undermine the reliability and validity of the assessment tools. Therefore, it is vital to develop measurement instruments that accurately reflect the complex nature of design thinking without unnecessary repetition. Evaluating design thinking capabilities allows individuals to recognize their strong points and areas needing improvement, providing insights into their creative, critical, and systemic thinking skills. Identifying these strengths enables individuals to apply them effectively in problem-solving and innovation. Simultaneously, by identifying areas that require skill enhancement, individuals can strengthen their design thinking abilities, thus deepening their understanding of creative thinking skills such as ideation, fluency, flexibility, and originality.

2.6 Generation of Key Capabilities of Design Thinking

Among the models, each provides a distinct perspective on its processes and critical elements. To pinpoint the central capabilities of design thinking, a comparative analysis of these models is essential. By exploring the common elements across different frameworks, this research aims to identify the core elements related to design thinking approach. This analysis bridges theoretical elements and practical practices, highlighting that encapsulate the core of design thinking through a detailed comparison of notable models. Through this, an understanding of the fundamental components that make up design thinking is built. This not only enhances clarity but also guides the practical application of design thinking in various contexts, providing a robust foundation for practitioners to address creative problem-solving.

Within the literature on design thinking, a significant array of models presents a spectrum of approaches to innovative problem-solving. Each model, constructed through different lenses of academic and practical expertise, contributes to a nuanced understanding of the concept. To navigate through the intricacy of these models and identify the unifying core elements, a comparative analysis is embarked upon that scrutinizes the structure and methodology of each.

The literature review has carefully examined six prominent design thinking models, each outlining a structured progression of phases from identifying issues to achieving solutions. Although these models vary in their frameworks, a thematic analysis identifies shared cognitive and practical activities within these models. An in-depth

comparison has facilitated the extraction of key design thinking capabilities that form the essence of a universal framework.

IDEO, HCD, and IBM Models present the design thinking process through a tripartite lens: Inspiration, Ideation, and Implementation. Each stage, though simply named, encompasses a complex array of activities (Lewrick, Link, & Leifer, 2018).

Inspiration: This phase is characterized by empathetic engagement, where practitioners immerse themselves in the problem environment, gathering insights through ethnographic techniques and user interviews (Dam & Siang, 2020). Ideation: Divergent thinking takes center stage, as multidisciplinary teams brainstorm and leverage creative problem-solving methods to generate a plethora of potential solutions (Brown, 2009). Implementation: Prototyping is not merely about building models; it's about storytelling, user interaction, and feedback integration, thereby embodying a test-and-learn approach (Kelley & Kelley, 2013).

Double Diamond and Jeanne Liedtka Models underscore design thinking’s nature iterative, presenting 4 phases: Discover, Define, Develop, and Deliver. It emphasizes how important the diverging as well as converging at each phase is to explore the problem space and refine solutions (Stickdorn et al., 2018). Jeanne Liedtka's model, with its abstract leanings, stresses the importance of mental models and the removal of cognitive biases in its four-stage approach, highlighting the reflective nature of the design thinker's journey (Liedtka, 2015).

HPI Model incorporates an additional stage that some scholars endorse—a reflective evaluation phase that follows testing (Plattner et al., 2011). This approach enables a comprehensive evaluation of solutions not only based on technical specifications but also considering emotional factors (Scheer et al., 2012).

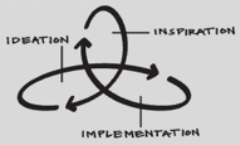
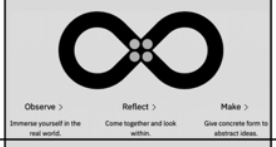
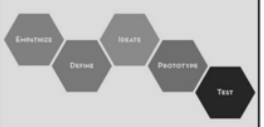
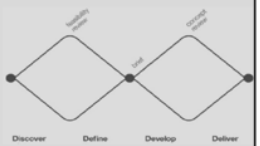
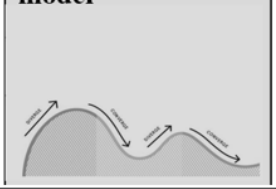
Design Thinking Models			
IDEO model 	● Inspiration ● Ideation ● Implementation	**IBM model** 	● Observe ● Reflect ● Make
HPI model 	● Empathize ● Define ● Ideate ● Prototype ● Test	**Jeanne Liedtka's model** 	● What is? ● What if? ● What wows? ● What works?
Double diamond model 	● Discover ● Define ● Develop ● Deliver	**Human-centered design (HCD) model** 	● Inspire ● Ideate ● Implement
Inspiration; Empathize; Discover; Observe; What is?; Inspire			
Define; Define; What if?			
Ideation; Ideate; Develop; Reflect; What wows?; Ideate			
Implementation; Prototype; Test; Deliver; Make; What works?; Implement			

Table 2-3 Comparitive analysis of key design thinking capabilities

The overlap among these models indicates a fundamental set of capabilities essential to the design thinking process. Which go beyond the specifics of individual models. From the comparative analysis, four key capabilities have been identified:

Empathy and user focus: This foundational aspect of design thinking emphasizes a deep understanding of the user. It serves as the cornerstone of the entire process, ensuring that solutions are closely aligned with genuine human needs and experiences.

Problem framing and definition: The process begins with a well-defined problem statement, which directs the ideation phase. This step consolidates insights derived from empathy to precisely delineate the problem area.

Ideation and creativity: At the heart of design thinking lies the ideation phase, which prioritizes creative thinking to generate a diverse set of possible solutions without limitations.

Prototyping and interaction: Through prototyping, ideas are transformed into physical forms that enable user interaction. This phase is essential for eliciting user feedback and refining the design through iterative development.

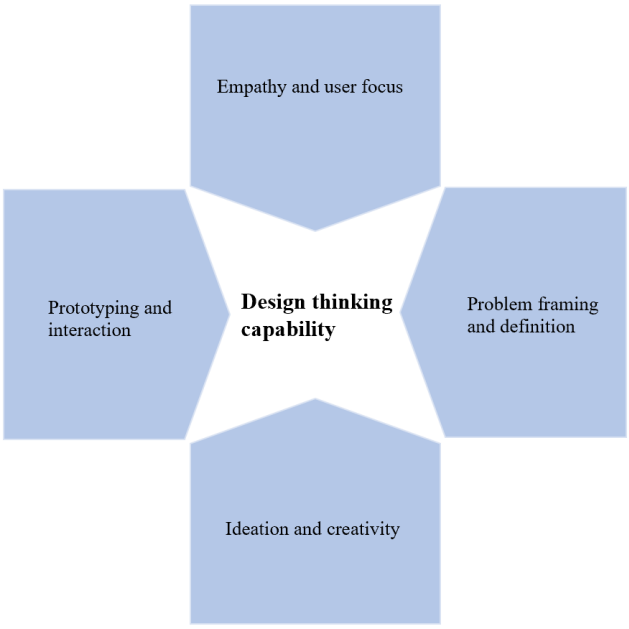


Figure 2-7 Key design thinking capabilities

These core elements provide a fundamental framework for applying design thinking. Which contributes to a structured yet flexible methodology that based on human-centered and iterative. This framework helps practitioners achieve a solid grasp of the critical components and allows to meet the specific needs of different sectors and challenges.

As design thinking evolves, the details and characteristics of these models continue to shape both practice and research in the field. This investigation indicates that despite variations in terminology and phases, a consistent dedication to empathy, problem definition, ideation, and prototyping underpins the diverse array of design thinking methodologies. The understanding of fundamental elements and their interactions within different models provides the necessary knowledge to implement design

thinking. This ensures the solutions developed not only drive innovation but also align closely with user needs and desires.

The capabilities identified through the analysis represent collective wisdom, outlining the essential elements integral to the practice of design thinking. This not only emphasizes a common understanding but also highlights the flexibility and cohesive nature of this framework, making it suitable for fostering innovation and problem-solving across various domains.

2.7 Key Capabilities of Design Thinking

Essential capabilities crucial for the innovation process have been widely recognized and explored in the literature. It serves as foundational elements that facilitate the successful application of design thinking in solving problems. This section will dig in these capabilities: Empathy and User-Centricity, Problem Framing and Definition, Ideation and Creativity, and Prototyping and Interaction.

Empathy and User-Centricity: Empathy stands as a fundamental element of design thinking, enabling practitioners to forge a profound understanding of the users' experiences and emotions (Brown, 2008; Fraser, 2007; Martin, 2009). Through direct engagement and observation of users in their actual environments, design thinkers can craft solutions that genuinely align with user needs (Liedtka & Ogilvie, 2011). Brown

and Wyatt (2010) highlight the role of empathy is not only functional but also emotionally resonant with users. The same as user-centricity ensuring the design process remains focused on the user's perspective throughout (Lockwood, 2010). Liedtka and Ogilvie (2011) emphasize the importance of immersing deeply in the customer's environment to extract insights that lead to impactful innovations.

Problem Framing and Definition: The skill to accurately frame and define the problem is crucial in steering the design thinking process. A clearly articulated problem statement provides a solid base for the ideation and subsequent development of solutions (Dorst, 2011). Empathy informs the framing process, ensuring that the problem is viewed through the lens of the user's experience (Martin, 2009). Dunne and Martin (2006) highlight the ability to reframe problems based on user feedback as a hallmark of adept design thinkers.

Ideation and creativity: Ideation is the generative phase of design thinking where a multitude of ideas are created. Creativity is paramount during ideation, as it allows for the exploration of novel and unorthodox solutions (Brown, 2008; Kelley & Kelley, 2013). Junginger (2007) asserts that ideation should be expansive, pushing the boundaries of conventional thinking. Lawson (2006) notes how important both divergent and convergent thinking is in navigating ideation procedures effectively.

Prototyping and interaction: Prototyping is an exploratory tool that translates abstract ideas into concrete forms (Brown, 2008). It enables engagement with the concepts, providing concrete experiences that can be assessed and improved (Buchenau & Suri,

2000). Interacting with prototypes allows designers to challenge assumptions and incorporate user feedback (Buxton, 2007). Sanders and Stappers (2008) underscore that prototyping involves more than just constructing models, it also facilitates learning and comprehension through the act of creation.

2.8 In Summary

In conclusion, our extensive review has analyzed and assessed several well-known design thinking models, which, despite their differences in structure and focus, converge around four central elements: empathy and user-centricity, problem framing and definition, ideation and creativity, and prototyping and interaction. These components are vital to the design thinking process, ensuring it remains user-oriented and iterative.

Empathy and user-centricity are foundational, urging designers to deeply engage with the user's environment to gather meaningful insights. Problem framing and definition direct the course of the ideation process, offering a clear focus for developing solutions. The ideation and creativity stage celebrates diverse thinking, where numerous potential solutions emerge. Prototyping and interaction exemplify the iterative nature of design thinking, facilitating ongoing refinement of solutions through user feedback.

The models reviewed, from IDEO's three-phase approach to HPI's detailed five-stage process, each adds unique insights and methodologies to the field of design thinking. The Double Diamond model demonstrates a dynamic interplay between exploratory

and convergent stages, while Jeanne Liedtka's model integrates cognitive aspects designed to marry innovative thinking with business practicalities. The HCD model emphasizes a balance between desirability, feasibility, and viability, and the IBM model highlights the critical role of continuous user feedback. From this perspective, design thinking is not a master key style methodology, it is a flexible and adaptable method, could be used to meet the specific needs and constraints of various fields and industries. Design thinking's nature underscores the importance of ongoing learning and adapting solutions in response to real-world complexities and user feedback.

This literature review sets the groundwork for understanding design thinking. It provides a foundation for the subsequent discussion on the methodology. Building on the insights from the review, the next chapter will detail the research strategy, design, and methods employed in this research. It will describe how the essential elements of design thinking are applied in a practical setting. Upcoming sections will outline the criteria for participant selection, as well as the tools and techniques for data collection and analysis, and the measures taken to ensure the reliability and validity of the findings. The methodology will embody a commitment to an iterative process, promoting continuous refinement and adjustment throughout the study.

The following chapter seeks to offer a clear and detailed description of the research design, ensuring that the methodology of the study is thorough, systematic, and aligned with the foundational principles of design thinking elucidated in this review.

Chapter Three

Research Design and Methodology

Dealing with the endeavor to create a solid tool for evaluating design thinking capabilities, this chapter carefully details the research design and methodology used to develop such a scale. The central research question driving this methodological journey is: What are the constituent items of a valid and reliable scale that can measure design thinking capabilities? and how can this scale be methodologically developed. To address this question, this research crafted a multi-phase research strategy that integrates both qualitative and quantitative approaches to scale development, ensuring meticulous attention to validity and reliability.

The subsequent question that underpins the empirical facet of this study is: In what ways does the case study enhance the comprehension of design thinking in practice, and how to refine the scale based on these insights? To explore this, a case study approach was employed to witness the complex nature of design thinking within a real-world setting and provide a fertile ground for refining the scale against practical benchmarks.

Moreover, it is crucial to close the gap between theoretical constructs and practical utilities. Thus, the question is considered: What are the practical implications of the research findings for the implementation in diverse organizational settings, and how can the scale facilitate this application? The methodology is tailored not only to validate the scale but also to elucidate its practical value in various organizational environments, thereby contributing meaningful insights for practitioners and scholars alike.

3.1 Methodological Framework

In this study, a mixed-methods strategy was employed to create a measurement tool for assessing individual design thinking capabilities. This methodological approach integrates both quantitative and qualitative research methods, capitalizing on the strengths while addressing the limitations. The combination of qualitative research's in-depth exploration allows for a thorough investigation into the complex and layered nature of design thinking. Qualitative methods provide a deep dive into personal experiences and perceptions related to design thinking, offering detailed insights that are beyond the reach of quantitative techniques. On the other hand, quantitative methods are used to transform these rich qualitative insights into quantifiable variables, facilitating the empirical examination of their interrelationships and enhancing the generalizability of the results (Creswell & Creswell, 2017).

The sequential exploratory design was selected, which begins with a qualitative phase followed by a quantitative phase. This design is particularly suitable for developing scales as it allows for the initial creation of potential scale items and dimensions through qualitative methods. These items are subsequently rigorously tested and validated using quantitative techniques. The qualitative phase consists of in-depth interviews aimed at collecting diverse viewpoints on design thinking. In contrast, the quantitative phase utilizes surveys to assess the framework and reliability of the proposed measurement scale (Teddlie & Tashakkori, 2011). This sequential method ensures that the scale is not only empirically robust but also deeply rooted in practical relevance.

3.2 Research Design

Phase 1: Qualitative study

The initial stage of this research comprises a qualitative inquiry aimed at gaining a deeper understanding of design thinking and its various aspects. This stage is crucial for creating a comprehensive set of scale items that accurately capture the complexities and subtleties of an individual's capabilities in design thinking.

Semi-structured interviews were conducted with 12 participants. The decision to include this group of participants was based on the need for a rich and diverse set of qualitative insights while maintaining manageability in data collection and analysis. Considering the qualitative focus of semi-structured interviews, this sample size facilitates a thorough examination of participants' experiences and viewpoints while maintaining manageability in the research process. It is sufficient to identify recurring themes and variations while ensuring that each interview can be conducted and analyzed thoroughly.

Participants were recruited through professional networks and design-related forums. Initial outreach was conducted via email, targeting individuals who had expressed an interest in design thinking. Additionally, invitations were shared within relevant online communities and at industry events, ensuring a broad reach to potential participants.

This approach facilitated the recruitment of individuals with substantial experience in the design field who met the study's criteria.

Ethical considerations played a crucial role throughout the research process. Prior to the interviews, informed consent was secured from all participants, ensuring they were fully aware of the study's objectives and their rights. To protect confidentiality, all data was anonymized, and interview transcripts were securely stored. Participants were informed that their input would be utilized exclusively for research purposes and that they had the right to withdraw from the study at any point without facing any negative consequences.

During the interviews, participants were encouraged to discuss their experiences and insights, exploring their understanding of design thinking processes and capabilities. They also discussed the importance of evaluating design thinking skills, considering their impact on both academic and professional settings.

To comprehensively capture the insights of the interviewees, their responses were carefully recorded. This approach provided a detailed dataset for further in-depth analysis. The interviews were conducted either in the participants' offices or via video conferencing platform Zoom, chosen to ensure a familiar, comfortable, and undisturbed setting. The location's confidentiality and privacy were taken into account to encourage open sharing of sensitive or detailed information without disturbances from external sources. Topics and questions for the interviews were sent to the participants via email a week before the interview to help them prepare and feel at ease and confident during

the conversation. The interviews were designed to last about 15 minutes, a duration chosen to balance the need for detailed content with the time constraints of busy professionals and academics. The insights gleaned from these interviews are expected to contribute significantly to the nuanced understanding of design thinking, aiding the subsequent phases of scale development and validation in this study.

Phase 2: Scale development

Building on the foundational insights from the initial qualitative analysis, Phase II of this research signifies a crucial shift toward the empirical aspects of scale development. This phase aims to convert the in-depth qualitative data and extensive insights from the literature review into a measurable, quantifiable scale for assessing design thinking capabilities. This phase bridges the theoretical and practical realms, transforming the conceptual framework derived from the accumulated knowledge of industry experts and academic scholars into concrete scale items. The goal is to encapsulate the core elements of design thinking in a manner that not only endures rigorous empirical testing but also reflects the complex realities faced by professionals in the field.

Extensive research was done to gather a wide range of self-report questionnaires that are closely linked to the main topic of this study. The goal was to grasp what these questionnaires assess, what specific questions they ask, and how people are supposed to answer them. To make this scale inclusive for individuals from various backgrounds, the questions were carefully crafted to be relevant to everyday situations. The questions were crafted using straightforward and accessible language to ensure that participants

could easily comprehend them, which in turn improves the accuracy and reliability of their answers.

In the context of design thinking, empathy plays a crucial role, distinctly different from sympathy, which, while related, fulfills a different purpose in interpersonal interactions (Eisenberg & Strayer, 1987). Empathy in design thinking goes beyond mere cognitive understanding to encompass an affective response, fostering a deeper connection with the user's experiences. This deeper understanding is crucial when creating test questions to evaluate design thinking skills; the questions should focus on this empathetic connection rather than just identifying someone else's feelings.

The design thinking approach highlights the significance of observing and listening closely to users, using methods that accurately pinpoint user requirements. While sympathy can aid in understanding the user, it is not a central competency in design thinking and thus is not a primary focus of this study's assessments. For developing empathy-related test items, the Toronto Empathy Questionnaire (TEQ) (Spreng et al., 2009) was referenced. From this tool, four questions were carefully selected to align with the design thinking skill of "observing and listening to the user":

1. *When someone else is feeling excited, I tend to feel excited too.*
2. *I can discern when others are sad, even if they do not verbalize it.*
3. *I am sensitive to and aware of other people's moods.*
4. *The sight of someone in distress elicits in me a strong desire to assist them.*

Additionally, to assess the capability of "employing appropriate methods to study user needs", three further questions were formulated:

5. I make a concerted effort to listen actively to others' concerns, emotions, and experiences, refraining from interruption or judgment.

6. I remain open to adapting my perspectives in the face of differing views to better address end-user needs.

7. I value users' feedback and experiences as highly as quantitative data analysis in shaping the final product.

These questions are intended to measure the respondents' empathy and their application of user-centric methods effectively, two competencies that are vital in design thinking. The inclusion of these specific items in the test is predicated on their ability to reflect the depth and breadth of design thinking as it is applied in real-world scenarios.

Problem framing and definition

This part aims to test the capacity to identify and define the core problem or challenge that needs to be addressed. Reference was made to the widely recognized and extensively cited Problem Solving Inventory (PSI) developed by Heppner in 1998. The focus of capability of problem framing and definition in the design thinking process is

not to come up with a quick solution, but to put the focus on meeting the real needs of the users. Based on the previous analysis, problem framing and definition capabilities are tested through user-centric focus; reframing the problem, and a deep understanding of the problem context.

User-centric focus:

8. When solving a problem, I often engage in user research and empathy-building activities to gain deep insights into their challenges and aspirations.

9. When solving a problem, I collaborate with users or stakeholders to co-create problem statements and ensure alignment with their needs.

Reframing the problem:

10. When solving a problem, I try to rethink the current understanding to develop a deeper insight into it.

11. I prefer to list all required conditions based on my understanding before solving problems.

12. When I have a problem, I think of as many possible ways to handle it as I can until I can't come up with any more ideas. (Heppner, 1998)

A deep understanding of the problem context:

13. I prefer to define each problem carefully before trying to solve it.

14. I'm skilled at identifying the root causes of problems rather than addressing the symptoms.

Ideation and creativity

When considering assessments of creativity, the prevailing focus is predominantly directed towards the aspect of originality. However, an important distinction arises in the context of design thinking, as it necessitates more than just originality. Within the design thinking process, creativity can stem from specific information rather than relying solely on a lofty, abstract creative capacity. Given that design thinking serves as a problem-solving approach, the creative ability within this framework extends beyond the original design. Under the characteristics of design thinking, the capabilities required for this section are listed below:

Exclusively related to creativity. In formulating the questions for this particular section, the researcher drew upon a diverse range of references encompassing several creative capability tests (Creative Behavior Inventory, Hoceva, 1979; Biographical Inventory of Creative Behaviors, Batey, 2007; California Psychological Inventory, Gough, 1987). Through meticulous analysis, the questions featured in these tests were systematically categorized based on their relevance to assessing an individual's creative capacity. This approach facilitated the development of a comprehensive framework for question design, ensuring that the assessment covered a wide spectrum of creative abilities: writing or drawing, organizing or forming, designing or creating, filming or programming. 4 questions were designed to address these four areas: The test is mainly

for originality: writing and drawing, cooking and crafting, singing and dancing, programming, organizing activities, forming clubs, etc. This questionnaire uses a self-assess scale using 1-7 to measure from “strongly disagree” to “strongly agree”, To maintain consistency in the form of the questions, the questions were designed as:

15. I enjoy exploring new ideas and perspectives and actively seek out opportunities to learn or engage with unfamiliar concepts.

16. I often find myself coming up with unique solutions to problems and frequently I challenge traditional approaches and think outside the box.

17. I feel comfortable expressing my creativity and often engage in creative activities such as writing, drawing, designing, creating, filming, programming, cooking, crafting, etc.

18. I believe in my ability to generate original ideas and I trust my intuition and take risks in expressing my creativity.

Prioritize user feedback or preliminary research to identify relevant “pain points” before engaging in creative endeavors, questions designed with this principle in mind include:

19. When faced with a complex problem, I tend to allocate time to developing a strategy to collect information that would help define the nature of the problem.

20. When solving a problem, I prefer to consult someone with similar experience and adjust based on the advice as opposed to following a plan to the letter.

21. I am open to feedback and suggestions from others by seeking input from different sources to broaden my thinking and incorporate diverse perspectives.

Fostering divergent thinking, divergent thinking is essential for creativity (Silvia et al., 2008) researchers, therefore, referred to the divergent thinking test and found a topic suitable for use in self-assessment in the context of everyday situations, for example:

22. I am comfortable with brainstorming and generating a large quantity of ideas to expand my creative possibilities.

23. I am comfortable thinking about something new, different from what already exists.

24. I enjoy exploring multiple possibilities and generating a wide range of ideas.

Prototyping and interaction

In response to the fact that a mature questionnaire for prototype and interaction has not yet been developed, the researcher combined the description of the prototype stage of design thinking in the literature review section with Jensen's (2015) and Yang's (2005) viewpoints to conclude that the prototype stage is the process of transforming ideas derived from the ideation & creativity stage into testable ideas based on certain criteria when an individual is using the When design thinking approach to problem solving, the prototype stage is the process of transforming the ideas derived from the ideation &

creativity stage into a process that can be tested to refine the ideas based on certain criteria. The questions in this section address the following areas:

The habit of using prototypes: The test subject has the habit of using prototypes before doing something. The question design is as:

25. When faced with a tough problem, I prefer to simulate real-life scenarios in my head, testing and validating ideas before finalizing a solution.

26. I enjoy experimenting with different materials and tools to bring ideas to life.

27. I can quickly translate ideas into tangible prototypes.

28. I often engage in rapid prototyping techniques to explore and validate different design concepts.

Attitude of iteration: The test subject is flexible and good at learning from mistakes. “Prototyping is learning.” (Yang, 2005) An important factor in prototyping is the perception that an individual gains during the problem solving process. Prototyping and interaction can lead to other problems that could not have been considered before. For example,

29. I am comfortable with embracing failure and using it as an opportunity for learning and improvement.

30. I am open to making changes and iterating on my prototypes based on user feedback to enhance user experiences.

31. I'm open to pushing the boundaries of traditional solutions and experimenting with innovative concepts.

Understanding of user-centered principles: The core of design thinking is understanding the user's needs, so it is still an important part of this stage. For example,

32. I often seek feedback from others (users or stakeholders) to gather insights for improvement.

33. I enjoy exploring alternative solutions and refining my prototypes based on user feedback and new insights.

3.3 Population and Sample

The target population for validating the Design Thinking capability scale consists of university students. This demographic is selected for several compelling reasons:

1. Educational Background: University students, by their academic involvement, are likely to possess the cognitive skills necessary to comprehend and reflect upon the questions posed in the scale. Their

educational experience equips them with the analytical capabilities required to provide informed and discerning responses.

2. Relevance to Design Thinking Training: As future professionals who may incorporate design thinking into their careers, students' feedback on the scale can provide valuable insights into the educational needs and gaps in current design thinking curricula. This aligns with the study's objective to offer educational recommendations for future design thinking training programs.

3. Homogeneity in Age Group: Concentrating on a more homogeneous age group helps control for generational differences in the understanding and application of design thinking concepts, which could otherwise introduce variability that would confound the analysis of the scale’s validity.

4. Accessibility: University students are readily accessible for research purposes, often willing to participate in studies for academic credit or personal interest, which facilitates the recruitment process and helps in achieving the desired sample size within a reasonable timeframe.

5. Potential for Longitudinal Research: Engaging with this demographic opens the possibility for longitudinal studies, where changes in design thinking

capabilities can be tracked over time as students progress through their education and into their professional lives.

3.4 Sample Size and Technique

3.4.1 Sample Size Justification

In scale validation research, the sample size is a critical factor that influences the strength and stability of the factor analysis results. While there are various guidelines for determining the ideal sample size for such analyses, practical constraints such as time, resources, and participant availability often dictate the feasible sample size. For this study, a total of 281 university students participated, yielding a final analyzable dataset of 268 responses after accounting for incomplete or unusable submissions. The sample of 268, therefore, provides a sufficient basis for conducting robust psychometric evaluations, including exploratory factor analysis, given the scale's presumed clarity and relevance to the student population.

3.4.2 Reflection on the Sampling Process

Although the achieved sample size of 268 is considered adequate for the analyses planned in this study, it is important to reflect on the limitations of the sampling technique used. Convenience sampling can introduce bias, as the sample may not be perfectly representative of the broader student population or

other groups that might benefit from design thinking training. Nonetheless, the insights gained from this sample provide valuable initial data on the scale's psychometric properties and its potential utility in educational settings.

In the future, to strengthen the generalizability of the findings, researchers might consider using probability sampling techniques as part of the scale validation effort. Future studies could focus on replicating the validation procedure using larger and more varied samples to further substantiate the scale's reliability and validity in various settings.

3.4.3 Ethical Considerations

Ethical considerations take priority in research activities, particularly when involving human subjects. The study was based on the following ethical principles and procedures to protect the rights and welfare of the participants:

Informed Consent: First, participants received a detailed information sheet explaining the study's purpose, their role, the duration of the survey, and any potential risks. Participation was entirely voluntary, and participants were assured they could withdraw at any time without any repercussions or the necessity to explain their decision. Consent was obtained from all individuals before the survey, confirming their informed willingness to take part.

Anonymity and Confidentiality: To ensure the privacy of participants, responses were collected anonymously without recording any personally identifiable information. Data were securely stored and access was restricted to the research team only. The reporting of results is managed in a manner that individual responses cannot be linked to specific participants.

Data Protection: In compliance with data protection standards stringent measures were adopted in handling participant data. Data were encrypted and maintained on secure servers. Information about data access, retention duration, and usage in research was communicated to participants.

Risk Minimization: The design of the study aimed to reduce any potential risks to participants. The questions posed were non-intrusive and avoided sensitive personal topics. Additionally, the survey was structured to avoid placing undue time demands on participants.

Ethical Approval: Ethical clearance for this study was granted by the Hong Kong Polytechnic University Ethics Committee (Application No.: HSEARS20211019007), ensuring compliance with the institution's ethical standards prior to commencing data collection. Any modifications to the study were also subject to review and approval by the committee.

3.5 Case study

Besides individuals with different professional backgrounds, this research aims to test if DTCS could be applied in measuring individuals without formal design education who can nonetheless possess and effectively apply design thinking competencies. Thus, the researchers conducted a case study to verify the hypothesis.

This case study aims to explore the presence and application of design thinking competencies among staff members of a senior activity center in Shenzhen, China, who have no formal training in design disciplines. The center was selected due to its recognized excellence in activity design and its expansion supported by the Shenzhen government. The selected senior center has garnered multiple awards for its innovative activity designs and has recently expanded its operations. This expansion is partly due to increased funding from the Shenzhen government, reflecting the center's significant impact on the local community. The concept of "smart aging" has become increasingly relevant as economic development, improvements in living standards, and advancements in healthcare contribute to a growing elderly population. This demographic shift has heightened the demand for specialized social activities, positioning centers like the one in Shenzhen as crucial community resources.

The team involved in this study consists of 10 members, which has different rankings to ensure smooth operation and management of the center's activities. Two managers work as the decision makers overseeing the development and supervision of the center's entire range of activities. Four middle-level staff work as project leaders whose

responsibilities are multifaceted including encompassing on-site maintenance, overseeing project operations, and managing financial aspects. Four operational staff play an important role in the direct execution of the project, including organizing event platforms, procuring event supplies, and ensuring events run smoothly. This structured team allocation allows efficient management and execution of center activities, ensuring that each staff's skills are appropriately leveraged to enhance the overall functionality and impact of the center's programs.

Field visit and observation was conducted in the first stage to gather information relevant to this research. Afterward, in-depth interviews and structured surveys were conducted to capture detailed insights into the management team's working methods of planning and executing activities for elderlies. The interview serves as a foundational element of qualitative research, facilitating a dynamic and adaptable conversation where staff members have the opportunity to thoroughly explore and share their experiences, cognitive strategies, and decision-making approaches (Rubin & Rubin, 2011). This approach proved especially useful for revealing the unspoken knowledge and inherent design thinking abilities utilized by the staff, despite their lack of formal training in design methods. These techniques were deliberately selected to examine the natural use of design thinking concepts among individuals without formal design education. This strategy matches the goals of the research to identify hidden design thinking skills in groups not trained in design, offering a basis for comprehending how these skills are applied in real-world professional environments.

3.6 In Summary

This chapter provides a structured overview of the research design and methodology employed in this study. The inquiry is rooted in a quantitative framework, employing a survey as the primary instrument for data collection. The focal point of the study is the assessment of a novel educational scale, with data derived from a carefully selected sample of university students. Commenced with a clear delineation of the research questions, it sets a targeted direction for the investigation. A decision driven by the research context sampling strategy is employed and provides a comprehensive rationale for the sample size determination, incorporating a discussion on the potential impact of the sampling method on the study's external validity. Emphasizing the importance of ethical considerations, this section details the protocols established to protect participants' rights, secure informed consent, and uphold data confidentiality in accordance with established ethical standards. It has delivered a detailed and methodical account of the research design and methodology, ensuring a transparent and replicable framework that supports the credibility of the subsequent findings. The methodologies implemented are robust and thoughtfully chosen to address the research objectives, promising to contribute new and meaningful insights to the domain of educational measurement and evaluation.

Chapter Four

Data Analysis and Results

This chapter provides a comprehensive analysis of the empirical data collected during the research study, with a particular focus on the Design Thinking Capability Scale (DTCS). The primary objectives of this analysis are twofold: first, to statistically validate the scale's measurement accuracy, and second, to evaluate its effectiveness among a diverse group of respondents.

The findings from expert interviews underscore the critical importance of the DTCS in both theory and practice. The structured interview questions were designed to explore several key dimensions, including the understanding of design thinking capabilities, the necessity of the scale, its measurement validity, feasibility of application, and recommendations for its further development. Through this multifaceted approach, the chapter aims to illuminate the role of the DTCS in enhancing design thinking practices and to provide actionable insights for future research and application.

In this study, an expert interview was conducted to gether the insights of from professionals with extensive experience in the design field and a total of 12 experts were recruited. The selection of these individuals was based on their strong academic backgrounds and extensive experience in design-related fields, ensuring a profound understanding of the subject matter. Specifically, the cohort comprised 8 scholars who specialize in design research and have publications related to design thinking, alongside 4 fashion designers boasting over 15 years

of practical experience in the industry. This diverse mix of expertise, encompassing both academic and practical perspectives, enriches the research findings and enhances the overall validity of the study. The experts were primarily sourced from Mainland China and Hong Kong, reflecting a geographical diversity that adds depth to the analysis.

Due to the ongoing pandemic, the interviews were conducted using a hybrid format. 7 interviews took place via Zoom, allowing for flexibility and safety, while 5 were conducted face-to-face in the experts' offices, providing a more personal interaction. Each interview lasted approximately 15 minutes, enabling focused discussions on key topics. Ethical considerations were a top priority in this study, with consent secured from all participants regarding their participation and the utilization of their data. To foster open and honest discourse (Kruger et al., 2018) about their understanding of design thinking, the experts were informed that their information would not be confidential, thereby encouraging candid responses.

Aspect	**Details**
Number of Experts	12
Diversity of Background	• 8 university scholars specializing in design, each with published research on design thinking. • 4 fashion designers with over fifteen years of industry experience. • Originate from Mainland China or Hong Kong.
Interview Format	• 7 interviews conducted via Zoom due to the pandemic. • 5 interviews conducted face-to-face in the experts' offices.
Duration of Interviews	Approximately 15 minutes each.
Consent and Ethics	Consent was obtained from all experts for participation and data use.

Table 4-1 Expert interview overview

Part	Interview questions	Verbal statement	Interviewee code
1	Understanding of design thinking	➢ Design thinking is a user-centric methodology aimed at solving complex problems through multiple capabilities.	➢ Ex1,Ex2,Ex3,Ex4,Ex5,Ex6,Ex7,Ex8,Ex9Ex10,Ex11,Ex12
		➢ Design thinking is not just a set of tools but a mindset that emphasizes a deep understanding of users' needs and continuous refinement of solutions based on user feedback.	➢ Ex1,Ex2,Ex5,Ex6,Ex7,Ex9,Ex11, Ex12
		➢ The application of design thinking varies across different projects, with experts citing its use in product development to organizational strategy and innovation processes.	➢ Ex1,Ex2,Ex3,Ex4,Ex5,Ex6,Ex7,Ex8,Ex9,Ex10,Ex11,Ex12
2	Measurement of design thinking	➢ There is a noted gap in tools specifically designed to measure design thinking abilities directly.	➢ Ex1,Ex2,Ex4,Ex5,Ex6,Ex7,Ex8,Ex10,Ex11,Ex12
		➢ Existing tools and methodologies focus more on facilitating the design thinking process than assessing individual capabilities.	➢ Ex2,Ex4,Ex5, Ex7,Ex8,Ex11,Ex12
		➢ The challenges in creating a standardized measurement scale including the subjective nature of creative skills and the dynamic, context-specific applications of design thinking.	➢ Ex1,Ex2,Ex4,Ex5,Ex7,Ex8,Ex10,Ex11,Ex12
3	Application of the scale	➢ In educational settings, it could guide curriculum development, assess student progress, and enhance teaching methodologies.	➢ Ex1,Ex2,Ex5,Ex7,Ex8,Ex11,Ex12
		➢ In professional realms, it could be used for personnel development, improving team composition, and strategic hiring decisions.	➢ Ex1,Ex2,Ex4,Ex5,Ex7,Ex10,Ex11
		➢ The scale is seen as beneficial for systematically fostering and evaluating key design thinking skills, thereby enhancing both learning outcomes and professional efficacy in various industries.	➢ Ex1,Ex2,Ex4,Ex5,Ex7,Ex8,Ex10,Ex11,Ex12
4	Final thoughts	➢ The development of a design thinking scale involves continuous feedback from both educational and professional sectors to maintain relevance and practicality.	➢ Ex1,Ex2,Ex5,Ex7,Ex8,Ex10, Ex11,Ex12
		➢ It should be an approach that blends both qualitative insights and rigorous quantitative methods to ensure the scale's reliability and validity.	➢ Ex1,Ex2,Ex4,Ex5,Ex6,Ex7,Ex8,Ex10,Ex11,Ex12
		➢ The scale should evolve in response to new developments in the field of design thinking.	➢ Ex1,Ex2,Ex4,Ex5,Ex6,Ex8,Ex10,Ex11,Ex12

Table 4-2 Expert interview result analysis

All interviewed experts stressed the importance of creating a scale to evaluate design thinking capabilities, pointing out substantial shortcomings in the existing theoretical research on this topic. The outcomes consistently indicated a need for more robust methods to assess individual skills in design thinking, highlighting a gap in the current methodology research.

The pilot study was instrumental in the preliminary evaluation of the DTCS, focusing on its reliability and construct validity. It facilitated the refinement of the scale's items by providing essential data, enhancing clarity for participants, and laying the groundwork for the statistical assessment of the tool. Subsequently, the application of the improved DTCS to a wider demographic is explored, shedding light on the scale's durability and its consistent ability to measure design thinking capabilities across different groups of respondents. A comparative analysis also examines how scores vary with participants' educational and professional

backgrounds. The chapter will integrate these insights to assess the overall results of the DTCS, presenting a detailed perspective within the education.

4.1 Pilot Test Result Analysis

The initial stage of this study involved a pilot test aimed at refining the DTCS and confirming the validity of its components. The purpose of the test was to assess the clarity of the survey questions, the simplicity of the data collection process, and the initial reliability of the scale. A sample of 30 individuals, representative of the target population for the main study, participated. These participants completed the DTCS, which comprised 33 items designed to evaluate various aspects of design thinking capabilities. They responded to each item on a 7-point Likert-type scale, ranging from “strongly agree” to “strongly disagree”. This scale choice was primarily influenced by the subjective nature of the cognitive elements being measured, which are optimally examined through self-assessment (Batra & Vohra, 2016). The use of a Likert-type scale allowed participants to precisely express their agreement or disagreement with the presented statements, thereby facilitating the collection of insightful data regarding their perceptions and experiences of their design thinking skills. After finishing the scale, participants were encouraged to offer feedback about their experience, including the clarity of the instructions and the questions.

The data from the pilot test were then analyzed for item-level reliability, employing Cronbach's alpha coefficient to determine internal consistency. Cronbach's alpha is calculated from the correlations among scores from different items on a questionnaire,

helping to ascertain whether various sections consistently measure the same concept. A Cronbach's alpha value of 0.7 or higher generally indicates good internal consistency, reflecting a stable structure and similarity among the items measured.

The analysis indicated that the DTCS scored a Cronbach's alpha of 0.894, positioning it within the optimal range of (0.8 to 0.9). This score demonstrates excellent internal consistency, aligning with established guidelines for assessment reliability.

Cronbach's alpha	N of items
0.894	33

Table 4-3 Pilot Cronbach's alpha reliability coefficient for the overall items

Additionally, item-total correlations were inspected to identify any items that did not correlate well with the overall scale. Upon the completion of the pilot survey, the responses were analyzed using SPSS to evaluate the internal consistency of the items. Cronbach's alpha coefficient was calculated to assess the reliability, while the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity were employed to determine the suitability of the data for factor analysis. The Kaiser-Meyer-Olkin (KMO) measure primarily assesses the partial correlation among variables. When its value approaches 1, it suggests a strong correlation between the variables. On the other hand, Bartlett's test of sphericity is used to determine whether the correlation matrix is an identity matrix. This test's statistic follows a chi-square distribution, and if the test does not reject the null hypothesis (i.e. if the p-value is greater than 0.05), it implies that the data may not be suitable for factor analysis. Therefore, a questionnaire is considered to

have good structural validity only if the KMO measure is greater than 0.5 and the significance p-value of Bartlett's test chi-square statistic is less than 0.05.

The KMO measure yielded a value of 0.869, surpassing the commonly recommended threshold of 0.6, and suggesting that the sample was adequate for factor analysis. Furthermore, Bartlett's test of sphericity resulted in a chi-square value of 154.678 with 78 degrees of freedom, reaching a significance level of 0.000, which strongly rejects the null hypothesis that the variables are uncorrelated in the factor analysis.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.869
Bartlett Test	Approx. Chi-Square	154.678
	df	78
	Sig.	.000

Table 4-4 Pilot test results of the overall validity of the scale questions

Given the high Cronbach's alpha, no items were removed due to poor internal consistency. However, based on the detailed item analysis and respondent feedback, minor refinements were made to enhance the clarity and readability of certain questions. These adjustments were aimed at eliminating any potential ambiguity and improving the participant experience in the main study.

The pilot test of the DTCS was essential in confirming the scale's reliability and ensuring that participants could comprehend and interact with the questions effectively. The robust Cronbach's alpha and KMO values, coupled with the significant results from Bartlett's test,

provide a solid basis for the upcoming formal assessment. The modifications implemented in the DTCS after the pilot test have prepared the groundwork for a more dependable and valid evaluation of design thinking capabilities in the expanded sample.

4.2 Formal Test Result Analysis

The primary testing phase was implemented to authenticate the effectiveness of the Design Thinking Capability Scale (DTCS) with a wider array of participants, following enhancements from the initial pilot study. This testing phase sought to solidify the scale's reliability and accuracy in measuring design thinking skills among a varied group of individuals. The participant group included individuals aged between 18 and 35 years, all of whom had achieved a minimum of a university degree and came from various academic fields. These participants were recruited from universities throughout Hong Kong and Mainland China. The administration and retrieval of the survey were conducted through WeChat and Email, leveraging two popular online platforms: wenjuan.com and Google Forms.

To ensure comprehensibility and precision in responses, the survey was presented in both Chinese and English, allowing participants to choose their preferred language. This bilingual strategy was intended to cater to the diverse linguistic needs of the participants, thereby improving the clarity of the survey items and the dependability of the data collected.

Participants were asked to indicate their level of agreement with each survey item using a 7-point Likert scale, which ranged from "strongly agree" to "strongly disagree." This scale was selected to accurately capture the nuanced opinions of the respondents. Additionally, all survey questions underwent rigorous testing for reliability and validity during the earlier pilot phase. Therefore, for this formal phase, the DTCS, consisting of 33 questions, was utilized. A total of 281 responses were collected in this phase. Following a meticulous review to weed out incomplete or inaccurate responses, 268 valid responses were analyzed. The inclusion of participants from a broad age range and diverse educational backgrounds, along with the option for language-specific surveys, was intended to ensure that the results could be generalized across a young adult demographic in an educational setting. The strategy of using dual platforms for survey distribution was designed to optimize participation rates and accessibility, thus bolstering the reliability and validity of the ensuing data.

4.2.1 Reliability Assessment

The consistency of the DTCS was measured through Cronbach's alpha, a tool used to evaluate the internal harmony of the scale. The alpha coefficient achieved was 0.892, demonstrating a robust level of internal consistency. These findings align with those from the initial pilot study, indicating that the DTCS items consistently and effectively measure a unified underlying construct.

Cronbach's alpha	N of items
0.892	33

Table 4-5 Formal Cronbach's alpha reliability statistics for the overall items

4.2.2 Validity Assessment:

The Kaiser-Meyer-Olkin (KMO) statistic was utilized to assess the adequacy of the sample for conducting factor analysis. The KMO value reached was 0.821, which significantly exceeds the acceptable minimum of 0.6, signifying that the sample size is appropriate for the analysis. This high KMO value implies that the correlation patterns among variables are sufficiently dense, suggesting that the factor analysis is likely to identify clear and reliable factors.

Furthermore, Bartlett's test of sphericity was performed to evaluate whether the data set was fit for factor analysis by testing the assumption that the observed variables interrelate and that the correlation matrix is not an identity matrix. The test yielded a chi-square value of 2573.462 with 528 degrees of freedom, and the result was highly significant ($p < 0.000$), well below the standard threshold of 0.05. This significant outcome verifies that there is an adequate correlation among the variables for performing factor analysis, thereby supporting the reliability and validity of the questionnaire.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.821
Bartlett Test	Approx. Chi-Square	2573.462
	df	528
	Sig.	.000

Table 4-6 KMO and Bartlett test results of the overall validity of the scale questions

4.2.3 Factor Analysis:

Following the confirmation of the data's suitability for factor analysis, an exploratory factor analysis was conducted to identify the underlying structure of the DTCS. The results of the factor analysis, including factor loadings and the total variance explained, will be provided in this section, along with any necessary rotations that were performed to achieve a clear factor structure.

The formal test results provide robust evidence for the internal consistency and construct validity of the DTCS. The high Cronbach's alpha value reaffirms the scale's reliability, while the KMO measure and significant Bartlett's test reinforce the validity of the factor analysis performed on the data. These findings support the DTCS as a credible and reliable tool for measuring design thinking capabilities, indicating that it is well-suited for use in larger and more diverse populations. The factor analysis has the potential to uncover the dimensionality of the scale, which can be discussed in detail in the subsequent sections of the chapter.

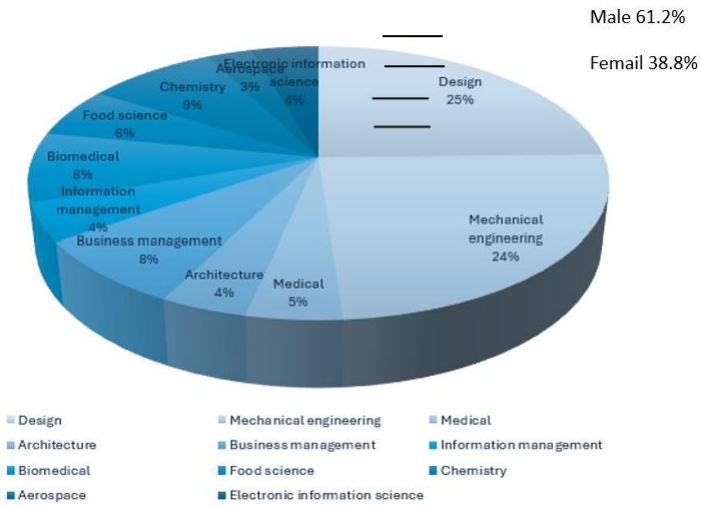


Figure 4-1 Demographics of formal test participants

The study surveyed a total of 268 participants, with a gender distribution of 164 males (61.2%) and 104 females (38.8%). This distribution confirms that all responses were considered valid, as the valid percentage aligns with the computed percentage, and the cumulative percentage reached 100% after accounting for both genders. The data indicates a male majority, but there was also substantial female representation, reflecting gender diversity within the participant pool.

Academically, the participants were predominantly from the Design and Mechanical engineering programs, which accounted for 24.6% and 24.3% of the respondents, respectively. These programs were closely followed by students majoring in Chemistry, Biochemistry, and Management. The significant representation of Mechanical engineering and Design majors suggests a strong presence of these disciplines, but the inclusion of majors such

as Chemistry, Biochemistry, and Management indicates a broader academic diversity.

This wide range of majors demonstrates that the participants came mainly from fields related to management, engineering, and design. However, the presence of students from almost every conceivable academic category underscores the diversity of the respondents and enriches the potential applicability and relevance of the study's findings across different academic disciplines. This diversity is particularly valuable in exploring the interdisciplinary applications of design thinking capabilities.

There were a total of 268 participants, of which 164 were male (61.2% of the total) and 104 were female (38.8%). The valid response rate matched the overall response rate, confirming that all submissions were deemed valid. The cumulative percentage of responses rose from 61.2% for male participants to 100% when including female participants. This indicates that although males formed the majority of the survey participants, a substantial proportion of females also contributed. Understanding the distribution of genders can be instrumental in examining potential differences in design thinking skills across genders.

This study specifically examined the development and application of design thinking skills by comparing students from Design and Mechanical Engineering disciplines. The rationale for selecting these particular fields lies in their

fundamentally different educational approaches and their distinct methods of engaging with problem-solving and creativity. Various studies, such as those by Cross (2004), Dym et al. (2005), Atman et al. (2007), and Crismond & Adams (2012), have investigated the cognitive and problem-solving variations between design and engineering disciplines, underscoring the value of such comparative analysis. These comparisons aim to refine educational strategies and enhance interdisciplinary skills vital for addressing complex problems today.

In terms of educational focus, design education generally prioritizes creativity, empathy towards users, and iterative prototyping—all key aspects of design thinking. In contrast, Mechanical Engineering typically emphasizes quantitative analysis and a systematic approach to applying engineering principles. With Design and Mechanical Engineering students representing 24.6% and 24.3% of the participants respectively, such a comparison not only sheds light on potential differences in design thinking abilities across these disciplines but also offers insights into how curricular emphases may shape these abilities. Thus, analyzing how educational paths affect the development and application of design thinking skills in various academic and professional contexts can provide valuable insights.

By examining the descriptive statistics related to the questionnaire scores, we gain detailed insights into two major areas: "Design Scores" and "Engineering Scores." These metrics offer an overview of how participants fared in assessments related to their respective fields.

For Design Scores, a total of 66 questionnaires were completed validly, with scores ranging from 146 to 209. The mean score was 189.82, and the standard deviation was 15.86. This high average indicates that most participants demonstrated strong performance in the assessment of design-related knowledge and skills. The relatively small standard deviation indicates a concentrated distribution of scores, implying that while some participants scored slightly lower or higher, the majority clustered around the mean.

Engineering Scores: There were 65 valid responses for engineering, with scores varying from 126 to 206. The average score was 173.94, with a standard deviation of 16.81. Compared to the design scores, the average for engineering was somewhat lower, which may indicate a generally lower performance in this domain. The higher standard deviation suggests greater variability in engineering knowledge or skills among participants, indicating a more dispersed score distribution.

Description	N	Minimum	Maximum	Mean	Standard Deviation
Design Score	66	146.00	209.00	189.82	15.86
Engineering Score	65	126.00	206.00	173.94	16.81

Table 4-7 Descriptive analysis of questionnaire scores

				Mean equivalence t-test						
									Difference 95% confidence interval	
		F	Significance	t	Degree of freedom	Sig. (two-tailed)	Mean difference	Standard error difference	Lower limit	Upper limit
Score	Assumed equal variance	.008	.0328	.0458	129	.0411	1.87972	2.85473	3.76844	7.52788
	Not assuming equal variance			.0458	128.300	.4512	1.87972	2.85602	3.77127	7.53071

Table 4-8 Levine's test of variance equivalence

To delve further into the statistical significance of this difference, an independent sample test was carried out. The results of Levene's test for equality of variances (F=0.008, significance=0.0328) advised caution in assuming variance equality in further analyses. Despite this, the t-test for equality of means (t=0.0458, degrees of freedom=129) indicated that the mean score difference between the groups (Sig. two-tailed=0.0411) was statistically significant, solidly demonstrating better performance by the design group.

The significance of this analysis extends beyond statistical importance; it potentially impacts educational and professional development strategies. Particularly, the findings highlight the value of design thinking and skills in today's professional environment, which may prompt education policymakers and curriculum designers to place greater emphasis on education and training in the design field. It also provides a rationale for engineering students and practitioners to develop design-related skills to enhance their professional competencies.

Moreover, the 95% confidence interval for the mean difference (from 3.76844 to 7.52788) further establishes the superiority of the design group over the engineering group, providing a quantified reference for educational and industry practices. Future research could investigate the specific reasons behind this difference and explore how to foster the complementarity and integration of skills across disciplinary backgrounds, thus promoting innovation and development in individuals and organizations. This research underscores the importance of interdisciplinary skills and innovative thinking in the rapidly changing global market and technological landscape, offering professionals across various fields the motivation to understand and develop these skills more deeply.

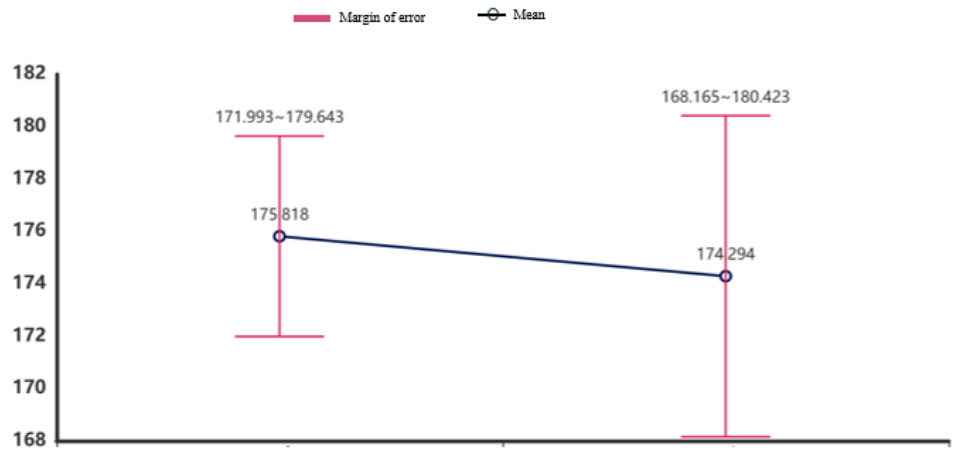


Figure 4-2 Error bar chart

In the comparative study, performance differences on specific assessments were analyzed between individuals from two distinct professional backgrounds—design and engineering. The analysis utilized data from two groups: a cohort of 66 participants from a design program, who recorded a mean score of 189.8182 with a standard deviation of 15.85503, and a cohort of 65 engineering majors, who achieved a mean

score of 173.9385 with a standard deviation of 16.81134. This preliminary comparison demonstrated that the design program participants significantly outperformed their engineering counterparts on the assessment. The higher mean score among the design students suggests that educational background in design may enhance certain capabilities that positively influence performance on this dimension of the assessment, highlighting a notable divergence in skill sets cultivated by the two different academic programs.

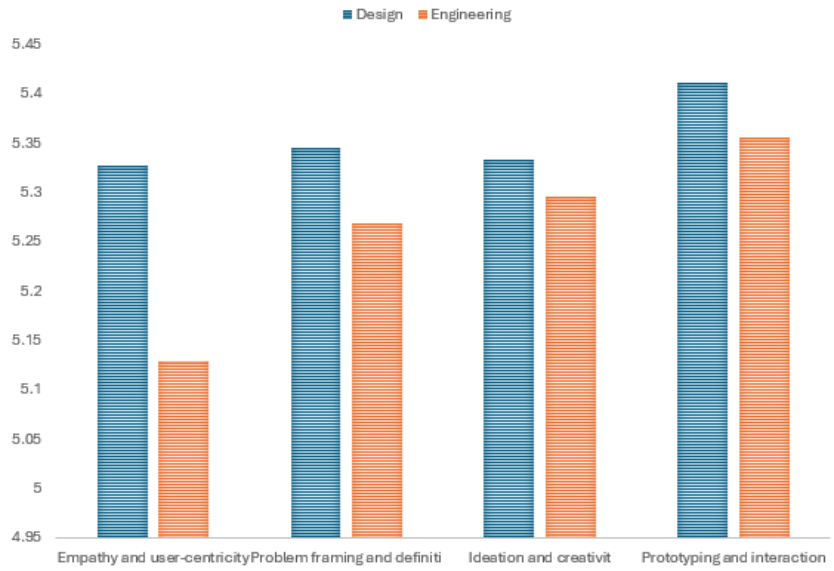


Figure 4-3 Comparative analysis of test results between design and engineering students

The comparative analysis of test results between design and engineering students indicated a modest but notable advantage in Empathy scores among the design students. This subtle difference suggests that design students possess a slightly enhanced competence in Empathy and User-Centricity part of the DTCS, likely reflecting the emphasis on human-centered principles and empathetic engagement within their educational curriculum. While not a dramatic disparity, this advantage highlights the

influence of targeted educational practices in cultivating specific emotional and cognitive skills, distinguishing design students from their engineering counterparts in their ability to understand and relate to users' perspectives and needs.

In summary, the descriptive statistics provided not only reflect the performance levels of participants in the areas specific to design and engineering but also illuminate notable differences between these domains. The differences in average scores suggest that participants might exhibit greater proficiency or knowledge in the design area relative to engineering. Additionally, the variation in standard deviations indicates a disparity in the consistency of performance across these disciplines, with engineering showing more variability in participant outcomes. These findings are instrumental in understanding how knowledge and skills are distributed across different fields and could be vital for evaluating the impact of educational or training initiatives designed for these sectors.

4.3 Case Study

The primary objective of this study is to develop a robust scale for measuring individuals' design thinking capabilities while elucidating the contextual factors that influence these abilities. Through a comprehensive series of reliability and validity assessments, the Design Thinking Capability Scale (DTCS) has been established as a reliable instrument for evaluating the varying degrees of design thinking strengths among individuals. This chapter focuses on a critical investigation into whether individuals lacking formal design training or relevant educational backgrounds possess inherent design thinking capabilities and can effectively leverage these methodologies

for problem-solving. To explore this hypothesis, an elderly center has been chosen as the focal point for observation and analysis.

The decision to select the elderly center is based on the recognition that its activity design processes closely align with the core principles of design thinking. These processes prioritize empathy, user engagement, and iterative development—essential components for successful design thinking practices. By analyzing how staff members at the center design and implement activities tailored to the unique needs and preferences of elderly residents, this study aims to illuminate the manifestation of design thinking in real-world contexts, particularly among individuals who may not have had access to formal design education.

Furthermore, the elderly center serves a distinct demographic that often requires careful consideration of diverse needs, making it an ideal setting for examining the application of design thinking principles. The complexity involved in crafting engaging, accessible, and meaningful activities for older adults provides a rich context for assessing the presence of design thinking capabilities. This case study not only seeks to validate the DTCS developed in earlier chapters but also aspires to deepen the understanding of how design thinking can be effectively applied across various fields and by individuals from diverse backgrounds. The case study was meticulously structured into several distinct phases, each designed to gather comprehensive data from different perspectives and sources. By exploring these dynamics, this research contributes to ensure a thorough exploration of design thinking capability among the staff at the senior activity center

and the broader discourse on the accessibility and adaptability of design thinking methodologies in diverse contexts.

4.3.1 Phase 1: Field visits

The preliminary exploration method involved onsite visits to directly observe the environment and daily activities at the senior activity center. By immersing themselves in this environment, researchers were able to gain a comprehensive understanding of the work context of the center's staff. This approach not only allowed researchers to observe the specific situations faced by employees in their actual work but also provided important insights into their operational challenges and opportunities (Yin, 2014). Through this field observation, researchers could capture subtle interactions and behavioral patterns that are often difficult to obtain through traditional interviews. Furthermore, the data collected from these observations laid a solid foundation for the subsequent interviews and evaluations, enabling a deeper investigation into the staff's design thinking capabilities and their practical application in the workplace.

Following the field observations, the research incorporated interviews to gather more in-depth qualitative data. Interviews provided an opportunity to explore how ideas are generated among the staff, allowing researchers to delve into their thought processes, motivations, and experiences in implementing design thinking principles. During these interviews, staff members were encouraged to share their perspectives on the challenges they encounter in their roles, as well

as the strategies they employ to overcome these obstacles. This conversational approach not only facilitated a deeper understanding of the context in which design thinking is applied but also illuminated the nuances of team dynamics and collaborative problem-solving.

The interviews were semi-structured, allowing for flexibility in responses while ensuring that key topics related to design thinking were addressed (Irvine et al., 2013). This format enabled participants to elaborate on specific instances where design thinking methodologies influenced their work, thus revealing the practical applications of these concepts in the elderly center's activities.

By triangulating the data obtained from both field observations and interviews, the research gained a comprehensive understanding of the staff's design thinking capabilities. This dual approach enriched the findings, offering a holistic view of how ideas are generated and transformed into actionable solutions that effectively meet the needs of the elderly population. Ultimately, this combination of methods enhanced the validity of the study and contributed to a more nuanced analysis of design thinking in practice.

During the visit, it was observed that the elderly center operates robustly, remaining open six days a week, from 8 a.m. to 6 p.m. This schedule reflects the center’s commitment to providing consistent support and engagement for its residents. The center has thoughtfully developed a diverse range of activities tailored to meet the needs of two primary segments of the elderly population:

those with mobility issues and those in good physical condition who seek social interaction and skill development. To address the varied needs of these groups, the center has organized its services into three main categories: support services, recreational serices, developmental services.

Support Services: These services are carefully crafted to assist seniors who need daytime assistance in the absence of their caregivers. They include providing nutritious meals and supervision to ensure the seniors' fundamental daily needs are addressed in a caring environment.

Recreational Services: Centered on health and mobility, this category includes services like physical therapy and general healthcare, which are essential for sustaining or improving the seniors' physical health and, consequently, their overall quality of life.

Developmental Services: This vibrant category offers a variety of modern educational courses designed to match the interests and abilities of the elderly. The center also hosts social functions such as birthday celebrations and cultural events. These activities are crucial for cognitive stimulation and emotional health, promoting community bonding and addressing social and emotional needs.

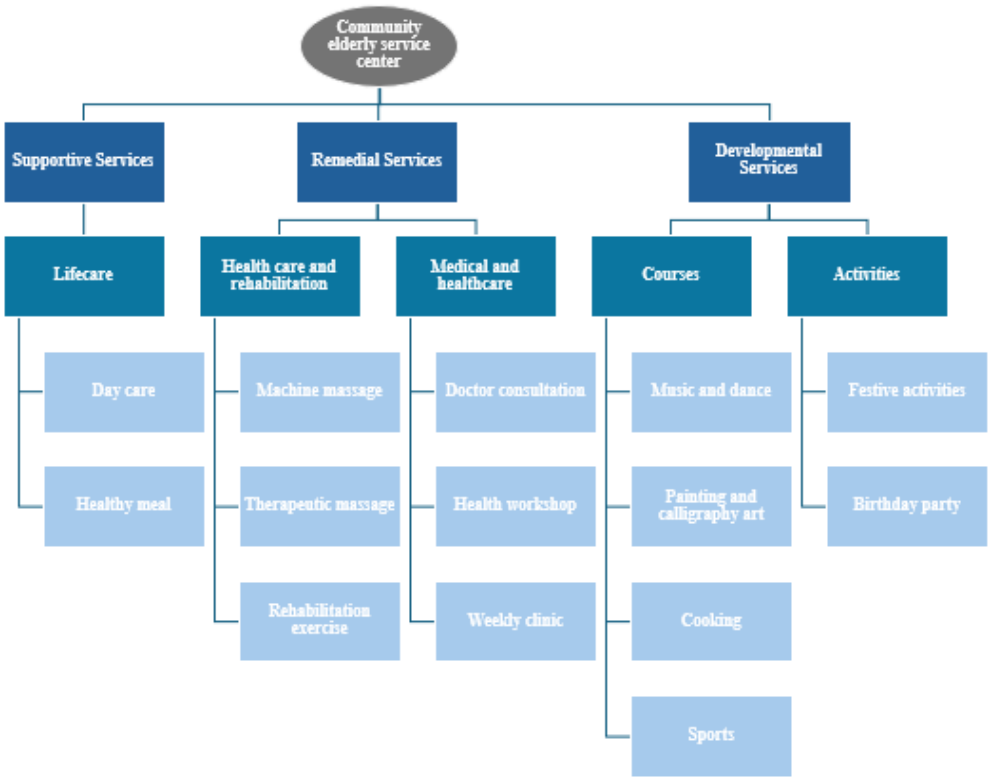


Figure 4-4 Elderly-centered design services provide by Dongxiao elderly service center

Each category of service is meticulously tailored to meet the specific physical and mental health needs of the seniors while fostering a dynamic, supportive community atmosphere. The center's strategic service layout reflects its commitment to inclusivity and comprehensive care, significantly enhancing the well-being of its participants. These offerings distinguish this elderly activity center from more traditional models, highlighting its unique approach to senior care.

4.3.2 Phase 2: User interviews

To assess the effectiveness and impact of the center's initiatives, our research team carried out in-depth interviews with senior attendees who frequently participate in the center's activities. These interviews were carefully planned to collect extensive feedback from the participants, focusing on factors like user satisfaction, engagement frequency with the center's services, and any recommendations for enhancements. These structured interviews played a crucial role in pinpointing the needs and satisfaction levels of the users, thus serving as a measure of the overall success of the programs developed by the staff. Notably, this feedback mechanism is essential for grasping the empathetic and user-focused aspects of design thinking, which are vital for ensuring that the services truly align with the users' needs and expectations (Kouprie & Visser, 2009).

Figure 4-5 Photos of activities of Dongxiao elderly service center

The interview process was conducted over a comprehensive six-day period, aligning with the six-day cycle of activities offered by the elderly service center. This approach allowed for the collection of more comprehensive feedback from participants regarding their experiences and opinions on the programs provided. Focusing on gathering insights from elderly individuals who participate in

activities offered by the center more than twice a week. A total of 32 participants were involved, with an age range of 60 to 82 years, comprising 14 males and 18 females.

The interviewing method employed face-to-face interactions, ensuring a more intimate and engaging environment for participants (Muthanna, 2019; Irvine et al., 2013). Each session lasted approximately five minutes, allowing for the efficient collection of meaningful data while respecting the comfort and time constraints of the elderly respondents.

The feedback received was predominantly positive, indicating a high level of satisfaction and active engagement with the center's programs. This enthusiastic response underscores the effectiveness of the center's strategies in catering to the diverse needs of its elderly users. Furthermore, it highlights the critical importance of integrating user feedback into the program development cycle to enhance service delivery and improve overall user experiences.

4.3.3 Phase 3: Interviews with senior center managers and staff

To deepen the understanding of the operational strategies and planning methods used by the center's managers and staff, the research of this study employed a mix of reconstructed and semi-structured interviews (Gubrium & Holstein, 2001; Irvine et al., 2013). There are total of ten staff members working at this center, and all of them participanted in the interviews. The interview questions

were tailored to delve into the staff's techniques for planning and managing events, with a particular focus on their intuitive use of design thinking principles like iteration, prototyping, and process refinement within their daily operations.

Throughout these conversations, the researchers carefully examined how the center's managers structure and detail the content and framework of the activity plans. This examination showed that their planning methods are closely aligned with well-recognized design thinking models, focusing on user-centricity, ongoing refinement, and quick prototyping. This congruence indicates that, even in the absence of formal training in design methodologies, the staff effectively integrates these crucial elements into their planning activities through an implicit yet efficient adoption of design thinking practices.

The insights derived from these interviews not only demonstrated the staff's proficiency in embedding design thinking into their event planning but also highlighted the effectiveness of their strategies in crafting engaging and impactful experiences for the center's attendees. This method ensures that the activities are not only well-organized and carried out but are also continuously modified to better suit the changing needs and preferences of the participants, thus boosting overall engagement and satisfaction.

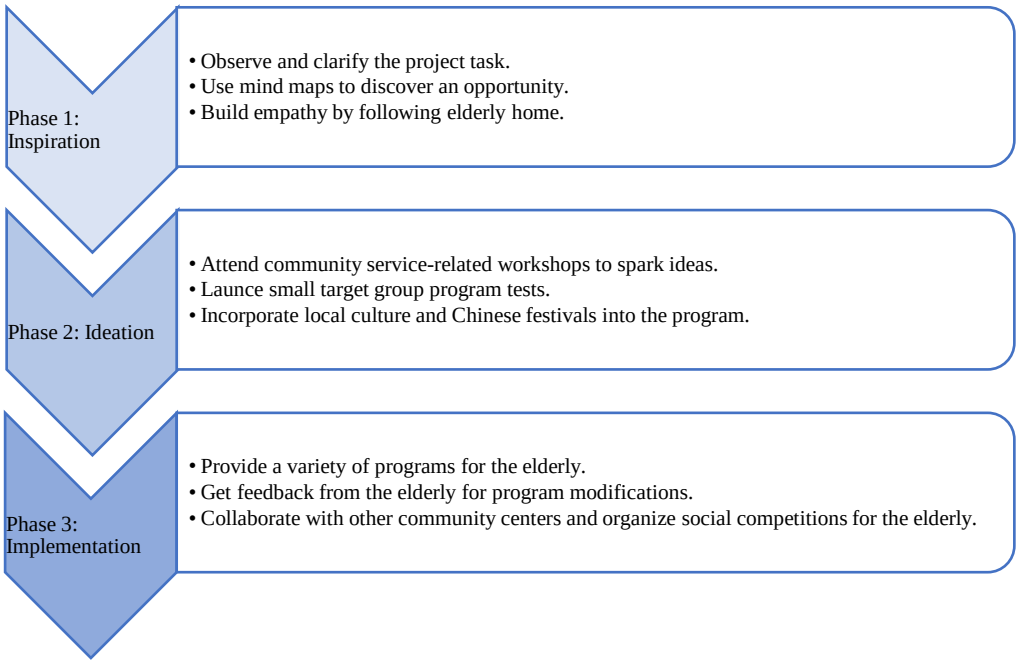


Figure 4-6 Design thinking concept application in elderly service design

4.3.4 Data analysis

To more formally assess the capabilities of the staff in employing design thinking principles, the design thinking capability scale (DTCS) was used to generate quantifiable data that could be analyzed alongside the qualitative insights gathered from the interviews, providing a comprehensive view of the employees' skills and approaches.

The center's team consists of ten staff members, divided into distinct roles that ensure smooth operation and management of the center's activities. At the helm are two managers acting as decision makers in the team tasked with overseeing the development and supervision of the center's entire range of activities. Beneath them, four middle-level staff members function as project leaders. Their responsibilities are multifaceted, encompassing on-site maintenance,

overseeing project operations, and managing financial aspects. Additionally, four operational staff members play an important role in the direct execution of projects. Their duties include organizing event platforms, procuring necessary event supplies, and ensuring that each event runs smoothly. This structured team hierarchy allows for efficient management and execution of center activities, ensuring that each staff member's skills are appropriately leveraged to enhance the overall functionality and impact of the center's programs.

	N	Minimum	Maximum	Mean	Standard Deviation
Decision maker	2	5.52	6.48	6.0000	.68568
Middle-level staff	4	4.27	5.55	4.8636	.55020
Operational staff	4	2.12	5.88	4.4242	1.61110

Table 4-9 DTCS results of Dongxiao’s team members

According to the self-assessment data of these 10 subjects, decision makers achieved a relatively high mean score of 6.0000 with a standard deviation of 0.68568. This indicates strong performance, albeit from a small sample size of 2 members, which typically results in a broader range of scores (5.52 to 6.48). The high average score suggests that decision makers are likely proficient in aspects such as problem framing and definition, and ideation and creativity. Their role requires them to oversee and direct significant organizational changes and innovations, necessitating strong capabilities in these areas. However, the range in scores might indicate varying levels of empathy and user-centricity,

suggesting some decision makers may excel more in strategic oversight than in user-focused design processes.

Middle managers, with a group size of 4, displayed a narrower range of scores (4.27 to 5.55) and a mean of 4.8636 with a standard deviation of 0.55020. This suggests more consistency in their performance compared to the other groups. The consistency in scores among middle managers indicates a reliable level of proficiency across the four aspects of the DTCS, particularly in problem framing and ideation. Their role often bridges strategic directives from decision makers and operational execution, requiring a balanced skill set that ensures they can effectively translate high-level concepts into actionable plans. However, the lower average score relative to decision makers suggests there might be room for enhancement, particularly in fostering deeper empathy and user-centricity.

Operational staff members showed the highest variability in scores, ranging from 2.12 to 5.88, with an average of 4.4242 and a significant standard deviation of 1.61110. This indicates substantial differences in individual performance levels. The wide range of scores among operational staff suggests diverse capabilities and potential gaps in design thinking skills. Given their direct interaction with the end-users or products, high proficiency in empathy and user-centricity would be expected; however, the variability suggests that while some staff excel, others might struggle. This diversity highlights a need for

targeted training in prototyping and interaction, ensuring that all operational staff can effectively test and iterate on solutions in real-time environments.

The performance disparities and consistencies observed across the different organizational levels underscore the varying strengths and developmental needs in design thinking capabilities within the organization. The insights derived from this analysis are critical for tailoring development programs that address specific gaps and leverage strengths in design thinking across the organization. The differences in performance and consistency seen at various levels within the organization emphasize the diverse strengths and areas for improvement in design thinking skills. Understanding these findings is essential for creating tailored development programs that address specific weaknesses and build on strengths in design thinking throughout the organization. This strategic approach will not only improve individual and team skills but also promote a more innovative, responsive, and user-focused organizational culture.

These figures not only show the performance variations among different levels of the organization but also reveal the differing levels of consistency within each group. This analysis is important for identifying areas where targeted training or development efforts may be necessary to enhance overall performance and minimize disparities within the workforce.

The data uncovers several key findings. Firstly, decision-makers have the highest average scores in the assessments, indicating a superior level of

expertise or knowledge in the areas being evaluated. This high level of proficiency may be due to their extensive experience and higher-level roles. This analysis is crucial for identifying areas where targeted training or development interventions might be needed to enhance overall performance and reduce discrepancies within the workforce.

These data reveal several key insights. First, decision-makers possess the highest average scores in the assessments, indicating that they exhibit a higher level of proficiency or expertise in the areas being assessed.This high proficiency could be attributed to their extensive experience and higher-level responsibilities.

Second, the performance of middle-level staff, while lower on average than that of decision-makers, exhibits greater consistency. This reflects a more uniform distribution of skills and experience within this group, indicating that middle-level staff may have a more balanced skill set that is crucial for their operational roles.

The score range and larger standard deviation among operational employees highlight significant performance differences within this level. This variability may stem from the diverse nature of tasks assigned to operational employees and the wide range of skills required for their roles. Such disparities suggest a heterogeneous group with varying degrees of expertise and training needs.

In general, these statistics that describe performance not only show differences in how well people at different levels of management do on a test, but also highlight how consistent or varied each group is. For companies, it's important to understand these differences and patterns in order to create better training programs. For instance, given the large performance disparities among operational employees, the organization might consider implementing more personalized and diversified training programs to elevate the overall competency level. Such programs could focus on bridging skill gaps and enhancing job readiness. This hierarchical analysis provides crucial insights that enable more precise identification of development needs across different employee levels within the organization. By strategically addressing these needs, the organization can not only enhance individual performance but also boost overall organizational effectiveness.

4.3.5 In Summary

This scenario offers a fascinating glimpse into “implicit design thinking”, where individuals instinctively employ design thinking principles effectively without formal education or explicit awareness of these methodologies. This phenomenon suggests that design thinking capabilities can naturally develop through experiential learning, transcending the conventional boundaries that confine it to formally trained designers. The case study serves as a testament to the adaptability and universality of design thinking processes, demonstrating

their relevance and applicability across diverse sectors and professional backgrounds.

The insights from this study challenge the prevailing notion that design thinking is an exclusive skill set reserved for professionally trained designers. Instead, they suggest a much broader applicability, extending into various fields such as social services for the aging population. These findings provoke a need for further research to explore the mechanisms through which these competencies are informally acquired and to assess their impact on organizational performance and innovation. Such research could significantly broaden our understanding of how non-traditional sectors can harness the power of design thinking to enhance their service delivery and problem-solving capabilities.

The case study conducted at the senior activity center in Shenzhen provides compelling evidence of the natural integration of design thinking principles in environments not traditionally associated with design. It underscores the notion that design thinking is not just a methodological approach confined to problem-solving in design disciplines but is a versatile, universally applicable strategy that can drive innovation and improvement across all sectors. This realization reinforces the value of design thinking as a transformative tool that can cross the traditional boundaries of education and training, making it accessible and beneficial to a wider audience.

Chapter Five

Conclusions and Discussion

Due to the rapidly growing global industries and educational systems, innovative and effective problem-solving has received attention. Design thinking, characterized by its user-centric approach, collaborative processes, and iterative problem-solving techniques, has emerged as a methodology to meet these challenges. This approach not only encourages creativity but also innovation adaptable to various challenges across all sectors. Recognizing the critical role design thinking plays, there arises a significant need to measure and enhance these competencies systematically.

The attention to design thinking that began in the 1990s has intensified over the decades. Initially, the focus was on refining design thinking methodologies and theoretical frameworks. Then attention has shifted towards understanding and developing the capabilities of individuals. This approach not only encourages creativity but also innovation adaptable to various challenges across all sectors. There arises a significant need to measure and enhance these competencies systematically in recognizing the critical role design thinking plays. Despite numerous success stories attributed to the design thinking approach, the comprehension of its mindset remains relatively nascent. Key questions persist: What characteristics define a person who excels in design thinking? What factors influence an individual's ability to think like a designer? To date, answers to these questions remain not conclusively defined.

In order to tackle the current challenges in developing design thinking skills effectively, the Design Thinking Capability Scale (DTCS) was created. This new tool represents a significant step forward in the field by quantitatively assessing design thinking abilities, giving educators, managers, and leaders a reliable way to evaluate and improve these skills in their teams and organizations. The DTCS is designed not only for integration into educational curricula and professional development programs but also to facilitate individual growth. By incorporating this scale, it becomes feasible to monitor progress, pinpoint areas needing enhancement, and customize training methods to meet the distinct requirements of learners or employees.

The creation of the DTCS fills an important need by connecting the theory behind design thinking with how it can be used in different real-life situations. Additionally, the DTCS provides useful information to people, helping them fully grasp their design thinking abilities. This self-awareness enables individuals to pursue targeted self-improvement strategies, focusing on specific areas where they can enhance their design thinking skills. Consequently, the DTCS not only serves organizational goals but also supports personal development, guiding individuals on a path to becoming more effective innovators and problem-solvers. This dual functionality enhances the DTCS's utility, making it an essential tool in the arsenal of those seeking to foster a robust culture of innovation and creativity.

The primary objective of this study is to offer a comprehensive examination of the development, validation, and outcomes associated with the Design Thinking Capability Scale (DTCS) across a variety of demographic and situational contexts. This research aims to verify the reliability and validity of the scale to affirm its efficacy for measuring design thinking capability. Furthermore, this study discussed the broader implications of the DTCS, emphasizing its

potential to foster a deeper comprehension of design thinking as a critical competency in the 21st century.

Through testing the DTCS in various settings and with different groups of people, this research aims to investigate how well it can adapt and work in different situations. This includes looking at how it functions in different cultures, within different types of organizations, and among individuals with varying educational backgrounds. This examination not only checks how strong the DTCS is but also helps us understand better how design thinking skills can be developed and evaluated on a global scale.

Additionally, the DTCS sparks new ideas and approaches in design thinking research. It doesn't just give researchers a good starting point for studying the details of design thinking skills but also provides practical tools for further research in this exciting field. For individuals, the DTCS offers a reliable way to assess themselves and focus on improving their design thinking skills. This is especially useful for professionals who want to enhance their problem-solving and innovation abilities in a structured way. From an organizational point of view, the DTCS gives valuable insights that can guide decisions about hiring and team formation. This could ensure that people with the right design thinking skills are in roles where they can contribute effectively to innovation and solve creative problems.

5.1 Interpretation of Findings

The Design Thinking Capability Scale (DTCS) demonstrated high reliability and validity, indicating its effectiveness in measuring design thinking capabilities across different contexts. The development of this scale used a mixed-methods strategy. By blending qualitative insights with quantitative analysis, to ensure a comprehensive framework. In the first stage of the research, interviews were conducted with practitioners from the design-related industry and academics specializing in design theory. To refine the direction and formulate pertinent research questions. Their perspectives on the crucial capabilities required for design thinkers were instrumental in guiding the subsequent phases of research.

The second stage was a thorough literature review to identify the six most frequently cited models in design thinking. An in-depth examination of the process employed in these models revealed that they were developed through meticulous observation, analysis, and summarization of successful applications of design thinking. It became apparent that while these models were consistent in their core methodologies, they adapted the focus to suit specific application scenarios.

This structured analysis not only validated the relevance and applicability of the identified models but also highlighted the universal themes inherent in successful design thinking practices. By synthesizing these elements into the development of the Design Thinking Capability Scale (DTCS), the study aimed to create a tool that

effectively measures the essential capabilities that underpin this sophisticated process across various contexts.

In the comparative analysis of these models, it was observed that despite variations in terminology and the sequence of steps, they could be condensed into four essential stages critical to the design thinking process: Empathy and user-centricity; Problem framing and definition; Ideation and creativity; Prototyping and interaction.

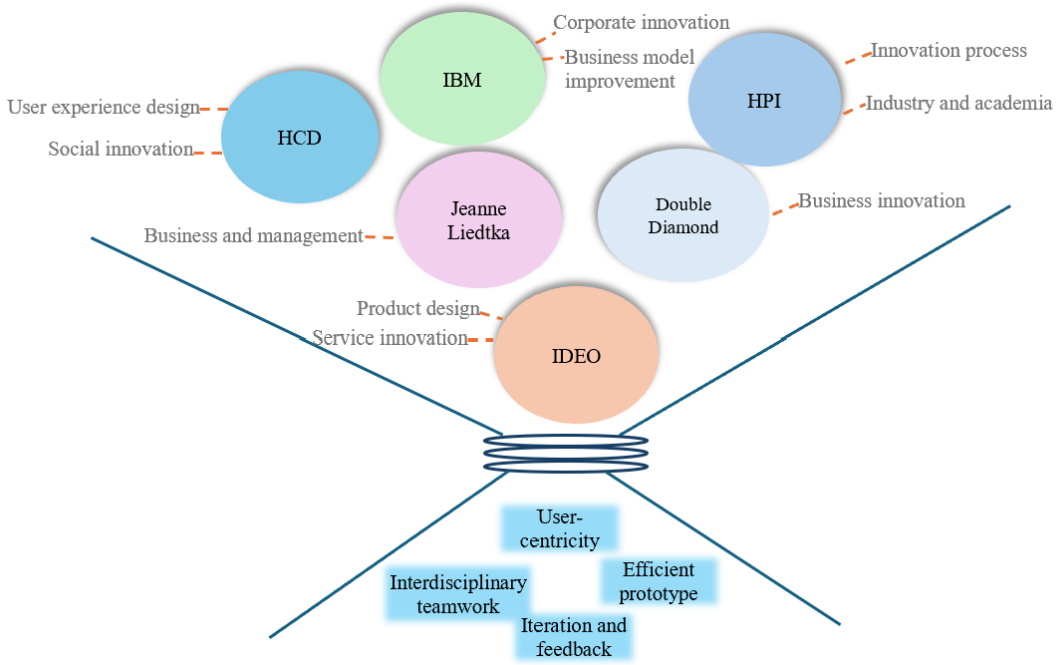


Figure 5-1 Design thinking capability key elements generated from design thinking models

After establishing the framework for the Design Thinking Capability Scale (DTCS), craft the questions for the scale. This was conducted by careful consideration of existing instruments that have demonstrated efficacy in related domains. Particularly the Toronto Empathy Questionnaire (TEQ) by Spreng et al. (2009), which evaluates emotional empathy, the Problem Solving Inventory (PSI) created by Heppner in 1998, which measures an individual's perceived problem-solving skills, and the Biographical Inventory of Creative Behaviors compiled by Batey in 2007, which aims to quantify creative activities and accomplishments. Given these established questionnaires, a comprehensive DTCS (comprising 33 items) was developed.

Then it was a priority to define the experimental objectives and select an appropriate demographic for testing. Given the significant impact of participants' reading comprehension abilities and educational background on the accuracy of their responses, the test group was carefully chosen. The study focused on university students between the ages of 18 and 35 who held at least a bachelor's degree. This choice was based on the assumption that students from this educational background have the necessary cognitive and linguistic skills to understand and accurately answer the DTCS, thus ensuring the reliability of the data collected. This demographic orientation is critical to gathering meaningful insights and achieving the research goal of validating the DTCS in a controlled environment.

The initial phase of testing was a pilot group experiment. This pilot study convened 30 participants, all of whom had similar educational and demographic backgrounds to maintain consistency in the baseline data. After administering the DTCS to this group,

reliability and validity assessments were conducted. The results of the assessment indicated that the questionnaire was highly reliable and valid for subsequent experiments.

Further, the study was extended to a larger and more diverse sample to further test the applicability of the scale in a wider population. A total of 268 valid responses were collected in the second phase of testing. After another rigorous assessment of the reliability and validity of the DTCS, the results showed that the scale continued to perform well, maintaining high scores on both assessments.

These findings are important because they demonstrate the ability of the DTCS to accurately measure an individual's design thinking ability. The consistency of the results across groups confirms that the DTCS can reliably capture and reflect individuals' true design thinking abilities, which makes it important both for subsequent experimental studies and in terms of enhancing individuals' understanding of design thinking abilities.

The participant population in this study was diverse in terms of professional backgrounds, with a larger portion coming from the design and engineering fields, accounting for half of the total number of participants. This demographic distribution is of interest to researchers, particularly because many studies have highlighted the clear differences in cognitive styles between design and engineering students.

Given this context, a comparative analysis of DTCS scores between students majoring in design and those in engineering was conducted. The results of this comparison revealed that design students generally achieved higher scores on the DTCS, particularly in the domains of 'Empathy and User-Centricity' and 'Prototyping and Interaction.' This discrepancy suggests that the curriculum and pedagogical approaches in design education, which often emphasize user-centered design principles and hands-on prototyping activities, may better prepare students for excelling in these areas of the DTCS.

This finding emphasizes the impact of educational frameworks and teaching methods on the development of design thinking skills. From the test results, it is clear that engineering curriculum design could incorporate more elements of design thinking. In particular, elements that facilitate the promotion of empathy and focus on user needs. Thus, students are better equipped with balanced skills suitable for interdisciplinary and innovative environments.

To explore whether individuals without a formal design-related background exhibit differences in design thinking capabilities, and to understand the factors influencing these differences, this study conducted a focused case study with the management service team of a nursing home institution. The team was selected because their innovative approach to event design was closely aligned with the needs of the target audience and reflected design thinking elements in the execution.

The fieldwork employed a variety of methods to ensure a comprehensive analysis. These included: on-site observations, in-depth interviews with team members, interviews with center users, and a detailed assessment of team members in the design thinking test. A notable finding of this study was that team members' scores were directly related to their role in the organization. Specifically, decision makers on the team scored significantly higher than other members.

Several factors may have contributed to this difference. First, differences in background and experience between decision makers and business people may affect their design thinking skills. In addition, people with strong design thinking skills seem to be more likely to be in leadership positions in their teams. This observation suggests that design thinking skills are not only a beneficial trait but may also be a key factor in career advancement in certain situations. Thus, developing design thinking skills at all levels of an organization may not only improve individual performance but also influence organizational dynamics and leadership.

5.2 Theoretical and Practical Implications

The results of this study make an important contribution to existing research on design thinking. It confirms that design thinking skills transcend traditional subject areas and can be systematically developed and assessed across a wide range of fields. This study broadens the theoretical framework of design thinking and advocates its relevance and adaptability in a variety of educational and professional settings.

The study challenges the traditional scope of application of design thinking by pointing out that these skills are essential for a wide range of careers, not just those traditionally associated with design. The study concludes that design thinking is a versatile tool for improving problem solving and innovation across disciplines. The findings are therefore far-reaching, urging a reassessment of how design thinking can be integrated into curricula and professional development programs, and emphasizing the potential of design thinking as a key competency.

The Design Thinking Competency Scale (DTCS) will be an important tool for assessing and improving design thinking competencies in all walks of life. The scale provides a quantitative measure of an individual's creative problem solving and innovative thinking skills. These competencies are increasingly recognized as critical in today's complex and changing environment. The versatility of the DTCS makes it applicable not only in educational settings, but also in systems such as corporations, non-profit organizations, and government. The following describes scenarios where DTCS may be applicable, demonstrating its use and impact in different environments.

Institutions of Higher Education: The DTCS can be used to assess and improve the design thinking skills of students across disciplines. The scale will measure a baseline of students' design thinking skills to inform curriculum development. Integrate targeted design thinking enhancement programs. These initiatives are designed to reinforce specific competencies for improvement, thereby enriching students' overall educational experience and preparing them to solve complex problems in their future careers.

Corporate Training Programs: Companies will incorporate DTCS into their employee training programs to foster a culture of innovation and creativity. By assessing the design thinking skills of its employees, the company will be able to identify specific training needs and customize its development program to meet those needs. This targeted approach will optimize team composition for project assignments. And it will ensure a balanced skill set on the team, which will enhance collaborative innovation.

Nonprofits: Nonprofits, especially those involved in social innovation and community development, will use DTCS to assess the effectiveness of their training. Measure the design thinking skills of staff and volunteers before and after training sessions. This data will enable them to make informed decisions about future training strategies and effectively optimize their resources.

Government Agencies: In the public sector, DTCS will serve as a tool to improve the problem-solving skills of public servants. For example, a municipality could use DTCS to assess the design thinking skills of its urban planning department, improve the team's ability to interact with citizens and develop more effective, user-centered services and policies. This approach will help bridge the gap between government operations and community needs, thereby improving government effectiveness.

Entrepreneurial Ecosystem: Using DTCS to assess and enhance the design thinking capabilities of entrepreneurial teams. Providing targeted advice, conducting workshops or other measures. This support will significantly improve the chances of success for startups developing innovative products and services.

Research and Development: In a research setting, DTCS will be used to study the impact of design thinking on fostering innovation and creativity in teams. Scholars will use the scale to evaluate how various interventions impact design thinking abilities over time, thereby providing valuable data to contribute to the academic literature on the effectiveness of design thinking training.

The widespread adoption of the DTCS across various sectors underscores its effectiveness and versatility as a tool for enhancing design thinking capabilities. From higher education to corporate training and beyond, the DTCS has proven instrumental in identifying and cultivating the skills needed for innovative and strategic problem-solving. As organizations and institutions continue to recognize the value of design thinking in achieving competitive and innovative outcomes, the DTCS remains a vital resource. It not only supports the development of individual competencies but also contributes to the collective success of teams and organizations, ensuring they are well-equipped to tackle future challenges with agility and creativity. This ongoing integration of the DTCS into diverse training and development frameworks highlights its crucial role in shaping the problem solvers and innovators of tomorrow.

5.3 Conclusions and Discussion

This study has developed a scale (DTCS) to measure individuals' design thinking capabilities, a critical competency in contemporary problem-solving and innovation. The findings indicate that the scale effectively captures the nuanced dimensions of design thinking, providing a valuable tool for both academic research and practical application.

In the context of Industry 5.0, which emphasizes the integration of advanced technologies with human-centric approaches, the importance of design thinking becomes increasingly evident. As industries evolve to prioritize collaboration between humans and intelligent systems, the ability to think creatively and adaptively is paramount. This study contributes to the discourse on how individuals can harness design thinking to navigate complex challenges in rapidly changing environments.

The implications of this research extend beyond the academic realm, suggesting that fostering design thinking capabilities will be essential for organizations aiming to thrive in the era of Industry 5.0. By equipping individuals with the necessary skills to innovate and solve problems effectively, organizations can enhance their competitive advantage and drive sustainable growth.

5.3.1 Limitations

The Design Thinking Capability Scale (DTCS) provides a valuable framework for evaluating and enhancing design thinking skills across various sectors. However, like any assessment tool, it has limitations that users must consider to ensure its effective application and interpretation. Here are some detailed limitations of the DTCS:

1. Subjectivity in responses: The DTCS relies heavily on subjective assessments, either through self-reporting or evaluations conducted by others. This subjectivity can introduce personal biases or social desirability effects, where participants might respond in ways they believe are expected or favorable rather than truthful. This issue can lead to inaccuracies in measuring true capability levels, affecting the reliability and validity of the results.

2. Cultural and contextual variations: Design thinking is influenced by cultural and contextual factors that the DTCS may not adequately account for. Different cultures may have varying interpretations of creativity and problem-solving, which can impact how design thinking skills are demonstrated and assessed. Without careful adaptation, the DTCS might not fully capture the richness and diversity of design thinking practices across different cultural backgrounds.

3. Dynamic skill development: Design thinking skills evolve with experience, training, and the changing dynamics within a project or organization. The DTCS

might not adequately reflect these dynamic changes if used only at specific intervals. Continuous or periodic reassessment is necessary, which can be resource-intensive and challenging to implement systematically.

4. Potential for misuse: If not used carefully, the results from the DTCS can be misused, such as pigeonholing individuals into specific roles based on their assessed capabilities or using results to make high-stakes decisions without considering other factors. This misuse can have negative implications for team dynamics and individual career growth.

By understanding these limitations, individuals, organizations, and educators can better plan how to integrate the DTCS into their practices, ensuring that they mitigate potential drawbacks while leveraging the scale's benefits to enhance design thinking capabilities effectively.

5.3.2 Future research

The Design Thinking Capability Scale (DTCS) has proven to be a valuable tool for assessing and developing design thinking skills in various contexts. There is a rich avenue for future research to explore how individuals without formal design training spontaneously develop and refine design thinking competencies. Investigating the prevalence of such patterns in other sectors and cultural contexts could provide deeper insights into the universal applicability and adaptation of design thinking principles. This research could pave the way for

the development of new methodologies that facilitate the adoption of design thinking strategies in non-conventional fields, potentially revolutionizing standard practices and enhancing outcomes across a variety of industries. Understanding these dynamics could also help in crafting educational and training programs that promote the intrinsic qualities of design thinking, making these skills more accessible and impactful on a global scale.

However, to enhance its effectiveness and applicability, several areas require further research. Addressing these gaps will not only improve the tool itself but also contribute broadly to the field of design thinking in both academic and practical applications. Here are proposed initiatives based on the outlined limitations:

Sample diversity: The primary groups studied—university students and employees at an aging agency—restrict the generalizability of our findings to broader educational backgrounds and professional environments. The study's insights are primarily reflective of the perspectives and experiences of these specific groups. To enhance the applicability of the Design Thinking Capability Scale (DTCS) and to better understand its relevance to diverse groups, future research should aim to include participants from a wider array of disciplines, professional levels, and sectors. This expansion would help to determine whether the observed trends hold across different demographic and professional landscapes.

Cross-sectional design: The cross-sectional design of this study limits our ability to conclude the development and evolution of design thinking capabilities over time. While this approach provides a snapshot of design thinking capabilities at a single point, it does not capture changes or growth that may occur with continued education or professional practice. Longitudinal studies, tracking the same individuals over an extended period, could provide deeper insights into how design thinking capabilities evolve and what factors most significantly influence this development.

Potential bias in self-reporting: The DTCS relies heavily on self-reported data, which can be susceptible to various biases, such as social desirability or response bias. Participants may, consciously or subconsciously, alter their responses to align with perceived expectations. While efforts were made to mitigate these issues through careful questionnaire design and anonymization of responses, the complete elimination of bias is challenging. Future iterations of the study might incorporate more objective measures or triangulate self-reported data with observational data or peer assessments to enhance the reliability of the findings.

Cultural factors: The study was conducted within a specific cultural context, which could influence both the teaching and application of design thinking in educational systems and professional environments. The effectiveness of the DTCS and the interpretation of its results might vary significantly across different cultural contexts. Future studies should consider implementing the

DTCS in varied cultural settings to explore how cultural factors affect design thinking capabilities and the effectiveness of the scale itself.

Small differences in empathy: While the study highlighted a slight advantage in empathy scores among design students, the practical significance of this difference remains to be fully understood. It is essential to investigate whether these small differences translate into measurable impacts on professional outcomes or personal development. Further research could explore the role of empathy in professional success and personal growth within design and engineering fields, potentially guiding curriculum developments to foster these soft skills more effectively.

This thesis not only establishes the DTCS as a reliable tool for measuring design thinking capabilities but also illuminates the impact of educational and professional environments on the development of these essential skills.

Addressing these limitations in future studies will not only strengthen the validity and reliability of the DTCS but also enrich the understanding of design thinking as a multifaceted and dynamic capability. By broadening the scope of research and employing more robust methodologies, researchers can better capture the complexities of design thinking and its impact on innovation and problem-solving across various sectors.

Appendix 1 A comprehensive review of design thinking models

Design Thinking in Process:

A Comprehensive Review of Design Thinking Models

Abstract

Design thinking is the core role in industrial production, business renovation and civil life, contributing greatly to our daily life. Guiding by various process frameworks, to date, many different types of design thinking models have been developed and adopted to diverse kinds of applications. To enable its further perfection, it is therefore necessary to compare and contrast these previous design thinking models to derive the necessary processes for the successful implementation of design thinking and analyze the capabilities that a design thinker should possess. This review conducted a comprehensive analysis of six commonly adopted process models, with intensive comparison among their characteristics, frameworks and practical applications. An in-depth conclusion and perspectives about effective design thinking processes, including understanding, definition, ideation, prototype, testing and realization are also included. Furthermore, key attributes for designers like cognitive capabilities, interpersonal skills and design-specific skills are summarized in detail along with exploring intrinsic relationship between these attributes and design thinking process.

Keywords: Design Thinking Process; Creativity; Capability; User Centered Design

1. Introduction

1.1. Background on design thinking and its significance in various fields

Under continuous globalization and integration of the world economy, human consumption demand is expanding showing trend of diversification and multi-level, which can be reflected in the product market favoring frequent modification, optimization and diversification. The complex requirements of this dynamic change make it urgent for individuals, teams, and companies to compose standard and appropriate operation process. The design of such programs often requires the development of innovative technologies and interdisciplinary cooperation. However, there are two challenges in the design of such a solution. On one hand, such dynamic and complex developments make obtaining insight into exact core needs through conventional analysis challenging. On the other hand, cooperation and technological innovation in interdisciplinary fields also lack the systematic guide.

Design thinking through the dynamic iterative process, from the people-oriented perspective to achieve solutions and innovative design, is promising for overcoming above existing issues. In the business world, design thinking ensures center position for customer during products development process, resulting in favorable acquirement of customer needs and prompt improvements and innovations to existing processes (Levy and Huli, 2019). Design thinking also positively influences education and learning, by encouraging students to think about the construction of a theory-to-practice framework in interdisciplinary collaboration, and education to explore innovation in a more open, ethical way (Chon and Sim, 2019; Beligatamulla et al., 2019). In multiple organizations, employment of design thinking improves user-centered or member-centered plans, review management styles and organizational structures, and build organizational culture in more effective fashion (Elsbach and Stigliani, 2018). In the field of engineering, design thinking contributes to in-depth understanding of user

needs, as well as facilitating cross-domain cooperation in complex system engineering and coordinating members of various roles (Durantin et al., 2017). For example, in the design of sustainable building intelligent system, the combination of design thinking can deconstruct the motivation and specific methods of the whole stage of the design (including discovery, definition, development and delivery), and realize the user-centered scheme design (Tushar *et al.*, 2020).

Design thinking is a comprehensive mode of thinking and methodology that integrates multiple disciplines and competencies, emphasizing innovative approaches to complex problems from the perspective of users (Lee et al., 2020). Advantages of design thinking, like user-centered, empathy-emphasis and collaboration, have been recognized by scholars. However, design thinking itself is so abstract making its directly application complicated. In order to facilitate the guidance of practitioners and realize the concretization of design thinking, different design thinking models have been proposed and optimized. It is usually a structured framework that divides the application of design thinking in actual production along with civil usages into different stages to guide designers and practitioners. The model serves as a roadmap to guide practitioners through the stages of empathy, definition, ideation, prototyping, and testing to create innovative and user-centered solutions (Skibina and Taratukhin, 2022). It is therefore of vital importance to review and understand design thinking models so as to make the best use of them. Meanwhile, as the process of design thinking cannot be carried out without the participation of design thinkers, it is thus also necessary to identify and understand the key competencies that a design thinker should possess to support and drive the design thinking process. Specifically, key skills include but are not limited to cognitive abilities, including empathy, creativity and critical thinking; interpersonal skills (Andersen and Pitkänen, 2019.), including collaboration, communication and empathy; specific skills, including prototyping,

iteration, and visualization. Empathy endows designers with ability to acquire insight into user needs and emotions, creativity motivates designers to come up with novel and unique solutions, critical thinking encourages designers to analyze and evaluate problems, and collaboration and communication skills to promote cooperation and communication among team members. Prototyping and visualization allow designers to quickly convert ideas into practicable form and improve them through iteration (Veflen and Gonera, 2023).

In summary, the design thinking process model provides a systematic approach for guiding and organizing the innovation process, and key capabilities essential for design thinkers functions as indispensable support and assurance for realizing design solutions. To provide a comprehensive analysis to the design thinking models, this article reviews six different design thinking models, compares the stages and characteristics of these models, and analyzes the necessary processes for successful implementation of design thinking. Potential and perspectives of design thinking are also discussed after summarizing skills and abilities that thinkers need to possess in the process of effective design thinking and analyzing relationship between the necessary processes and key elements of research.

2. Comparative analysis of design thinking process models.

2.1 Overview of the prominent design thinking models:

2.1.1 IDEO design thinking process

Founded in 1991 by David Kelley, IDEO is one of the world's leading innovative design consulting companies, which proposes a people-oriented and interdisciplinary approach to innovation and practices it in a variety of business cases (Rau, 2020; Tschimmel, 2012). IDEO's early projects, including development of the first Apple mouse, exemplified their commitment to user-centered design principles. IDEO's design thinking philosophy has been disseminated

through publications, educational programs, and partnerships with a variety of industries (Grönman and Lindfors, 2021).

The core activities of the IDEO model include three parts: (i) Inspiration: the whole design process is started with cognition of the problem, brainstorming for a solution framework following with the observation and analysis of the problem (Waidelich et al., 2018; Filho et al., 2021); (ii) Ideation: after obtaining in-depth recognition of faced challenges, insights and thinking from a diverse and integrated team will be collected to seek creativity and solutions in this collision (Filho et al., 2021); (iii) Implementation: attempts for materializing adopted idea will be conducted by testing, iteration and advancement of design ideas and solutions through the means of prototyping (Kim and Park, 2021).

Mahmoud-Jouini et al. (2019) keenly found that the three-stage design thinking (Inspiration, Ideation and Implementation) based on IDEO revealed inconvenience in the company's practice process, such as cognitive limitations, collision between novel and traditional methods and concepts, and other inevitable contradictions. Therefore, they analyzed successful cases introducing IDEO's design thinking method to a large multi-department organization and summarized five elements aiming to design success. Design thinking in the practice of the company needs to adjust the strategy flexibly based on actual situations and show the influence of limited conditions on design thinking. At the same time, the application of design thinking requires learning and supplementing corresponding methods and skills in the process of development. Scholars founds optimized and enriched the IDEO model. Shapira et al. (2017) used design thinking in the framework of strategic sustainable development (FSSD) to examine the reliability of integrated processes. Firstly, based on IDEO, this paper divides the design thinking process into five stages (including discovery, interpretation, ideation, experimentation,

and evolution). According to the results of the specific structural analysis in FSSD, adequate sustainability preparation in this design thinking process is insufficient. Based on the existing IDEO framework, Glen et al. (2015) analyzed and proposed a design thinking framework for business curriculum education, where six stages are included: (1) problem finding, (2) observation, (3) visualization and sense-making, (4) ideation, (5) prototype and test, and (6) viability testing. Using this framework, the goals, and possible problems that students need to accomplish in each stage along with the feedback and guidance that teachers need to provide are analyzed comprehensively. It is also found that, since the uncertainty and ambiguity of the design process can easily cause academic anxiety and confusion, timely intervention is needed for lectures to form a consensus quickly.

2.1.2 Stanford design thinking process model (HPI d. school)

HPI design thinking model comes from the Hasso Plattner Institute for Design Thinking, a collaboration between Professor Hasso Plattner and the Stanford University School of Design (Wölbling et al., 2012; Muhtaseb and Burqan, 2021; Carlgren et al. 2016; Okai-Mensah et al., 2021; Traifeh et al., 2019). This model also relies on the principles of human-centered design and solves problems in a structured and iterative manner. It encourages designers to revisit and iterate through the stages as needed(Tham J., 2022; Helman, 2024; Bongiovanni and Louis, 2021). This adaptability allows for continuous improvement and ensures that the final solutions are truly responsive to user needs.

The HPI design thinking model typically consists of five key stages (Sakama, 2018): (i) Empathize: designers observe, collect, and understand the perspectives, needs, and challenges of the end users or stakeholders for whom they are solving problems; (ii) Define: synthesize the information to identify a clear core issue statement that will serve as a guiding principle for

subsequent phases; (iii) ideate: this stage encourages the generation of a wide range of creative ideas and potential solutions to the defined problem, where designers employ various brainstorming techniques, such as mind mapping and rapid prototyping, to foster innovation and explore unconventional concepts; (iv) Prototype: in this phase, designers create tangible representations of their ideas, often in the form of prototypes or mock-ups, which then are used to test and refine concepts, allowing for rapid iteration and improvement before the final implementation; (v) Test: the final stage involves gathering feedback on the developed prototypes through user testing and evaluation, where the feedback loop enables designers to assess the effectiveness of their solutions.

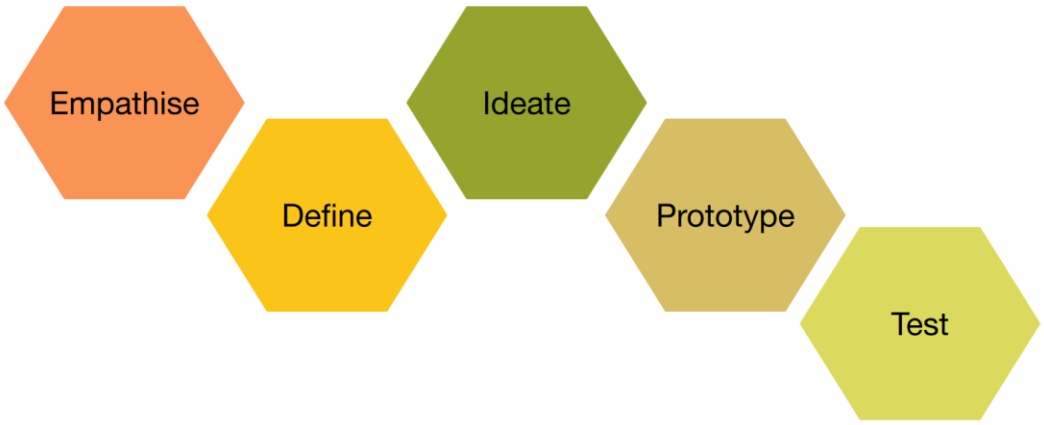


Figure 1 HPI model (Pata et al., 2021)

The HPI design thinking model serves as a comprehensive framework for fostering innovation in various fields. In the field of business, Bertão and Jung et al. (2023) analyzed the training design thinking of human resource development department of LG Company in South Korea. The method used in the training consists of six parts: empathize, define, ideate, prototype, test and assess. Moreover, pre-activities are added before training to provide learning opportunities and practice empathy observations. Pata et al. (2021) examined the ways in which agile and

lean methods are combined with design thinking in engineering. The analysis of this paper is also based on the design thinking model of HPI. The authors focused on the process of exploring information in the stages of empathize, definite, and ideate. Application of design thinking can bring focus on situational examples and stimulate creative discussion. Authors also encouraged visual expression and diverse team participation. HPI design thinking model also drives change in the curriculum of innovative education. Thienen et al. (2022) introduced neural design based on HPI model and modified the original model in six stages: understanding, experience, point of view, ideate, test prototypes and bring home. It also introduces three kinds of teaching thinking: creative thinking, visual thinking, and ambidextrous thinking.

2.1.3 Human-centered design (HCD) model

Human-centered design (HCD) is a people-oriented approach and principle aiming to gain insight into fundamental needs of human beings (Bender-Salazar R., 2023; Adikari et al., 2023; Chen, 2020). HCD roots in the early days of industrial engineering and human-computer interaction, where technology and engineering were developed with human needs and desires in mind obtaining combination between human needs and technical and economic feasibility (Boy, 2017). This way of thinking is formed in the constitution of development. HCD is a methodology arose from empathetic research, collaborative ideation, and iterative prototyping, focusing on creating products, services, or systems containing effective solutions for users' challenges and enhancing user experiences (Chung and Kong, 2016; Eberhart et al.,2019; Nijagal *et al.*, 2021). HCD and design thinking are complementary, and both of them prioritize understanding and issue-solving for users, i.e., top priority of people. Within the overall framework of design thinking, HCD provides more detailed and specific thinking and applications when focusing on user-relevant products, services, or systems.

The classic HCD consists of three stages (Bui et al., 2024): (i) Inspiration: this stage is collection of user observation, interview, and opinion, etc., to achieve the purpose of understanding user needs; (ii) Ideation: foster creativity and the generation of innovative ideas through brainstorming, etc. in the context of free exploration. (iii) Implementation: ideas generated in the previous phase are transformed into actual solutions, tested, and improved.

Involvement of three-stage HCD method in healthcare system take the experiences of patients into consideration to provide safer and more efficient care (Wymer et al., 2023). Some scholars also introduce the concept of implementation science into this model to achieve application of user-centered research methods (Chen et al., 2021). In order to truly meet user needs in learning analysis, Chatti et al. (2020) proposed a human-centered indicator design (HCID) approach combined with HCD. The method consists of four stages: observation, conception, prototyping and testing. In addition, in the application example of the University of Duisburg-Essen, researchers proved feasibility of HCID by confirming the analysis of course structure and course selection. There are also studies showing that the working principle of HCD method lies in two aspects. On one hand, harmony adhesion between the observation of users and the actual design practice can be built. On the other hand, the observation of users combines physical characteristics and emotional needs. Van der Bijl-Brouwer and Dorst (2017) proposed a progressive four-tier model for human needs and desires: solutions, scenarios, goals and themes. Leary et al. (2022) used the HCD method to analyze 24 relevant articles and summarized the proportions of the five stages, including empathy, definition, conception, prototype and test, in different articles.

2.1.4 Double diamond model

The Double diamond model is a strategic design framework that guides the design process and is developed in 2005 by the UK Design Council. The model combines divergent and convergent thinking and aims to solve problems through empathy and iteration (Schmidt and Von Der Oelsnitz, 2020; Peng and Kueh, 2022). It is typically structured in four phases (Buhl et al., 2019; Kwon et al., 2021)as: (i) Discover: this is the divergent thinking of exploring the problem situation, collecting user needs, and obtaining information; (ii) Define: this is the first convergence thinking that analyzes, filters, integrates, filters all the information, to construct design solutions and refine problem statements after synthesizing information; (iii) Develop: this is the divergent thinking of diverse teams conceiving and exploring solutions, often using visual representations, prototypes, etc., to develop, test, and iterate; (iv) Deliver: this is the convergent thinking of the designer to practice the solution selected after refactoring and adjusting. This phase also typically includes solution testing, elaboration, and practical preparation.

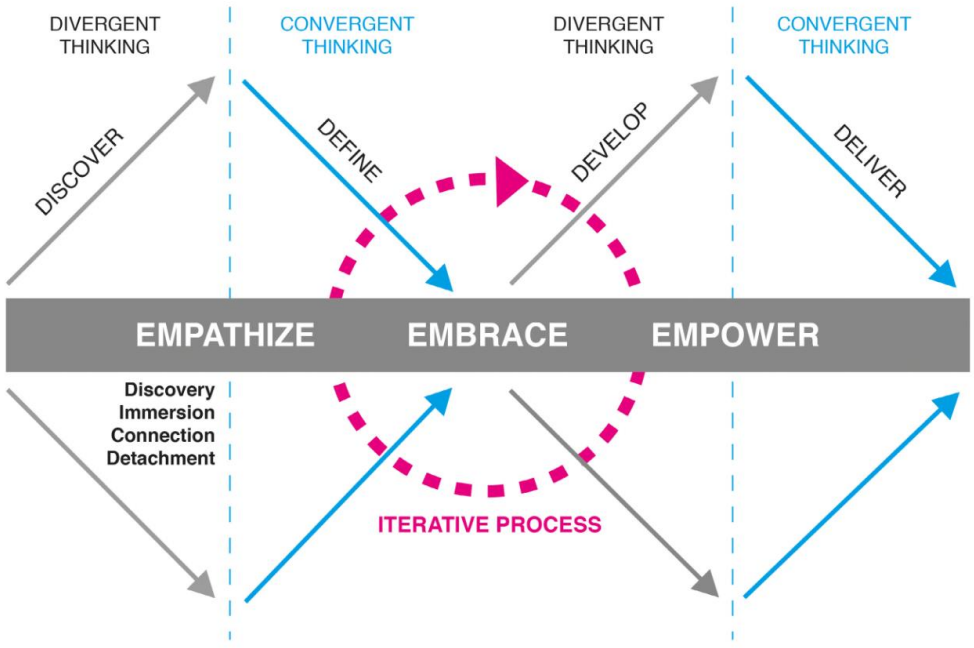


Figure 2. Double diamond model (Peng and Kueh, 2022)

The double diamond model serves as a structured guide within the design thinking process, offering a visual representation of the divergent and convergent stages critical to innovative problem-solving (Grönman and Lindfors, 2021; Hassenzahl, 2011). Its adaptability and versatility have facilitated its integration into various industries and disciplines. The significance of the two-drill model (Kochanowska et al., 2022) is presented through design engineering visualization and establishment of practical way for designers and users to cooperate. In addition, the framework and principles for evaluation are provided in cases where the uncertainty of the outcome exists. Wang et al. (2023) applied the double diamond model to the design of problems related to aging. The basic double diamond model (discover, define, develop, and deliver) integrates IDEO method cards to enable designer and user interaction at each step. The IDEO method card briefly introduces design methods, including learn, look, ask, and try four categories. This combination helps the actual process adapt to aging. Pyykkö et al. (2021) investigated the use of the same four stages double diamond model framework in supply chain management. The authors summarized four strategies under this model, which are co-creating change, pushing change, bringing about change, and forcing change. Co-creating change refers to the joint analysis and participation of multiple departments and roles. Pushing change means intensive utilization of private or public channels and resources for ensuring the introduction and implementation of innovative practices. Bringing out change means to generate resourceful alternatives. Forcing change is to change existing schemes and structures by organizations not directly involved in the design process. In the process of sustainable development, the model is used to develop strategies, and in line with existing patterns. At the same time, the implementation process requires full and smooth communication among members in all capacities. Huang and Hands (2022) explored the application of the basic double diamond model in business, and summarized the methodology of "the Three Gears of Business

Design", which contributed more attention to the end users and reduced the emphasis on strategic development.

2.1.5 IBM design thinking process

IBM design thinking framework is one of the newly developed design thinking models (Okai-Mensah et al., 2021). IBM's beginning motivation was the establishment of a design process to understand consumer needs and implement empathy. IBM's guidelines have three parts (Marcus and Rosenzweig, 2020; Micheli et al., 2019): a focus on user outcomes (understand the real needs of users and establish results metrics), restless reinvention (constantly developing existing prototypes and products for changing environments, markets and users), and diverse empowered teams (diverse teams achieve differentiated results and decisions) (Nedeltcheva and Shoikova, 2018; Legowo and Aditama, 2005). The IBM mental model is typically a loop of three stages, as shown: (i) Observe: rely on empathy to observe and understand the real needs of users and the environment; (ii) Reflect: diverse teams work together to flexibly integrate requirements and produce innovative solutions; (iii) Make: develop, test, and deliver prototypes to users and timely adjustment and reconstruction based on feedback.

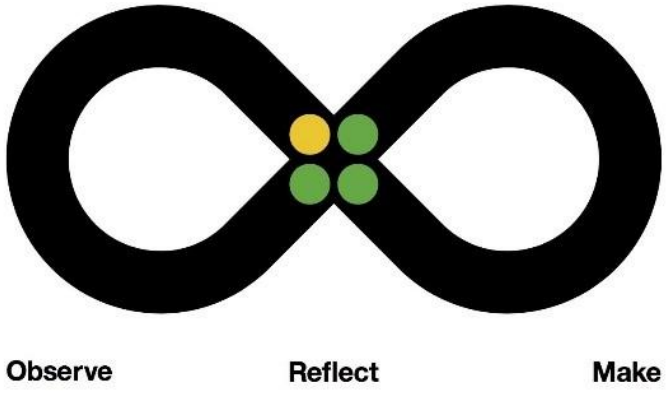


Figure 3. IBM model (Chebabi and Von Atzingen Amaral, 2019)

Realistic cases of design process employing IBM process have been widely presented. Chebabi and Von Atzingen Amaralet (2019) applied IBM to BlueJourney's four-stage model of investigation, ideation, prototype, pitch and selection. They worked with the human resources department in Brazil to complete the first stage through interviews and online surveys. Subsequent stages included: performed immersive physical examinations in the mind and integrated data with IBM toolkits; contacted company personnel in the prototype to build the best solution from multiple technical and business perspectives; displayed and selected in the final stage. Guided by this model, users can integrate with teams to find imperceptible problems accompanying with exquisite solutions in a funny way. In software development, Lucena et al. (2017) used IBM frameworks to extend design thinking principles to meet the needs of users for rapid development and capture at scale. Specifically, the model the authors modified consists of three stages: sponsor users, playbacks, and hills. Sponsor users understand the market and define users and corresponding policies. Real users are involved to provide additional input to modify the feedback. Hills takes each individual need to provide a corresponding achievable goal, but can ultimately constitute a complex goal value at the same time. In addition, iterations occur in this process. Playbacks are reviewed by teams and users that re-set goals or tweak solutions for each phase. Finally, 80% of users revealed satisfactory comments.

2.1.6 Jeanne Liedtka design thinking model

The Jeanne Liedtka design thinking model is a "design thinking for business innovation" model developed by Jeanne Liedtka in collaboration with Tim Ogilvie (2011). In their 2011 book, Design for Growth, based on the various types of models mentioned above, they make adaptive adjustments for business and management, reflecting the construction and application of this

model in business behavior (Hillner and Lim, 2018). The model establishes four phases: (i) ‘What is?’ phase: this means an accurate assessment of the situation and an empathetic analysis to define scope and goals, during which designers need to put aside personal empiricism and stand in the context of the current understanding. It is also a reference point for subsequent changes. Four common methods are visualization, journey mapping, value chain analysis, and mind mapping. (ii) ‘What if?’ phase: this stage is the embodiment of creativity and generation, during which designers are required to brainstorm ideas and then visualize proposed ideas based on existing data and information to think more creatively about future scenarios. This stage encourages breaking out of existing limitations by organizing and combining ideas. Two practicable methods are the brainstorming and concept development tools. (iii) ‘What wows?’ phase: after getting luxuriant ideas for the future, designers need to find amazing ideas making users ‘wow’. This requires the system development evaluation test process. The prototype obtained through experimental testing also needs to be delivered to users for feedback. Methods including assumption testing and rapid prototyping provide effective dentification of core parts of the hypothesis. (iv) ‘What works?’ phase: commercial value for the prototype test results obtained in the first three stages needs to be recognized, which means positive recognition from the market. Reconstructs and iterates existing prototypes and solutions through user and market feedback to continuously overcome the impact of high uncertainty. Finally, the commercialization of the product and the feasibility of the program can be realized. The appropriate methods for this phase are customer co-creation and learning launch.

Jeanne Liedtka's design thinking model is still influential in the field of business innovation. The model has been implemented in a variety of organizations that seek to integrate design thinking into their strategic planning and decision-making processes. While the details of its

application may vary, the enduring relevance of the model demonstrates its effectiveness in fostering a design thinking mindset in a business environment.

Jaskyte and Liedtka (2022) focused on the relationship between design thinking practices and intermediate outcomes, and data analysis showed that the process of definition, ideation, and testing appeared more commonly in literatures, while the final prototype and experiment show opposite trend. There are discrepancies between prepared ideas and the delivery of the testing process, and both the method of hypothesis testing and the degree of trust support of the organization show a significant impact. Liedtka (2014) linked four stages of the model to cognitive bias and analyzed prevention measures for three types of bias. For idea generation (corresponding to the first stage), this worldview leads to preferences that require adherence to empathy, advocacy of diverse teamwork, and democratization. For users (corresponding to the second stage), the customer's own inability to accurately express the intention will cause interference. Hence, they need to qualitatively analyze behaviors and feelings in order to help users activate feedback during the experience, use tools such as additional prototypes. For the test (for the third and fourth stages of the film), the misjudgments in the test and inspection process require their own deep experience and mental planning. At the same time, repetition and reflection can also help reduce the deviation of this process.

Among the staff of the US federal government, scholars (Liedtka et al., 2020) also put forward four problems of the model during utilizing design thinking, namely context, outcomes, enablers/barriers, measures and indicators. In context, design thinking can be reflected in different roles, environments, organizations and industries, and is mainly used in diversified solutions. In outcomes, design thinking can mobilize the communication between superiors and subordinates, change the original fear and prejudice, and produce innovative solutions

fitting needs better. Among enablers/barriers, proper and user-friendly training with instructive support from managers will play a positive role in the promotion of design thinking. However, misunderstandings of manage teams and time constraints can significantly limit design thinking. Satisfaction, efficiency, and engagement are used to evaluate design thinking, but the existing emphasis is still insufficient.

2.2 Comparison of the stages and steps involved in each model

According to the previous summary, design thinking is mainly divided into six categories according to the structure and modelling method. Each model contains a varying number of stages that distinguish design innovations from solutions. The classical stages of these six models are summarized.

The comparison found that the six models were concentrated in three to five stages. The classical stages of IDEO, HCD, and IBM models are all three stages with same clusters (inspiration, ideation, and implementation). Inspiration is the recognition, observation, and analysis of a problem. This is the ideation phase for the team to recognize and think about the problem for designing innovative solutions. The final implementation phase is all about actual testing, iteration, and the advancement of proposed ideas and solutions. The proportions of stages used in these articles are (Leary et al., 2022): 100% empathy, 83% definition, 67% ideate, 92% prototype, and 67% testing. Less than half of the articles included all five stages. The IBM phase is a three-stage cycle of observation, reflection, and formulation. Some scholars defined these three stages as sponsoring users, hills, and playbacks (Chebabi and Von Atzingen Amaral, 2019). In fact, research/sponsorship users show deep understanding of the market and users, insight into their needs, while hills/creativity is to propose an innovative design or solution that

can be realized. The final replay/pitch and selection is similar to the production process, with an emphasis on customer feedback and revision decisions.

The four-stage models compose the double diamond model and the Jeanne Liedtka model. Several double diamond models have been designed in sociology, management, and business. Huang and Hands (2022) used a three-stage model to explain. The first stage is an in-depth exploration of the user, defining the problem and context from users' views. The second stage is to explore and design solutions extensively through prototyping and visualization. The third stage is self-adjustment to align the design with the idea. Jeanne Liedtka's four-stage model is more abstract and is applied to business and management behavior. At present, the application in practice is less, and more attention is paid to the reflection of the existing design thinking process and the elimination of cognitive bias.

The HPI model consists of five stages: empathy, definition, ideation, prototyping, and testing, and most studies have adopted this classic stage division. Bertao and Jung et al. added an HPI model after testing, valuing this stage as six stages. In the evaluation phase, viewers or users measure each solution on five dimensions: innovation, emotional appeal, feasibility, functionality, and willingness to buy. In this way, the evaluation and feedback of the system from the users' point of view are conducive to the correction of the test results.

Models	**IDEO**	**HPI**	**HCD**	**Double diamond**	**IBM**	**Jeanne Liedtka**
Stages	Inspiration Ideation Implementation	Empathise Define Ideate Prototype Test	Inspiration Ideation Implementation	Discover Define Develop Deliver	Observe Reflect Make	What is? What if? What wows? What works

Table 1. Comparison of design thinking model stages

Although number and term of stages vary, the idea of the final reaction is common. Whether it's inspiration, observation, discovery, or empathy. All represent the initial research, analysis and summary of the user. The subsequent conception, reflection and other stages are the specific definition of the problem and the corresponding process of generating solutions. In the end, the obtained scheme and idea need to be revised through iteration, testing and feedback, and finally get a scheme that meets the needs of users and the market.

2.3 Identification of commonalities and differences among the models

These six models are based on the development of design thinking, among which there is a common core thinking. In general, design thinking models rely on human-centered principles and emphasize empathy to understand customer needs. Firstly, designers need to define a specific and clear problem expression based on analysis, screening, and summary of existing needs and information to build innovative designs and solutions. After that, the design scheme

is developed, tested and iterated to mature scheme fulfilling requirements. Integration of proposals from diverse interdisciplinary teams to drive innovative idea generation and design solution is of vital. The iterative and circular process ensures that the process responds speedy enough for adapting to changing market and environmental requirements. These common features are the basic consideration related to design thinking in solving problems and commercializing innovative design, which can ensure the efficient feasibility and comprehensive applicability of design thinking under any model.

Besides distinctions in the visual stage division, there are differences in the emphasis and specific process of each model. The original IDEO model was a general idea exerting keynotes on integration of the whole with reality and a continuous iterative process. On this basis, the HPI model subdivides the two steps of empathy and prototype. Empathy claims importance on observation and understanding of end and related users' needs and challenges. In prototyping, designers use efficient and concise prototyping or visualization to iconize innovative designs. The HCD model emphasizes on needs and wishes of users, and considers human needs, technical feasibility and economic feasibility at the same time when final decision is settled. HCD provides more detailed and specific thinking and applications when focusing on products, services or systems that are relevant to users. The double diamond model represents the divergence and convergence stages of the design process with a visual and intuitional diamond structure. Such a model is more flexible, applicable and versatile and can be integrated into various industries. The IBM model introduces an updated circular perspective, in which the design process is not dominated by the designers' team. User feedback and expectations occupy superior position in the design process. This iterative process is more in line with realistic users' demands. The Jeanne Liedtka model breaks through the limitations of the existing stage and transforms into a framework of four questions with focus on cognitive biases in the existing

design process, introducing reflection to reduce the gap between innovative ideas and actual testing. Furthermore, the model targets more on business and management, and assigns practical and actionable methods to each stage to provide reference for managers.

3. Deriving necessary processes for successful implementation of design thinking

3.1 Identification of key processes highlighted in the reviewed models

Each of the six design thinking models mentioned above is divided into different stages for implementation. These models obtain key processes and contents in each of their phases. For the IDEO model, the key to inspiration is to extract desired ideas and inspiration from users, stakeholders and the environment, so as to promote the innovation and creation process, and collect all aspects of information to lay the foundation for subsequent problem solving and innovative design. The key to the ideation is to produce a wide range of innovative designs exploring multiple solutions. Implementation is to visualize the idea through prototyping or testing. This is to ensure the feasibility and efficacy of the scheme.

In the HPI model, empathy is achieved by observing and immersing users in their needs and experiences. The definition requires extracting core requirements and obstacles from insights of the previous step and articulating the problems clearly and concretely. Prerequisite for constituting a convincing prototype is to visualize various ideas generated with a simple and intuitive prototype for facilitating communication of concepts. The testing stage functions for collecting users' feedback, to iteratively update the prototype for improving user satisfaction and scheme feasibility. The stages of HCD model are similar with those of IDEO model. In the double diamond model, due to the existence of divergence and convergence processes, consideration of re-improvement on each stage becomes necessary. The discovery phase involves reviewing the estimates and assumptions, while the definition phase involves

rebreaking the problem statement in light of changing requirements. Both the development and delivery phases require revisions and refactor of prototypes and ideas. For the IBM model, the key process is closed cycle of continuous iteration. Designers need to adjust the understanding respecting to variations of users' need through frequent observations to identify updated information and reflect on analysis in response, while flexibly reconstructing solutions and ideas in production to ensure that the result can meet the dynamic needs of users. The key process of the Jeanne Liedtka model is to reduce the cognitive bias in the practice of design thinking. Due to the cognitive limitations of the designers themselves, inaccurate representations by users and empiricism in the testing process need to be concisely considered.

3.2 Examination of the rationale behind the inclusion of these processes

Every mentioned design thinking model follows similar basic principles of problem solving and innovation, as follows:

User-centered focus: The users are placed at the absolute center of the whole design process, and their explicit and implicit requests need to be recognized, collected and analyzed carefully and considerately, more over interaction between users and their surrounds need to be taken into consideration.

Diverse interdisciplinary teamwork: Members with disparate backgrounds contribute a wide realm of knowledge, skills and perspectives, more adaptable to diversity and rapid variation of clients demands. Design teams should analyze problems efficiently and accurately from multiple perspectives through radical mind mapping and brainstorming to promote comprehensive innovative design integrating polynary solutions.

Efficient prototype testing: Through prototyping, resourceful proposals are becoming intuitional through visualization and demos for fast screening with precise control of cost and reduction. Settled ideas will be brought to the market for judgement, and optimized depending on market feedback.

Cycle of iteration and feedback: feedforward design process exerts poor adoption to ever-changing practical requirements and vague market. Through iteration and feedback, updated information should be integrated into each stage of design thinking to ensure ideas constantly adjusted and reconstructed for elevating user satisfaction and market adaptability of the final products and solutions. In addition, the presence of feedback allows the user to participate in the design process, further eliminating the inaccuracy of the users' own requirements.

In summary, the rationale behind incorporating these design thinking processes is to create a holistic and user-centered approach for problem solving. By systematically combining empathy, defining, ideation, prototyping, testing, and iteration, the design thinking model aims to produce innovative solutions that truly meet user needs and solve complex challenges. The different processes are collaborated and interacted to provide an instructive guidance for a creative and adaptive problem-solving journey.

3.3 Analysis of the effectiveness of these processes in real-world design thinking projects

With advancement of modern society putting people first, design thinking is employed with dramatical elevated frequency in the wide range of industries. Shapira and Ketchie et al. (2017) used design thinking in FSSD to examine the reliability of integrated processes. According to

the results of the specific structural analysis in FSSD, a lack of adequate sustainability preparation in this design thinking process was confirmed. According to authors' opinions, sustainable design thinking (SDT) process through experimental iteration with the help of HCD and propelling HCD model as add-ins can be more synthetic. Specifically, the authors used sustainability as a pre-determined condition for iteration, while complementing crucial constraints and iteration conditions for each stage for generating more systematic and sustainable prototypes. The circulation between iteration and feedback in this process demonstrates encouraging influence in process tuning. Bertão et al. (2023) customized the design thinking process in the training of the human resource development department of LG Company in South Korea. They optimized and integrated the management process of corporate training with developing the empathy of employees when facing customers, promoting the people-oriented core design practice simultaneously. User-centered is not only the core principle of the design thinking process, but also the innovative thinking implemented by the company in real life. For cases applying design thinking on developing complex software systems (Gabrysiak, 2011), scholars expected accurate and informative feedback in different scene tests to renovate the system design by prototyping. Designers use simulation-driven server systems to build scenario tests for multiple users gaining subjective feedback from the testing process. This efficient prototype testing demonstrates great convenience and favorable input-output efficiency in information technology field. For application on education at the University of Duisburg-Essen, designers (Chatti *et al.*, 2020) used the HCID method to assist students to collaborate in designing indicators about course structure and arrangement. This cooperative mode involving both designers and students (users) facilitate improved convenience, practicality, and satisfaction in the field of advanced education, confirming efficacy of HCID. In order to adapt to customers' subjective changes, Chebabi and Von Atzingen Amaralet (2019) reconfigured and reformed in team cooperation and prototype

design during cooperation with Brazilian human resources. The IBM team and their cooperators' employees work together to collect information through interviews and online surveys, and use sketches or build blocks to analyze processes and stages. The diverse team provides a solid foundation and a wealth of ideas for the practice of design thinking.

3.4 Synthesis of the necessary processes for successful implementation of design thinking

Based on above analysis and understanding of design thinking, successful implement the application of design thinking should include following stages and contents: (i) Empathy: Observation and interview contribute to insight into accurate users' needs and wishes. This process emphasizes superior position of users' need and focus on empathy. (ii) Define: Analyze, filtrate and organize collected information to obtain a clear and explicit representation of the problem and construct the design scheme. (iii) Ideate: Brainstorm among diverse interdisciplinary teams to generate innovative designs and ideas. In this process, creative and innovative divergent thinking is encouraged. (iv) Prototype: Design low-cost and low-reducibility prototypes, communicate ideas and innovative designs through visual expression, and realize fast and efficient idea testing. (v) Test: Confirm feasibility of selected ideas and innovative designs on real users and markets and incorporate users' feedback. Through this iterative process, ideas are constantly adjusted and restructured.

In the case of meeting the above five stages and their specific contents, while adhering to the user-priority and team cooperation principles, and constantly establishing prototypes and performance evaluation to match corresponding application scenarios, after multiple iterations and adaptive adjustments, design thinking will be realistically implemented in production and daily life.

4. Key capabilities for design thinkers

4.1 Overview of the essential skills and attributes required for effective design thinking process

Functional design thinking requires a series of essential skills and attributes assisting its practice, including cognitive capabilities (Wu X. et al., 2022; Jung and Chang, 2017; Eggers et al., 2017) interpersonal skills (Dragičević et al., 2023; Rusmann and Ejsing-Duun, 2022; Wang and Liou, 2018) and design-specific skills (Liedtka and Kaplan, 2019; Lane, 2018; Carella, 2023) each playing crucial roles in the design thinking process.

Cognitive capabilities, including empathy, critical thinking, and creativity are crucial for designers, to grasp user needs, identify essence of issues, and propose innovative solutions (Devecchi and Guerrini, 2017). Interpersonal skills include collaboration, communication, and empathy, which contribute to more efficient problem-solving, and ensure consistence between design solutions and users' needs. These skills play a pivotal role in the exchange of creative ideas and collaboration within design teams (Yilmaz, 2022). Design-specific skills, including prototyping, iteration, and visualization, energize more logical and effective presentation, communication and validation of design concepts (Lages et al., 2020). These skills endow designers with ability to showcase design concepts and promote optimization of design products.

A successful design thinking process requires a harmonious integration of cognitive capabilities, interpersonal skills, and design-specific expertise. By cultivating these skills and attributes, designers and teams can tackle complex challenges, inspire innovation, and deliver meaningful solutions proficiently.

4.2 Exploration of cognitive capabilities

The successful practice of design thinking is closely related to cognitive capabilities. Design thinkers need a strong set of cognitive capabilities of understanding users' requirements more clearly (Grönman and Lindfors, 2021), exploring the nature of design problems (Waidelich et al., 2018), and creating innovative solutions (Filho et al., 2021). This section discusses the impact and role of empathy, critical thinking, and creativity on designers and the design thinking process.

Empathy is the cornerstone of cognitive capabilities. Designers need a keen sense of perception and empathy to understand users' intentions through key information captured from the users' behavior, emotion, and environment (Devecchi and Guerrini, 2017; Coleman et al., 2003, Barnes and Preez, 2015). Siricharoen proposed the empathy map to help designers make decisions based on the consensus of users' needs (2021). The users' emotions and experiences are determined their thoughts, feelings, actions, and senses using products. Based on empathy, design focuses more on the user (Wu et al., 2022), aiming to products with positive remarks in user experience. Chan (2018) pointed out that empathy could explore the nature and root in the process of design thinking and discover the differences by establishing deep empathy connections, thus increasing authenticity. Instruction about empathy and empathetic design in designing products can help produce meaningful deliverables. However, empathy and meaningful design deliverables need the novel, effective, whole framework. Tracey and Baaki (2022) taught empathy for action to produce meaningful design results for students, and they taught 4-phase framework for empathy design, employing Batson's eight distinct empathy concepts to judge that empathy in design. They focused on the instances of empathy for others,

context, and oneself, and finally three of nine design groups got several meaningful design solutions as shown.

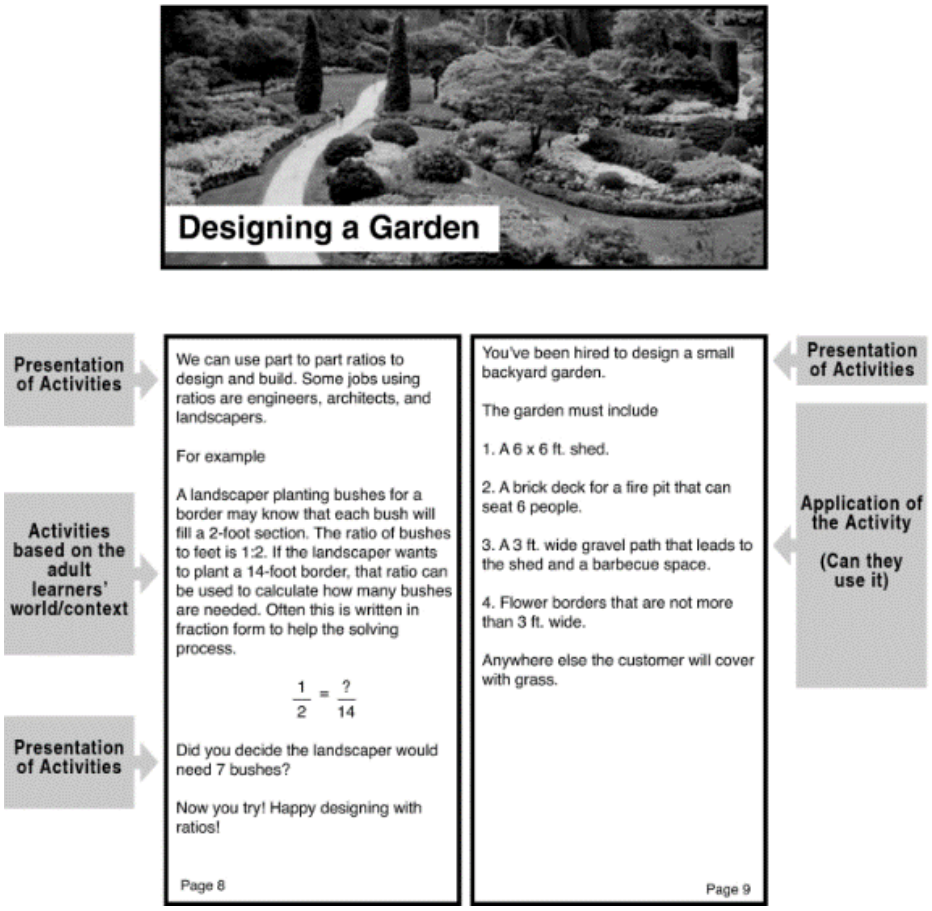


Figure 4. Mathematical Ratio Participant Guide (Tracey and Baaki, 2022)

Creativity is another of the core capabilities of design thinkers, who have to transcend traditional thinking patterns and propose innovative solutions. Creativity is a process of generating novel ideas that solve problems, and a drive that encourages individuals to use their potential to generate great ideas (Dell'Era et al., 2020). Jung and Chang (2017) proposed the concept of design convergence talent (DCT). Their research showed that DCTs completing at least two design studies were more creative than non-design convergence talents (NDCT), which was attributed to professional training through internalization, where the personal

creative thinking through training in design thinking. As for the enterprise level, design professionals can use creative mindsets and thinking to solve problems, which can promote exploratory pursuit of creative output. Then this structure constitutes a virtuous cycle. The synergy of design and creativity helps produce high-quality, original, and functional designs. Because creativity inspires designers to explore various design solutions within a design context. In Balakrishnan's study (Balakrishnan, 2022), the impact of design thinking in performing tasks was explored, specifically in the context of creative processes and motivation for creative thinking. The results showed that during the design thinking process, creative confidence was increased; interest and motivation for more thinking was enhanced, and respondents are encouraged to think creatively. What's more, design educators also need to identify appropriate teaching strategies that promote students' active participation in the creative process and motivate them to think more creatively. In addition, design thinkers also need to use creativity to transform users' needs into specific design solutions to achieve optimization and innovation of users' experience (Kim, 2020).

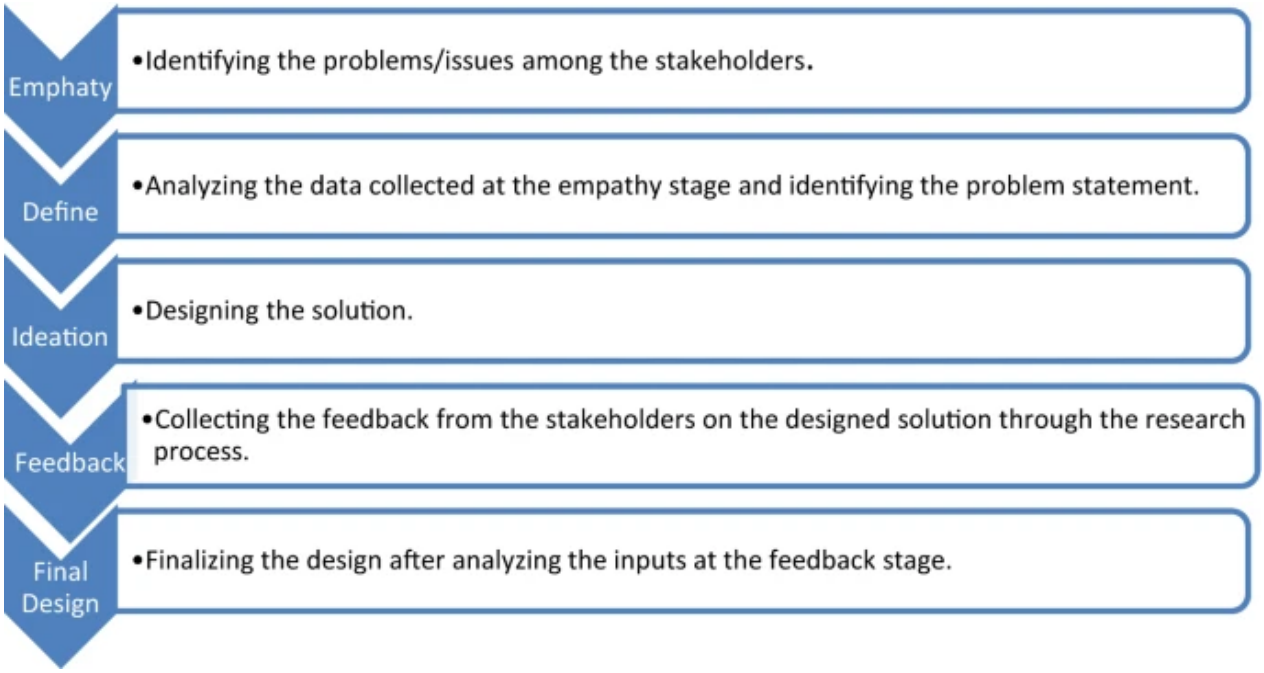


Figure 5. Modified design thinking process of the research in design course (Balakrishnan, 2022)

Design thinking emphasizes solving complex problems through in-depth analysis and evaluation, and critical thinking is key for achieving this goal. Critical thinking is the ability to analyze and evaluate situations thoughtfully and recommend courses of action that consider stakeholders, impacts, and consequences. Especially when dealing with large amounts of information, designers need to integrate disparate data into meaningful patterns to understand multiple aspects of a problem. Eggers et al. (2017) mentioned six steps of critical thinking, including identifying and summarizing key issues, determining key assumptions and considering stakeholders, analyzing alternatives and consequences, analyzing supporting data, providing recommendations and action plans, and considering the consequences. Evaluating the total number of unique product designs found that critical thinking can improve creativity, which in turn improves business performance. As a long-term goal of education, critical thinking needs to be integrated into design thinking, as shown in Figure 6. The relationship between elements of problem-solving and critical thinking in the three approaches. In addition,

as important components of critical thinking (Hitchcock, 2018), observing, feeling, wondering, imagining, inferring, knowledge, experimenting, consulting, identifying and analyzing arguments, judging, and deciding, these 11 aspects (Ericson, 2022) can be mapped to various stages and activities of design thinking. Verganti et al.'s study (2021) mentioned that for educators and practitioners, critical thinking can guide the future research agenda of design teaching and practice, so effectiveness can be maximized for design process. In the practice of design thinking, designers need to establish habits for questioning and examining their own design assumptions to ensure the feasibility and effectiveness of the design plan and solutions.

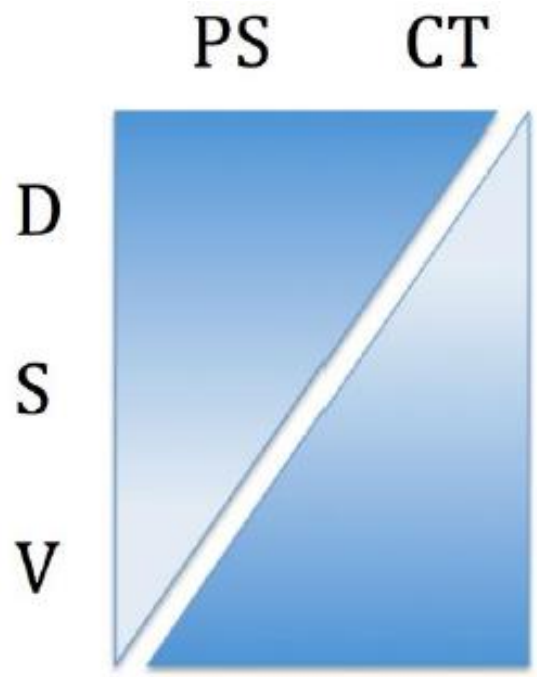


Figure 6. The relationship between elements of problem-solving and critical thinking in the three approaches (D = design; S = system; V = value; PS = problem-solving; CT = critical thinking) (Schooner et al., 2024).

Design thinkers need to fully develop their cognitive abilities in practice, which not only contributes to a more comprehensive understanding of problems and user needs, but also

provides a solid foundation for innovative design solutions. By developing and improving cognitive skills, design thinkers are better equipped to tackle complex challenges and achieve more innovations.

4.3 Examination of interpersonal skills

In design thinking, interpersonal skills are indispensable abilities for design thinkers to develop effective operation of the design team and the realization of innovative solutions. Essential skills include collaboration, communication, and empathy. Collaboration and communication skills can improve the efficiency of the design team and drive the production process of settled products (Figure 7. Thematic summary of findings). Empathy can ensure the effectiveness of the design of products, making it more suitable for users.

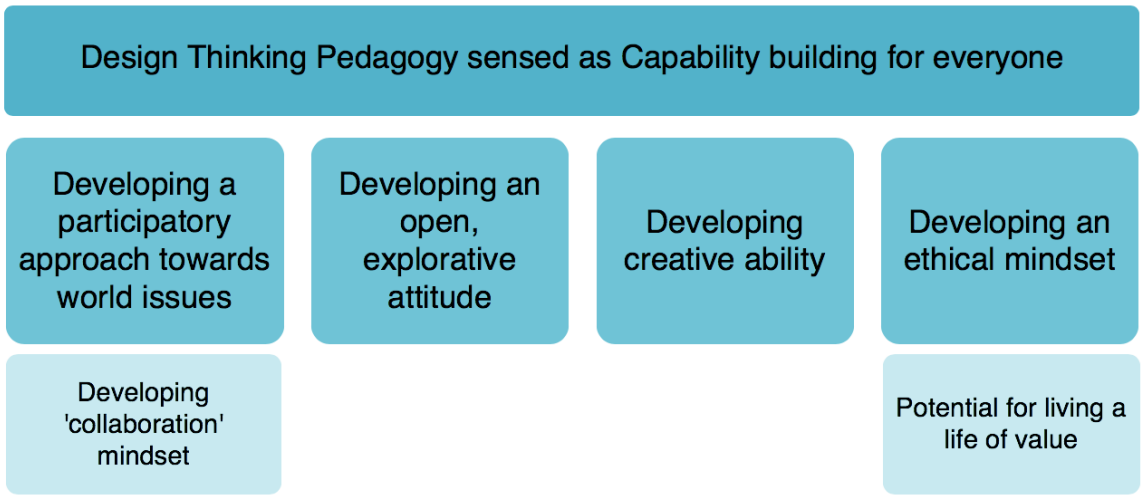


Figure 7. Thematic summary of findings (Beligatamulla et al., 2019)

Design problems often involve multiple aspects and require interdisciplinary and even cross-team expertise and skills. Therefore, design thinkers need to hold good collaborative skills and be able to work effectively with team members to solve complex problems, as shown in Figure

5. In the field of advanced education, interdisciplinary collaboration is extremely important, especially in design-related courses (Dragičević et al., 2023). By bringing together different disciplines in education, it can help solve complex problems and thus help students develop skills beneficial for their future career. For example, in the field of engineering design (Ericson et al., 2009), designers from realm of economics and project management can provide a more comprehensive perspective on the course, thereby optimizing course design. The application of design thinking in the industrial and commercial world also requires cooperation. Olsen (2015) mentioned in the review that the design thinking team is composed of representatives of different target users and all project owners. Through cooperation among research, industry and market, it expands the innovation ecosystem and helps develop novel product concepts and business models. A successful design team often requires cross-departmental cooperation (Carlgren and BenMahmoud-Jouini, 2022), as shown in Figure 8. Value Creation Wheel approach to problem-solving, to optimize the production process by integrating experience and expertise in different fields and focus on effective output in an efficient manner, which is especially suitable for complex problems (Lages et al., 2020). Through effective collaboration, design teams can give full play to their respective strengths and promote project progress and achievement of results.

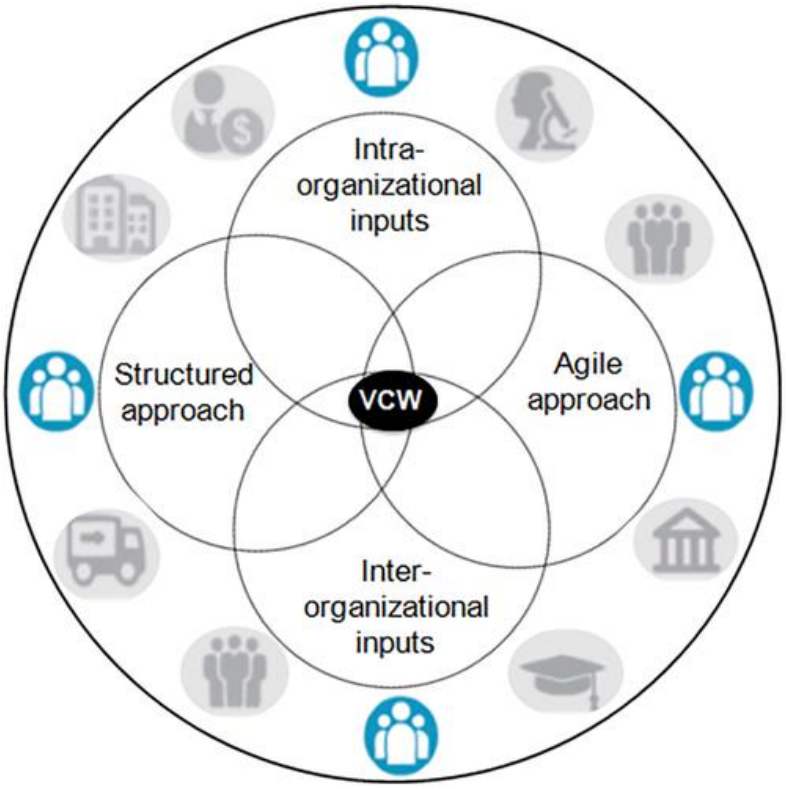


Figure 8. Value Creation Wheel approach to problem-solving (Lages et al., 2020)

Design thinkers need to be able to express and present their ideas and opinions clearly and communicate effectively with team members and stakeholders. Rusmann et al. emphasized communication in design thinking, which can assess design proficiency (Rusmann and Ejsing-Duun, 2022.). Students should be able to use material media to communicate ideas with others and demonstrate thinking in multiple modes to help come up with innovative solutions. Yilmaz provided a case of applying design thinking to communication classroom (Yilmaz, 2022). Students explored the nature of the problem, conceive solutions and other stages of the design thinking framework in group discussions to develop communication skills and participated in interactive experiences; Teachers providing more communication opportunities among students in the classroom can enhance their creative confidence and inspire students to have a deeper learning experience and motivation. Based on the case of dashboard design, Cahyadi et al. illustrated how cross-disciplinary and cross-team communication can promote the

production of feasible and effective products (Cahyadi and Prananto, 2015). The design team understood their actual needs through communication with users, thereby coordinating goals and solution standards, then provide satisfactory solutions and product designs. Communication is not only a fundamental management skill but also a strategic one. For instance, in the context of entrepreneurial leadership, the aspect of communication necessitates the distribution of resources across the organization (Rehman *et al.*, 2021). It involves articulating a vision of future prospects, sustaining competitiveness via effective communication, inspiring the team to take proactive steps, and continually adapting to changes through innovation. In essence, in the design process, prompt and lucid communication can prevent misinterpretations and disputes, fostering team collaboration and creative interchange. By means of effective communication, the design team can preserve the information flow and team unity, thereby enhancing the project's success rate and the quality of the outcomes.

Empathy is an indispensable interpersonal skill. Design thinkers must possess the ability to perceive and comprehend from the viewpoint of the users, gaining a profound understanding of their needs and anticipations. Empathy enables design thinkers to craft solutions that align with the users' psyche, thereby enhancing the user experience of a product or service. Throughout the product design process, the design team frequently undertakes user research and user experience evaluations. At this juncture, designers often need to acquire a comprehensive understanding of user needs and responses. Empathy serves as an effective conduit between designers and users. Wang et al. proposed that engineers should practice empathy throughout the entire process of the double diamond model of design thinking (Wang and Liou, 2018), which is the Guideline L.O.V.E., including listening, observing, valuing, and engaging. When engineers added and practiced empathy in the design thinking process, their final products often benefited users and enhanced efficient and meaningful user experiences.

Marsden et al. proposed that the design process and empathy with future users usually occur in a team environment (Marsden and Wittwer,2022.), revealing that the dynamics within the development team will affect the empathy process, and emphasized the need to establish empathy based on gender construction and considering empathy under the influence of team status. In addition, a designer's empathy can also influence other designers and design outcomes. Wu et al. (2022) revealed that in the design synthesis stage, the entanglement of empathy between designers affected the design results, and proposed the correct operating mode of empathy, that is, focusing on users and works to promote design. Through empathy, the design team can establish a good relationship with users, thereby maximizing user needs and optimizing user experience.

In summary, collaboration, communication, and empathy are vital interpersonal skills in design thinking. These skills not only facilitate effective collaboration and communication within design teams and between designers and users, but they also assist design thinkers in better comprehending and fulfilling users' needs.

4.4 Evaluation of design-specific skills

Evaluation of the importance of design-specific skills in design thinking concentrates on prototyping, iteration, and visualization. These design skills are critical to effectively implement innovative solutions and improve design quality. Successful design teams can visualize innovative ideas, which means that they should spread the design solution to the design team members and users through the medium. Prototyping uses simple models to test

and validate ideas at low risk and cost. Iteration can make the product continuously optimized and improved, to meet the expected requirements.

Prototyping enables design thinkers to transform abstract concepts into concrete objects showing firmer demonstration and verification of ideas. Using design tools to prototype innovative models and expected product functions, and combine cutting-edge results with actual needs, helps companies analyze product prospects and conduct strategic planning and adjustments intuitively, which is a key step in innovative business models (Liedtka and Kaplan, 2019). Prototyping is also a core component in engineering design and education, especially in technology-driven industries. Böhmer et al. took the ME203 course at Stanford University as a case (Bohmer et al. 2017) and revealed that prototyping is related to discovery, decision-making, and the acquisition of updated knowledge and information. The results show that students can contribute most optimal design with the correct prototyping strategy, while also supporting decision making and pushing the design forward. As an important design tool and capability, prototyping can reduce the cognitive burden between designers and users, supplement the designers' concept model, and even reveal defects in the primary model stage (Viswanathan et al., 2014), as shown in Figure 9. First and current prototypes of two major concepts in the project, thus providing a basis for the continuous improvement of designed products and subsequent modification. Furthermore, prototyping based on user needs enables design team members to comprehend design concepts more clearly, identify potential problems, and briefly make adjustments and improvements (Hirota, 2018).

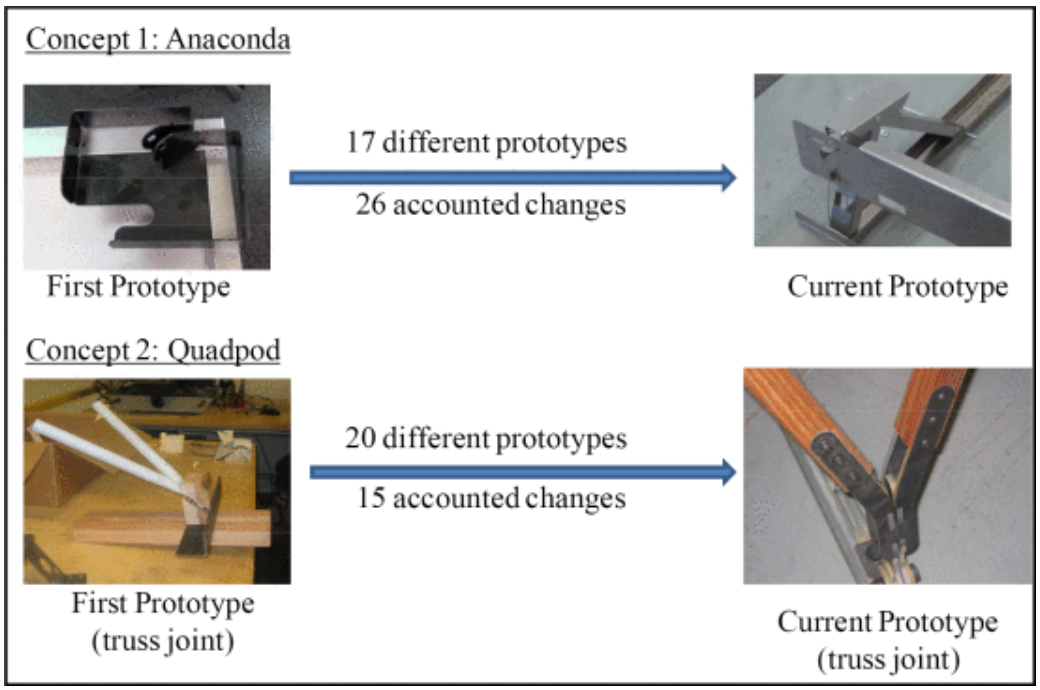


Figure 9. First and current prototypes of two major concepts in the project

(Viswanathan et al., 2014)

Iteration is universal and important in design thinking processes, product development, and project management. Design thinkers need to refine design solutions through iterations to approach the final solution gradually. During the iteration process, the design team will adjust to optimize the design plan based on user feedback and experimental results, thereby achieving better design quality and user experience (Lane, 2018). Moreover, whether it is at the micro level, namely the iteration of the internal activity process of an individual or group, or at the macro level, namely the large-scale iteration under the project context and requirements, both impact on the design and product development process is by promoting the progressive generation of knowledge and accumulation to increase value (Wynn and Eckert, 2017). Parallel iterations in the development process can also reduce the overall duration. Each in-line iteration contributes more thorough understanding of user needs, refines appropriate solutions, and even provides innovative insights for improvement (Cai et al., 2023). However, repeated iterations for many times do not necessarily lead to breakthroughs. It is necessary to coordinate the

strategic goals with the actual status of the team, and improve the fit between market demand, product performance and iteration results (Hölzle and Rhinow, 2019). In the comprehensive design and development stage where designers and customers participate together, iteration is also highly active. Through a gradual approach, designers continue to enhance their experience, thereby better supporting users' personalized needs (Kim and Park, 2021).

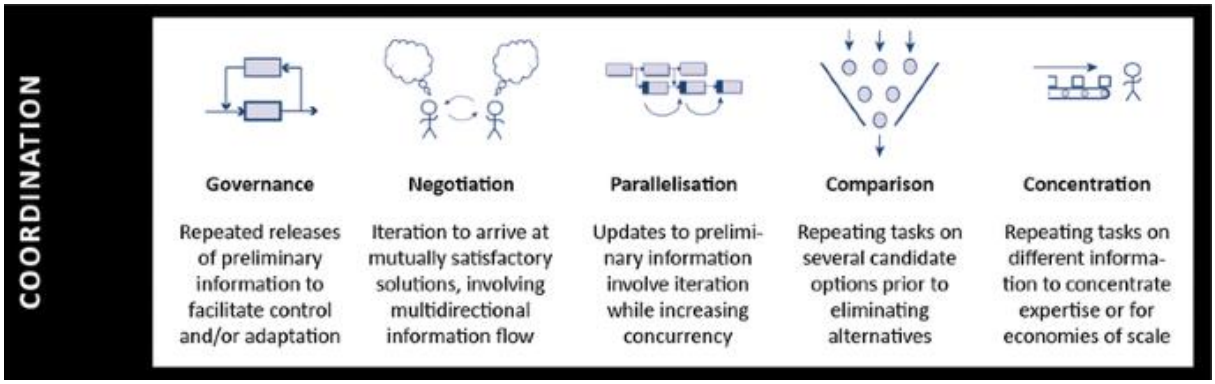


Figure 10. Stereotypes of coordinative iteration (Wynn and Eckert, 2017)

Design thinkers use visual tools to present complicated design concepts and information graphically. The most obvious function of visualization is swift comprehension and consensus between users and the design team by concretizing design concepts or ideas (Carella, 2023). Through visualization, design team members can accept design concepts in better manner and also help stakeholders better participate in the design process (Roth, 2023). For example, design thinkers often use mind maps, sketches, and prototypes to express their design ideas and intentions more clearly (Zheng, 2018), as shown in Figure 11. Opportunity map workshop showing group work on developing solutions for prioritised opportunities. For enterprises, visualization can help founders reach a consensus when the business concept is immature, promote entrepreneurial decision-making, and facilitate timely adjustments (Carella, 2023). Eppler et al. used interactive visualization to carry out corresponding design thinking activities (Eppler and Kernbach, 2016) relying on other media such as text, shapes, flow charts, patterns,

videos, etc. to display decision-making intentions or design concepts, so that team members can understand the design activities immediately and understand the design thinking. Visualization is one of the means to reduce cognitive biases and promote design activities through concrete description and visual impact. Liedtka (2015) complemented narrative visualization skills such as storytelling, metaphors, analogies, or presenting ideas on sticky notes and whiteboards. The skills can promote the sharing of design concepts and the efficient development of design products.

Figure 11. Opportunity map workshop showing group work on developing solutions for prioritised opportunities (Veflen and Gonera, 2023)

The skills of prototyping, iteration and visualization not only help design establish more straightforward demonstration and verify design concepts, but also help design thinkers optimize design solutions. By making prototypes, users and design teams can share design concepts; through prototype iteration, the user experience can be further enhanced, and design concepts improved; and through visualization skills, design concepts and strategic intentions

can be effectively displayed. Mastering these specific skills can facilitate the efficient operation of the design and product development process and the creation of novel solutions.

5. Synthesis and Discussion

5.1 Integration of findings from the comparative analysis of process models

As delineated in section 2, design thinking is a pioneering methodology that covers an array of steer and structure the design thinking process, such as IDEO, HPI, HCD, double diamond model, IBM, and Jeanne Liedtka design thinking model. These six models have their own characteristics in the process stage, theoretical framework, and practical application. By juxtaposing the commonalities and disparities among these six models, a more lucid and profound comprehension of the extant design thinking models can be gained.

From the vantage point of process stages, these models adhere to analogous analytical processes, but at the implementation process each model accentuates different aspects on each stage. The design thinking model proffered by IDEO design company (Glen et al., 2015) includes three stages: inspiration, ideation and implementation. The HPI model (Traifeh et al., 2019) contains five stages: empathy, definition, concept, prototype and testing. The HCD model (Wymer et al., 2023; Traifeh et al., 2019) mainly includes three stages: inspiration, ideation, and implementation. On this basis, it extends to the stages of understanding, defining, idea generation, prototyping and test. The design thinking process model proposed by IBM (Okai-Mensah et al., 2021) includes the stages of observe, reflect and make. The Double Diamond model (Kochanowska et al., 2022) proposed by the British Design Council divides the design thinking process into four stages: discovery, definition, development, and delivery, highlighting the two stages of discovery and delivery. The design thinking process model proposed by Jeanne Liedtka (2011) includes four key stages: what is, what if, what wows and

what works. In summary, the general processes of most design thinking models include the following steps: observing and determining the problem, defining the problem, generating concepts, developing prototypes, designing the final product, and obtaining feedback.

From a theoretical framework perspective, most design thinking process models underscore user-centricity, interdisciplinary collaboration, and innovative feedback. The design thinking model proposed by IDEO design company focuses on user experience and practicality, emphasizing user-centric design and swift prototyping. The HPI model details the role of user participation and open innovation in design thinking. The HCD model is user-centered, emphasizing a deep understanding of user needs and experiences, and continuously improving and optimizing solutions through an iterative design process. IBM design thinking introduces the concept of loop, focusing on three principles: consumer satisfaction, multidisciplinary collaboration, and rapid iteration. The double diamond model focuses more on two key perspectives through the use of divergent and convergent thought processes: understanding the problem and implementing the solution. Jeanne Liedtka's four questions provide a more abstract framework of design thinking process placing greater importance on feedback and reflection. Although the theoretical frameworks of design thinking process vary slightly, all emphasize human-centricity, attention to users' needs and feedback, and the use of innovative thinking to solve problems efficiently.

From a practical application standpoint, each design thinking process model has their own unique emphasis. As previously mentioned, the IDEO model prioritizes creative divergence and prototyping, and is extensively utilized in fields such as product design and service innovation. The HPI model emphasizes the open innovation process and has a profound influence in both industry and academia. The HCD model places considerable importance on

user participation and feedback and is widely used in user experience design and social innovation, such as policy formulation, healthcare security, and other fields. The IBM model concentrates on iteration and rapid prototyping and has a significant impact on corporate innovation and business model improvement. The Jeanne Liedtka model emphasizes more on reflecting the innovation process and breaking the cognitive bias, which has been gradually applied in the business and management disciplines.

A comprehensive comparison revealed that, despite their differences, all emphasize the importance of user needs, interdisciplinary cooperation, and innovation in the design thinking process. The four core principles of all design thinking process models are user-centricity, diverse interdisciplinary teamwork, efficient prototyping, and cycles of iteration and feedback. In actual applications, suitable models can be selected and applied based on specific project requirements.

5.2 Examination of the relationship between the identified necessary processes and key capabilities

The design thinking model maximizes creativity, collaboration, and development of solutions that truly meet the real needs of users by providing a structured and iterative approach. A complete design thinking process model consists of the following steps: understanding, defining, conceptualizing, prototyping, testing, and implementing. However, the key stages of the design thinking process model require the support and application of a variety of key capabilities and skills of the designer, promoting the great progress of the design process and the final successful solutions.

In the understanding stage, empathy and critical thinking dominate. Designers need empathy to understand the actual needs and emotions of users (Vassallo et al., 2023), and at the same time use critical thinking to evaluate problems (Watson, 2015) to ensure a comprehensive comprehension of the intrinsic nature and context of the problem. In the definition stage, critical thinking and communication are more important. Designers need to use critical thinking (Pusca and Northwood, 2018) to clearly define the scope and goals of the problem, and use communication skills (Stary, 2017) to reach consensus with team members and establish the direction and goals of the design. In the ideate stage, creativity and collaboration are crucial (Micheli et al., 2019; Oschinsky et al., 2022). Designers need to be creative, produce a variety of ideas and solutions, and actively collaborate with team members to promote the generation of creative ideas. In the prototype stage, creativity and prototyping are of higher significance. Designers need creativity to bring together various ideas and select the most promising solution (Carlgren et al., 2016) and use prototyping skills to transform these solutions into detailed prototypes or sketches (Brassett et al, 2019.) for further verification and improvement. In the test stage, empathy and communication are more vital. Designers need to use empathy to interact with users to deeply understand their experiences and feedback (Zeh, 2015), and use communication skills (Swayamprabha et al. 2020) to share and discuss test results with team members to identify and resolve potential issues. In implementation stage, collaboration and iteration are more important. Designers need to work closely with team members (Ericson et al., 2009) to promote the implementation and deployment of design solutions, and use iterative capabilities to optimize and improve design solutions continuously to adapt to changing needs and environments.

For the design thinking process model, various stages require different key abilities to support, and these key skills are often throughout the entire thinking design process. Different process

models may place greater emphasis on certain cognitive abilities, but they are key drivers in the design thinking process. The various stages require team members to work closely, communicate effectively, and establish emotional connections with users to ensure that the design solution meets user needs and expectations. At the same time, the design thinking process at various stages also requires designers to have skills such as prototyping, iterative optimization, and visual expression, to make the design process more efficient.

The design thinking process model and key capabilities are interdependent and promote the development and improvement of the design process. Design teams need to comprehensively develop and apply these key capabilities, combined with various design thinking process models, to arrive at innovative, effective, and user-centered design solutions.

5.3 Identification of gaps in existing literature and potential areas for further research

This article scrutinizes the correlation between key stages in various design thinking process models and cognitive abilities, interpersonal abilities, and specific competencies, underscoring the necessity for the support and application of diverse abilities at different stages to facilitate the seamless progression and successful implementation of the design process. However, the analysis and application of models in the existing literature are rudimentary, and the influencing factors are not thoroughly considered, which may result in constrained design outcomes. Although the existing models are segmented into different stages to articulate the specific content of design thinking, there are conspicuous disparities in the actual application methods and concrete implementation strategies across different fields. This discrepancy can lead to deviations between the application of design thinking model and actual production and life, making it challenging to promote on a large scale across various fields. Additionally, due to its

inherent empiricism, the uncertainty in users' expression, and the bias introduced by testing is not meticulously considered.

The design thinking process model can be further applied and practiced across different fields, such as the applicability and effectiveness evaluation of the established model in diverse industry backgrounds, the training and practice of design thinking capabilities in interdisciplinary teams, emerging technologies such as artificial intelligence, virtual reality, etc. Impact on design thinking processes and competency requirements, cross-cultural research on design thinking processes in the context of globalization, etc. In-depth research in these fields can further exert the influence of the design thinking process, provide more practical guidance and theoretical support, and thus promote the application and development of design thinking in different fields.

6. Conclusion

This paper provides a systematic summary and a comparatively analysis of six different design thinking process models, including IDEO, HPI, HCD, double diamond model, IBM design thinking process model and Jeanne Liedtka design thinking model. Each of these models possesses unique attributes and benefits in relation to process stages, theoretical underpinnings, and practical applications. An effective design thinking process model encompasses stages such as comprehension, definition, ideation, prototype, test, and implementation. Furthermore, this paper encapsulates requisite skills for design thinkers and their correlation to each phase of the design thinking process. Cognitive skills such as empathy, creativity, and critical thinking permeate the design thinking process, aiding designers in comprehending user needs, proposing innovative solutions, and conducting thorough analysis and evaluation of problems. Interpersonal skills, including collaboration, communication, and empathy, form the

foundation for cooperation and communication within design teams and are pivotal to the successful progression of the design thinking process. Specific skills, such as prototyping, iteration, and visualization, play significant roles in the design thinking process, facilitating the transformation of ideas into tangible forms and the swift validation and enhancement of design solutions.

In the realm of design thinking, a profound understanding of the design thinking process model and the key competencies can augment the efficacy of design practices, foster innovation, resolve intricate problems, enhance team collaboration, and nurture individuals with holistic capabilities. Design thinking can help the design team in organizing and directing the design process in a more logical and systematic manner, ensuring that the team possesses the necessary capability support at various stages. By employing unique design thinking models and skills, designers can address diverse types of problems with greater flexibility and generate more innovative and practical solutions. Furthermore, designers can gain a clearer understanding of each other's roles and responsibilities in the design process, communicate and collaborate more effectively, stimulate their own continuous learning and development, and advance the progression of design projects. Additionally, design thinking not only plays a guiding role in cultivating talents in the design field, but also holds significant value for enterprises and organizations in the process of innovation and development journey.

The design thinking process model can provide direction for future applications in different fields. The interdisciplinary and flexibility of design thinking can cater to the requirements of diverse fields and offer innovative concepts and methods for solving a range of complex problems. In the context of promoting education and talent cultivation, design thinking will pay more attention to cultivating students' comprehensive and practical abilities, emphasizing

the cultivation of interdisciplinary cooperation and innovative thinking to meet the evolving needs of the future design field. In terms of advancing product development and tool innovation, design thinking will concentrate on actual needs and innovation processes, in conjunction with emerging technologies and methods, to provide more effective and convenient support for design practice. In terms of fostering social practice and strategic innovation, design thinking will focus on the exploration of practical issues and applications and integrate different research methods to provide more comprehensive theoretical support and guidance for design practice and innovation.

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Appendix 2 Expert interview questions

Elderly Center Activity Participant Satisfaction Survey

1. How often do you participate in the activities offered by the center each week?
2. On a scale of 1 to 10, how satisfied are you with the activities provided by the center? Please explain your rating.
3. Which specific activities do you enjoy the most, and why do you find them appealing?
4. How have the center's activities impacted your overall well-being and social interactions?
5. What improvements or additional activities would you like to see offered at the center?
6. Do you find the activities accessible and easy to participate in? If not, what challenges do you face?
7. How would you describe your interactions with the staff during the activities?
8. Do you feel supported and engaged?
9. In what ways do you feel the center fosters a sense of community among participants?
10. How do you prefer to provide feedback about the activities and services offered by the center?
11. What has been your overall experience at the center, and how has it influenced your daily life?

Appendix 3 Elderly center activity participant satisfaction survey

Part 1	Understanding of design thinking
	1. How do you define design thinking in your professional practice or research? 2. Can you describe how design thinking is applied in your current projects or studies? Design Thinking Capabilities 3. In your opinion, what are the key capabilities or skills that constitute design thinking? 4. How do these capabilities differ between novices and experts in the field of design?
Part 2	Measurement of design thinking
	5. Are you aware of any existing methods or tools that measure design thinking abilities? If yes, what are their strengths and weaknesses? 6. What challenges do you foresee in developing a scale that accurately measures design thinking abilities? Necessity and Feasibility 7. How important do you think it is to have a standardized scale for measuring design thinking abilities? 8. From your experience, what factors should be considered to ensure the scale is both valid and practical?
Part 3	Application of the scale
	9. How could such a scale be useful in your field or industry? 10. What impact do you think a reliable design thinking scale could have on professional practice or education in design? Suggestions for Scale Development 11. What features or characteristics would you consider essential for a design thinking scale? 12. Could you suggest any specific methodologies or approaches that should be used in the development of this scale?
Part 4	Final thoughts
	13. Do you have any additional thoughts or suggestions regarding the assessment of design thinking capabilities? 14. Is there anyone else you think we should speak to or any additional resources you recommend consulting as part of this research?

Appendix 4 Design Thinking Capability Scale

Hong Kong Polytechnic University School of Fashion and Textiles
香港理工大學時裝與紡織學院

This questionnaire aims to assess design thinking capability from an individual's perspective. Please spend a few minutes to answer the following questions. The personal data provided will be collected and only used academically to compile aggregate statistics. Aggregate statistics refer to a form of survey results in which the individual data subjects will not be identified. The confidentiality of the information you provide will be carefully protected. Thank you for your participation.

此問卷調查旨在測試個人的設計思維能力。請您用數分鐘的時間回答以下問題。你所提供的個人資料，將會被收集作為總體統計之學術用途。有關資料只供本調查使用。總體統計是指一種概括性的調查結果，個別人仕的資料或數據將不會被顯示。我們將會小心處理你所提供的資料，並嚴加保密。多謝您的參與。

Design Thinking Capability Scale

Please spend a few minutes to answer the following questions. 請您用數分鐘的時間回答以下問題。

Personal Information 個人基本資料

1. Date 日期 _____

2. Have you taken any design thinking related course? 是否上過設計思維的課程? Yes 是 ☐ No 否 ☐

3. Faculty 學系 _____

4. Age 年龄 _____

5. Sex 性別 Male 男 ☐ Female 女 ☐

Please rate the following statements based on your level of agreement, where 1 indicates "strongly disagree" and 7 indicates "strongly agree":

請根據您的同意程度對以下陳述進行評分，其中 1 表示 "強烈不同意" ，7 表示 "強烈同意" ：

		Strongly disagree 強烈不同意						Strongly agree 強烈同意
1	When someone else is feeling excited, I tend to get excited too. 當別人感到興奮時，我往往也會感到興奮。	1	2	3	4	5	6	7
3	I can tell when others are sad even when they do not say anything. 即使別人什麼都不說，我也能看出他們在難過。	1	2	3	4	5	6	7
3	I find that I am "in tune" with other people's moods. 我發現自己與別人的情緒 "心有靈犀"。	1	2	3	4	5	6	7
4	I get a strong urge to help when I see someone who is upset. 當我看到別人不開心時，我會產生強烈的幫助衝動。	1	2	3	4	5	6	7
5	When engaging with others, I often actively listen to their concerns, emotions, and experiences without interrupting or judgment. 在與他人接觸時，我經常會積極傾聽他們的擔憂、情緒和經歷，而不會打斷或評判他們。	1	2	3	4	5	6	7
6	When facing conflicting opinions, I am open to revising my ideas to meet the needs of the end users. 面對相互衝突的意見，我願意修正自己的想法，以滿足最終用戶的需求。	**1**	**2**	**3**	**4**	**5**	**6**	**7**
7	I prefer to trust the users' evaluation results rather than the data analysis report. 我更願意相信用戶的評估結果，而不是資料分析報告。	**1**	**2**	**3**	**4**	**5**	**6**	**7**
8	When solving a problem, I often engage in user research and empathy-building activities to gain deep insights into their challenges and aspirations. 在解決問題時，我通常會參與用戶研究和建立同理心這類的活動，以深入瞭解他們所面臨的挑戰和願望。	**1**	**2**	**3**	**4**	**5**	**6**	**7**

9	When solving a problem, I collaborate with users or stakeholders to co-create problem statements and ensure alignment with their needs. 在解決問題時，我會與用戶或負責人一起，共同進行問題陳述，並確保與他們的需求保持一致。	1	2	3	4	5	6	7
10	When solving a problem, I try to rethink the current understanding to develop a deeper insight into it. 解決問題時，我會嘗試重新思考當前的理解，以便對問題有更深入的瞭解。	1	2	3	4	5	6	7
11	I prefer to list all required conditions based on my understanding before solving problems. 在解決問題之前，我傾向於根據自己的理解列出所有必要條件。	1	2	3	4	5	6	7
12	When I have a problem, I think of as many possible ways to handle it as I can until I can't come up with any more ideas. 當我遇到問題時，我會盡可能多地思考可能的處理方法，直到想不出更多的主意為止.	1	2	3	4	5	6	7
13	I prefer to define each problem carefully before trying to solve it. 在嘗試解決問題之前，我更願意仔細界定每個問題。	1	2	3	4	5	6	7
14	I'm skilled at identifying the root causes of problems rather than addressing the symptoms. 我善於找出問題的根源，而不是治標不治本。	1	2	3	4	5	6	7
15	Ideation and creativity 我喜歡探索新的想法和觀點，並積極尋找機會接觸或學習不熟悉的概念。	1	2	3	4	5	6	7
16	I often find myself coming up with unique solutions to problems and frequently I challenge traditional approaches and think outside the box. 我經常發現自己能提出獨特的解決問題的方案，並經常挑戰傳統方法，跳出框框。	1	2	3	4	5	6	7
17	I feel comfortable expressing my creativity and often engage in creative activities such as writing, drawing, designing, creating, filming, programming, cooking, crafting, etc. 我樂於表達自己的創造力，經常參與創造性活動，如寫作、繪畫、設計、創作、攝影、程式設計、烹飪、手工製作等。	1	2	3	4	5	6	7
18	I believe in my ability to generate original ideas and I trust my intuition and take risks in expressing my creativity. 我相信自己有能力產生獨創性的想法，我相信自己的直覺，並在表達自己的創造力時敢於冒險。	1	2	3	4	5	6	7
19	When faced with a complex problem, I tend to allocate time to developing a strategy to collect information that would help define the nature of the problem. 面對複雜問題時，我傾向於花時間制定策略，收集有助於確定問題性質的資訊。	1	2	3	4	5	6	7
20	When solving a problem, I prefer to consult someone with similar experience and adjust based on the advice as opposed to following a plan to the letter. 在解決問題時，我更願意向有類似經驗的人請教，並根據建議進行調整，而不是完全按照 計畫行事。	1	2	3	4	5	6	7
21	I am open to feedback and suggestions from others by seeking input from different sources to broaden my thinking and incorporate diverse perspectives. 我樂於接受他人的回饋和建議，通過尋求不同來源的意見來拓寬我的思路並吸納不同的觀點。	1	2	3	4	5	6	7
22	I am comfortable with brainstorming and generating a large quantity of ideas to expand my creative possibilities. 我善於集思廣益，得到大量想法，以提升我的創造力	1	2	3	4	5	6	7

23	I am comfortable thinking about something new, different from what already exists. 在現有事務的基礎上，我能產生新的想法。	1	2	3	4	5	6	7
24	I enjoy exploring multiple possibilities and generating a wide range of ideas. 我喜歡探索多種可能性，產生更多的想法。	1	2	3	4	5	6	7
25	When faced with a tough problem, I prefer to simulate real-life scenarios in my head, testing and validating ideas before finalizing a solution. 面對棘手的問題，我更喜歡先在腦海中模擬現實生活中的場景，在最終確定解決方案之前測試和驗證各種想法。	1	2	3	4	5	6	7
26	I enjoy experimenting with different materials and tools to bring ideas to life. 我喜歡嘗試使用不同的材料和工具來實現創意。	1	2	3	4	5	6	7
27	I can quickly translate ideas into tangible prototypes. 我能迅速將無形想法轉化為有形的實踐。	1	2	3	4	5	6	7
28	I often engage in rapid prototyping techniques to explore and validate different design concepts. 我常常利用快速原型技術來探索和驗證不同的設計概念。	1	2	3	4	5	6	7
29	I am comfortable with embracing failure and using it as an opportunity for learning and improvement. 我能夠接受失敗，並把它作為學習與提高的機會。	1	2	3	4	5	6	7
30	I am open to making changes and iterating on my prototypes based on user feedback to enhance user experiences. 我樂意根據使用者回饋對原型進行修改和反覆運算，以提升用戶體驗。	1	2	3	4	5	6	7
31	I'm open to pushing the boundaries of traditional solutions and experimenting with innovative concepts. 我願意突挑戰統解決方案的界限，嘗試創新的概念。	1	2	3	4	5	6	7
32	I often seek feedback from others (users or stackholders) to gather insights for improvement. 我經常向其他人（用戶或利益相關者）徵求回饋，以獲得改進的洞察。	1	2	3	4	5	6	7
33	I enjoy exploring alternative solutions and refining my prototypes based on user feedback and new insights. 我喜歡探索備選方案，並根據使用者回饋及新的見解對我的原型進行完善。	1	2	3	4	5	6	7

The personal data provided will be collected and only used academically to compile aggregate statistics. Aggregate statistics refer to a form of survey results in which the individual data subjects will not be identified. The confidentiality of the information you provide will be carefully protected. Thank you for your participation.
你所提供的個人資料，將會被收集作為總體統計之學術用途。有關資料只供本調查使用。總體統計是指一種概括性的調查結果，個別人仕的資料或數據將不會被顯示。我們將會小心處理你所提供的資料，並嚴加保密。多謝您的參與。

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