NURTURING DESIGN THINKING IN DESIGN EDUCATION IN CHINA

LI YATING

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LI Yating

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Certificate of Originality

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written, nor material that has been accepted for the award of any other degree or diploma, except where due acknowledgement has been made in the text.

Yating Li, Tina

Dedication

Abstract

Nurturing design thinking is widely discussed in educational research. However, there is a significant gap in pedagogical studies within this field in mainland China, with existing studies focusing primarily on theory. To address this lack of empirical research, a qualitative methodology was employed to identify educators' understanding of design thinking, their pedagogies, students' understanding, and the impact on students' problem-solving approaches.

The study selected 23 design courses across higher educational institutions in China, categorized into three clusters. In clusters 1 and 2, design thinking is an important teaching component. Cluster 1, which includes 10 project-based courses, focuses on identifying teachers' understanding of design thinking and their pedagogies, as well as students' understanding and its internalization in problem-solving. Cluster 2 consists of 10 lecture-based courses, aiming to further explore teachers' understanding. Cluster 3 includes three project-based courses that do not explicitly mention design thinking, identifying how it is nurtured through practice.

Multiple data collection methods were employed. In clusters 1 and 3, data were collected from 13 educators and 93 students using documentation techniques, semi-structured interviews, and the experience sampling method. Each educator took one interview. Each student took two interviews at different points in the course. Various documents such as course materials, student notes, reflective journals, assignments, and design works were collected. In cluster 2, document analysis was used.

A pilot study of two courses in cluster 1 confirmed feasibility of the research design, particulary data collection methods. Subsequently, interview questions were refined for clarity. These refined questions were implemented in the other 11 courses in clusters 1 and 3. Once all data were collected, thematic analysis was employed.

Findings reveal different understandings and pedagogies of design thinking among teachers, varying levels of student understanding, and various impacts on students' problem-solving approaches, mindsets, and attitudes. This study contributes

significant knowledge on nurturing design thinking within higher educational institutions in mainland China.

Publications arising from the thesis

Li, Y., & Ma, H. (2022). Exploring the Concept of Design Thinker in Western and Chinese Contexts. Human Factors in Communication of Design, 49, 51.

Li, Y., Ma, H., & Wong, Y. (2024) Beyond Limits: Enhancing Creativity by Breaking Perceptual Blocks in Design Flow. Cumulus Beijing 2023.

Li, Y., Ma, H., & Zhao, D. (2024). A study of student's learning experience impacted by using AIGC tools in design courses in China. DRS 2024 BOSTON.

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Contents

List of Tables

List of Figures

Chapter 1 Introduction

The introduction chapter offers an overview of the research conducted in this study. It commences with the inspiration behind undertaking an empirical investigation into fostering design thinking within higher educational institutions in China. Subsequently, the research background is provided, followed by an identification of the existing knowledge gap in the field. This chapter also outlines the research aim and objectives, as well as details the research approach and design.

1.1 Inspiration

From my experience as a graduate of Tsinghua University, a leading design school in mainland China, I've realized that despite receiving a comprehensive design education, I still struggle to articulate the concept of design thinking clearly. Each teacher had a different interpretation and approach to teaching design thinking, sparking my interest in understanding it better. After completing my studies, I began a career as a university lecturer at Jiangsu Ocean University. Transitioning into this role, I encountered significant challenges in teaching design thinking. Through discussions with colleagues and friends at other design schools, I realized many shared my confusion about effective methods for nurturing design thinking. This led me to contemplate researching how to nurture design thinking in China.

To begin, I conducted an initial literature review, searching academic databases for articles on design thinking education. It became clear that there is a lack of empirical studies specifically within Chinese design schools. Of the limited papers that discussed teaching design thinking, few focused on project-based courses. Based on this initial understanding, I am motivated to conduct an empirical study exploring the teaching and learning of design thinking in mainland Chinese design schools.

1.2 Research Background

The concept of design thinking is a widely discussed topic. Many universities around the world emphasize the importance of design thinking education. However, due to the developmental stage of design education in China, nurturing design thinking is still in its early phases. There are few studies on fostering design thinking in China, and this research is conducted against this backdrop.

Popularity of Discussions on Design Thinking

The rising popularity of design thinking is evident on a global scale, particularly amidst the unprecedented challenges spanning economic, technological, social, and

personal spheres. These challenges defy conventional solutions and demand innovative approaches.

Design thinking is an innovative problem-solving method that fosters new thinking styles and unlocks new avenues for addressing problems. Its human-centric approach is highly relevant in a world where adaptability, innovation, and collaboration are crucial. As individuals navigate dynamic job markets and evolving economies, the ability to think creatively, communicate effectively, and work synergistically with others becomes important. Design thinking, with its emphasis on designer's thinking style, is well-suited for these contemporary demands. This approach is being embraced in educational and professional settings globally as an effective means to tackle challenges in problem-solving. The discussion on design thinking education in China is still in an early stage. We find the knowledge gap through a literature review in Chapter 2.

What is Design Thinking

There is no single, unifying definition of design thinking. In this research, we discuss design thinking as a problem-solving approach used by designers. From this perspective, design thinking encourages a holistic approach to problem-solving. Unlike traditional methods that often follow a linear path, design thinking embraces a non-linear, iterative process.

Design thinking is not only about the commonly discussed models such as five-stage process (empathize, define, ideate, prototype, and test) but also includes essential elements that form a designer's mindset. These aspects include a holistic consideration of problems, an iterative process, a creative thinking style, and the use of cognitive tools. By applying these mindsets, design thinking empowers individuals and teams to tackle complex challenges with innovation. These mindsets are crucial for design thinkers to solve problems successfully, and we will review the historical development of design thinking and explore the key concepts further in Chapter 3.

Development of Design Thinking Education

The integration of design thinking into conventional education systems is a topic of extensive discussion. Design thinking, with its focus on creative problem-solving, complements traditional education by fostering a more innovative mindset. Significant progress has been made, particularly in business schools and online courses. Although design schools initially did not emphasize the term design thinking, they are gradually beginning to recognize its importance. As educators worldwide navigate these complexities, blending traditional problem-solving approaches with design thinking becomes increasingly important for nurturing future problem-solvers. Many design schools abroad have already conducted extensive research on teaching design thinking, which will be discussed in Chapter 4.

Development of Design Thinking Education in China

Design thinking education is just beginning in China. In the past decade, many design schools have started to focus on design thinking as a training goal. While China undergoes rapid changes, there is a growing recognition of the need to foster creativity and innovation in its education system. Only in recent years have teachers started to pay attention to these teaching methods. In Chapter 2, our search for papers related to design thinking education revealed few empirical studies. There is still much work to be done. Closing this knowledge gap is essential for the advancement of design education in China.

1.3 Knowledge Gap in Design Thinking Education

In 2021, I began my research by searching for studies on design thinking in university-level design education in China using CNKI (Chinese National Knowledge Infrastructure) at first. This search yielded 223 results. After reviewing the full content of these papers, 24 were found to be relevant, discussing design thinking education in Chinese design schools. Conducting the same search on English databases (Web of Science, Scopus, ProQuest, ScienceDirect, Taylor & Francis, Wiley Online, EBSCO, and JSTOR) revealed only an additional 7 papers. Of all these

31 related papers, only 12 papers focused on pedagogy. This highlights a significant lack of empirical research in design thinking education in China.

1.4 Research Aim and Objectives

This research aims to bridge the gap of insufficient empirical research in the teaching and learning of design thinking in universities in mainland China. To achieve this aim, four research objectives are presented as follows:

- **Objective 1:** To investigate educators' understanding of design thinking.
- **Objective 2:** To identify the pedagogies educators use in teaching design thinking.
- **Objective 3:** To explore students' understanding of design thinking from the pedagogies they receive.
- **Objective 4:** To examine how students' understanding of design thinking impacts their problem-solving abilities.

1.5 Research Approach and Design

To achieve the research objectives, qualitative research is adopted in this study. Samples are selected using a purposive sampling method. Ten lecture-based design courses and thirteen project-based design courses are selected for this research. Thirteen educators and ninety-three students participated. Data were collected from each participant through multiple methods, such as observation, document analysis, semi-structured interviews, and experience sampling. Data were analyzed using thematic analysis. The following sections explain the approaches and research design.

Research Sampling

This research employs a qualitative methodology, using purposive sampling to select relevant design courses in higher educational institutions in China. The selection criteria include: (1) the subject is from a design discipline; (2) design thinking is taught explicitly as a key component; (3) documents are available and accessible; (4)

participants are with high willingness. Based on these criteria, 10 design subjects were selected as cluster 1. They are project-based courses that explicitly include design thinking as a core component in the teaching material.

To gain insights into teachers' understanding of design thinking, another 10 lecture-based courses were selected as cluster 2. Cluster 2 consists of lecture-based courses related to design thinking, such as online courses from massive open online courses (MOOC) platforms and theoretical subjects in universities. However, since design thinking is more than just explicit knowledge to teach, it is also a problem-solving approach in design practice. To further understand how design thinking is nurtured, 3 additional project-based design courses that do not explicitly claim to teach design thinking were selected as cluster 3.

These 23 design courses were selected for data collection.

Data Collection

Data collection was conducted from September 2022 until December 2023. The data collection methods included observation, document analysis, semi-structured interviews, and experience sampling. Data were collected from the three clusters of design courses.

In cluster 1, data collection included documentation techniques and semi-structured interviews with educators and students, as well as experience sampling methods to gather data from different time points. Almost all students participated in 2 interviews, and their notes, assignments, and reflective journals from the course were collected. Each teacher participated in one interview and provided program information and teaching materials.

In cluster 2, data collection was based on documentation methods. Findings from cluster 2 served the first research objective, identifying educators' understanding of design thinking.

In cluster 3, data collection adopted the same methods as cluster 1. The data collected from cluster 3 addressed research objectives two to four.

Finally, we collected 190 one-hour interview transcripts and various documents generated from every students' design process.

Data Analysis

This research employs thematic analysis. The collected data were first converted into anonymous transcripts, with participants' names and personal information anonymized. The transcripts were then analyzed using the software MaxQDA.

Findings 1 to 5 are derived from Clusters 1 and 2, these findings helped identify educators' understanding of design thinking, addressing research question one.

Findings 6 to 10 originate from Cluster 1, these findings identified teachers' pedagogies of design thinking, addressing research question two.

Findings 11 to 20, derived from Clusters 1 and 3, provided additional insights from Cluster 3 to understand students' comprehension of design thinking in these courses. It was observed that a few students transformed through design thinking, addressing research questions three and four.

This study contributes to the knowledge of nurturing design thinking in higher educational institutions in mainland China. It will be beneficial for design educators in mainland China to advance pedagogy in nurturing design thinking, offering more understanding of how students learn design thinking and the impact of this understanding. The findings of this study can be applied by design educators to improve students' learning outcomes in design thinking.

Here is a figure for the research structure.

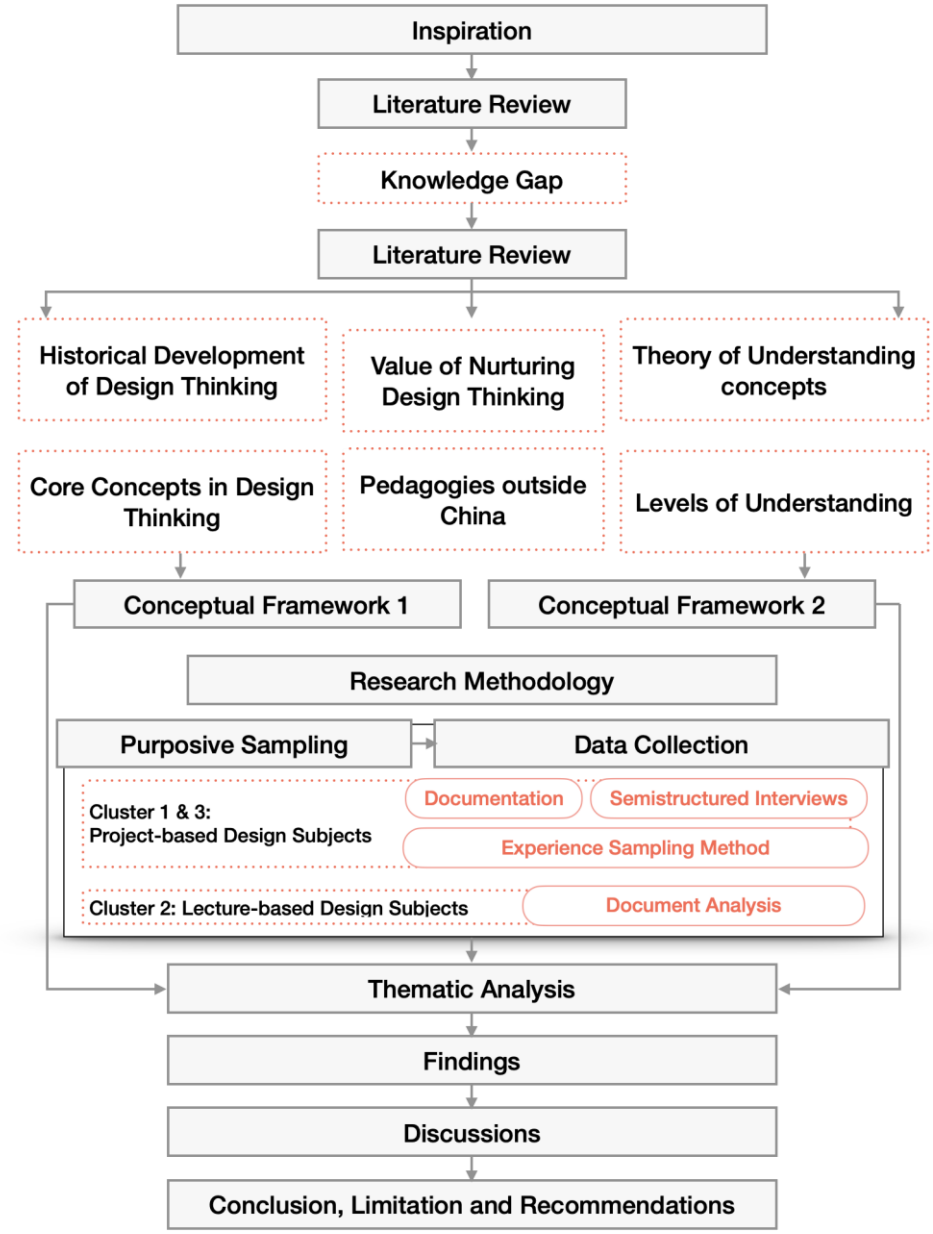

FIG. 1 Research structure

1.6 Chapter Summary

This chapter introduces the research background, emphasizing the importance of design thinking in design education and the gaps in empirical research on its teaching in universities in China. This chapter outlines the research objectives to address the identified knowledge gap. And it also explains the research approach, including qualitative methods, purposive sampling, and data collection techniques. This chapter also describes the data analysis methods and finding sources.

Chapter 2 Research Significance

This chapter delves into the rationale behind conducting the study, emphasizing its significance, identification of knowledge gaps, research objectives, and research questions. The significance of fostering design thinking in design education spans various realms, including national policy, school education, and designers' career development. However, the approach to nurturing design thinking lacks sufficient research. The knowledge gap stems from the literature review, where research on the pedagogies to nurture it remains vague. This research seeks to bridge this gap, and four research questions are proposed.

2.1 Significance of Nurturing Design Thinking in China

In light of the rising trend and growing popularity of design thinking, it is crucial to cultivate and integrate design thinking into design education in China. By fostering this mindset, we can better prepare students to tackle complex problems and become more competitive.

2.1.1 Value of Design Thinking in Design Education in China

Nurturing design thinking in China holds significant potential for driving innovation, enhancing competitiveness, and addressing complex societal challenges. As China transitions from a manufacturing powerhouse to a leader in technological and creative industries, embracing design thinking can facilitate a cultural shift towards more human-centric and sustainable solutions. This approach encourages interdisciplinary collaboration, critical problem-solving, and a deep understanding of user needs, which are essential for developing products and services that can compete globally. Moreover, design thinking can play a crucial role in tackling local issues such as urbanization, healthcare, and environmental sustainability, by fostering creative solutions tailored to the unique context of Chinese society.

2.1.2 Design Thinking is One of the Core in Design Discipline

Design thinking is fundamental to the design discipline, embodying the problem-solving mindset that defines how designers approach challenges. In design education, particularly in programs focused on problem-solving, cultivating design thinking problem-solving approach and mindset is a key objective (Cross, 2011). These core methods that are essential to effectively addressing and resolving problems.

As the discipline has evolved, design developed its independent methodology. Originally developed as a structured way to tackle complex problems, it now plays a crucial role in design practice. For example, the five stages model emphasizes empathy, define, creative ideation, prototyping, and testing. These stages work

together in an iterative way to foster a deep understanding of human needs and drive innovative solutions (Dorst, 2011).

The impact of design thinking has extended the scope of design beyond traditional boundaries. It now includes strategic and systemic challenges, allowing designers to engage more deeply with social, economic, and environmental issues (Panke, 2019). This broadening of focus has made design thinking a foundational component of the discipline, essential for addressing the diverse and complex problems faced by designers today.

2.1.3 Design Thinking Makes Students Competitive in Career

Design thinking gained its popularity for it has a positive change in approaches to our learning and solving problems (Dym et al., 2005; Fricke, 1999; Nagai & Noguchi, 2003). It is one of the skills we need to become successful in today's environment of highly developing technology and global competition(Buchanan, 1992). It is not only a dispensable part of design and engineering disciplines but also attracts large attention from the business field since design and its thinking style in service or product becomes an advantage in competitiveness, and many companies endeavour to be design leaders (Dunne & Martin, 2006). In the academic context, design thinking benefits students across disciplines for it generate solutions with creativity. Critical thinking, logical reasoning and complex problem-solving are required for 21st-century students (Rotherham & Willingham, 2009).

2.2 Knowledge Gap in Design Thinking Education

To understand the teaching of design thinking in Chinese universities, I first conducted a scoping review and found a limited number of 31 related articles. Then, the knowledge gap in this research field was identified.

2.2.1 Scoping Review

Because I was interested in how design thinking is taught in design education within mainland China and wanted to understand the current state and potential research topics in this field, I conducted a scoping review using relevant databases. This review was conducted following the PRISMA methodology. Below is the PRISMA flow diagram for this review.

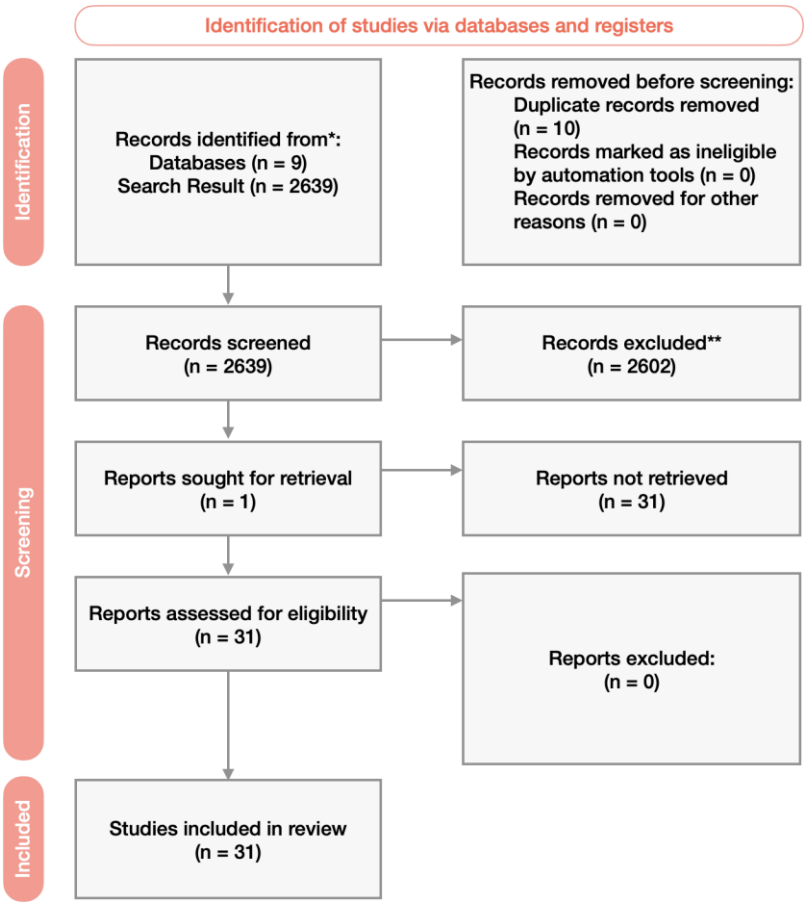

FIG. 2 PRISMA diagram

Here are the steps for the review. First, we needed to select appropriate databases. Below are the chosen databases, along with the reasons for their selection. Advanced search parameters in these databases were used to identify literature on design thinking education in design colleges within universities in mainland China.

TABLE.1 Selection of Databases

Database	Selection Reason
CNKI (Chinese National Knowledge Infrastructure)	Authoritative access to Chinese academic publications is essential for understanding the context and developments in design education within China.
WOS (Web of Science)	Provides extensive coverage of high-impact journals and conference proceedings, making it useful for identifying influential and highly cited research in design education.
Scopus	Offers a broad range of peer-reviewed literature across various disciplines, ensuring comprehensive coverage and access to up-to-date research in design education.
ProQuest	Includes a vast collection of dissertations, theses, and academic papers, which are valuable for in-depth research and for understanding emerging trends in design education.
ScienceDirect (Elsevier)	Provides access to a wide array of scientific and technical research, which is particularly beneficial for interdisciplinary studies involving design and technology in education.
Taylor & Francis	Offers a diverse collection of high-quality academic journals and books, providing resources in design education.
Wiley Online Library	Offers access to a wide range of academic journals and books, ensuring comprehensive coverage of both theoretical and applied research in design education.
EBSCOhost (Academic Search Premier)	A multidisciplinary database with a robust collection of academic journals, it offers a wide range of research articles that are relevant to design education.
JSTOR	Provides access to both archival and current academic journals, which are essential for historical research and understanding the evolution of design education theories and practices.

After selecting the databases, we used the following search string on each one. The first step in the PRISMA process is the identification of relevant papers using search strings. When searching for papers in Chinese, we used Chinese in the search strings. Here are a table of search strings used in this research, and it presents the search strings from the advanced search in these databases.

TABLE.2 Search Strings in Databases

Database	Search String and Conditions
CNKI	Search string A：((su='设计思维' or su='設計思維' or title='设计思维' or title='設計思維') AND (ab='大学' or ab='大學') AND (su='教学' or su='教學' or title='教学' or title='教學')) AND (PY Between('1915-01-01','2021-12-31'))。
	Search string B：((KY='设计思维' or KY='設計思維') AND (AB='大学' or AB='大學')) AND (PY Between('1915-01-01','2021-12-31'))。
WOS (Web of Science)	((((ALL=('design thinking')) AND ALL=('design education')) AND ALL=(China)) AND ALL=(university)) AND PY=(1990-2021)
Scopus	TITLE-ABS-KEY-AUTH (''design AND thinking'') AND ALL (university) AND ALL (''design AND education'') AND ALL (china) AND PUBYEAR > 1993 AND PUBYEAR < 2022 AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "PSYC") OR LIMIT-TO (SUBJAREA , "ARTS")) Note: In the refined search, select the years 1994-2021, the three subject categories social sciences, psychology, arts and humanities, and restrict the document types to articles and reviews.
ProQuest	su("design thinking") AND su("design education") AND su("university") AND su(‘'China") PY= 1990-2021 Note: Select literature types review articles and research articles, qualify full-text articles and peer reviewed.
ScienceDirect (Elsevier)	(‘design thinking') AND ('design education') AND ('university') Note: In the refined search, select the years 1990-2021, the three subject categories social sciences, psychology, arts and humanities, and restrict the document types to articles and reviews.
Taylor & Francis	[All: design thinking] AND [All: design education] AND [All: china] AND [All: university] AND [All Subjects: Education - Social Sciences] AND [Article Type: Article] AND [Publication Date: (* TO 12/31/2021)]
Wiley Online Library	'design thinking' in Keywords AND 'design education' in anywhere AND 'China' in anywhere AND 'university' in anywhere
EBSCOhost (Academic Search Premier)	design thinking AND design education AND university AND China. Peer Reviewed. Publication Date: 19900101-20211231
JSTOR	((((("design thinking") AND ("design education")) AND (university)) AND (China)) AND la:(eng OR en) Note: select Publication date 1990-2021 and select academic content of journals Select subject - education

The second step is screening. By reading titles, abstracts, and article content, academic journal articles related to mainland Chinese universities, design education were manually selected. Then, duplicates were removed.

The third step is to check eligibility. This involves verifying if the full text of the articles is available and removing any retrieved articles that do not meet the criteria.

The fourth step is to summarize the number of included articles.

Below are the results of the scoping review. A total of 2639 articles were identified through the search. During the screening phase and removing duplicates, 31 articles remained for eligibility checking. Ultimately, 31 articles were included.

TABLE.3 PRISMA Process

Database	PRISMA Process			
	Step 1: Idenfication	**Step 2: Screening**	**Step 3: Eligibility**	**Step 4: Included**
CNKI	117	20	20	20
	96	5(remove duplication, n=1)	4	4
WOS (Web of Science)	1447	5	5	5
Scopus	644	3 (remove duplication, n=2)	1	1
ProQuest	14	2	2 (remove retrived paper, n=1)	1
ScienceDirect (Elsevier)	216	1 (remove duplication, n=1)	0	0
Taylor & Francis	12	0	0	0
Wiley Online Library	42	1(remove duplication, n=1)	0	0
EBSCOhost (Academic Search Premier)	8	0	0	0
JSTOR	43	0	0	0

2.2.2 Knowledge Gap

After the PRISMA process, we found that the current research on teaching design thinking in universities in China is insufficient on empirical studies. Despite the growing discussion surrounding design thinking, much of the research in China focuses on design thinking education for secondary school students, particularly within STEM or STEAM education contexts (Zhang, Lin & Chen, 2017; Chen, Tian & Huang, 2019; Xia & Ma, 2019). There is a notable scarcity of literature discussing how design thinking is taught in Chinese universities. A scoping review revealed only

31 articles pertaining to design thinking education within mainland Chinese design schools. Some of them only discussed the concept with an absence of empirical study(Qu & Yu, 2019; Zhou & Wang, 2020). These articles with empirical study primarily focus on individual design courses, such as the application of design thinking in graphic design (Zhang, 2019) or animation design (Zhao, Sun & Li, 2018). Consequently, these articles offer only a limited glimpse into design thinking education in China.

Existed Research on design thinking education in China has some issues. Some articles addressing design thinking education fail to clearly define the concept of design thinking or elucidate teaching methods (Zhao, 2014). While there are 12 empirical studies talking about pedagogy, the majority of these are authored by instructors of the respective courses, with many lacking triangulation in empirical research methods (He, 2016). These studies are typically confined to investigating a single course and fail to provide a holistic view of design thinking education in China.

Therefore, there is a pressing need for empirical research to explore the cultivation of design thinking within design disciplines in Chinese higher education. This research aims to address the dearth of comprehensive empirical studies on teaching and learning design thinking in mainland Chinese universities. By collecting data from various sources, this research seeks to contribute to a deeper understanding of design thinking education in China and fill the existing gap in empirical research on the subject.

2.3 Research Aim and Research Questions

In order to bridge the knowledge gap, this study established four specific research objectives: (1) to identify educators' understanding of design thinking; (2) to explore the pedagogies that educators use in teaching design thinking; (3) to explore students' understanding of design thinking; (4) to identify students' changes in problem-solving by applying the design thinking approach.

According to the objectives of this research, this research addresses four research questions:

- RQ1: How do educators understand design thinking?
- RQ2: What pedagogies are educators using to teach their understanding of design thinking?
- RQ3: How do students understand design thinking based on the pedagogies they have received?
- RQ4: How does students' understanding of design thinking affect their problem-solving?

RQ1 How do educators understand design thinking?

This question aims to know educators' concepts of design thinking. These educators conduct design courses that regard design thinking as a core teaching component. Their understanding of design thinking is integrated into the course content. In their classes, they may regard design thinking as a cognitive perspective, a problem-solving approach, a mindset, etc. They may mention some fundamental concepts such as design thinking models and processes. For the study of the teaching of design thinking in China, these teachers' understanding of design thinking becomes very valuable. In addition, the answer to this question is a foundation for designing pedagogy to nurture design thinking in students.

RQ2: What pedagogies are educators using to teach their understanding of design thinking?

This question is concerned with what pedagogical approaches educators use to teach students about problem-solving in design practice. Whether or not a course presents design thinking as a core teaching component in the curriculum plan, students' thinking skills are trained during the practical design process. The purpose of this question is to understand the design of the course process and how educators provide instruction that develops students' understanding of design thinking during the process. Furthermore, it is crucial that students perceive the pedagogy. If a pedagogy is implemented and not well-received by students, it will not be fully effective in helping students to understand design thinking in class.

RQ3: How do students understand design thinking based on the pedagogies they have received?

This question seeks to identify what understanding of design thinking students have built up through the delivery of the subjects. Within this question, students may state some concepts of design thinking and may give some reflections on solving design problems in action. It should be noted that some students may already have knowledge of design thinking prior to the course, and some students may be encountering design thinking for the first time. Knowing what students have learned about design thinking in their previous lessons, and their pre-existing understanding of design thinking can shed light on the effectiveness of the teacher's teaching approach.

RQ4: How does students' understanding of design thinking affect their problem-solving?

This question aims to understand what changes have happened to the students in the course in the process of solving design problems. Students may realize that learning and applying design thinking brings about some changes to their personal status when solving design problems. These changes may be in their cognition of the problem, in their mindset about solving the problem, in their attitude toward solving the problem, or in their motivation to solve the problem. Alternatively, some students may not have changed or may have changed negatively. No matter these changes are positive or negative, the point that needs to be clarified is that whether they are a result of the understanding of design thinking that students have developed from the subjects.

2.4 Chapter Summary

This chapter outlines the significance of the study. It begins by highlighting the value of conducting this research and identifies the knowledge gap through a review of relevant literature. The chapter then presents the study's four research objectives and corresponding research questions, along with a detailed explanation of what each question seeks to explore.

Chapter 3 What is Design Thinking

This chapter introduces the origin of the term design thinking and discusses designers' ways of thinking by researchers from different backgrounds over time. Then the key elements in desig thinking is introduced. A conceptual framework for understanding design thinking is built.

3.1 Historical Development of "Design Thinking"

Design Thinking is at the heart of the design discipline and is generally defined as a designer's approach to problem solving, but it does not yet have a standardised definition. Design thinking refers to the designers' style of seeing and thinking (Liu & Group, 1996). Its iterative process that designers use can benefit them in seeing new ideas emerging in the problem-solving process, in drawing connections between problem solutions and in viewing what will bring further design efforts (Lloyd et al., 1995; Do & Gross, 2001). An innovation framework was theoretically developed to search for the next big idea through designedly ways of thinking (Leifer et al., 2016). Tim Brown mentioned that Design thinking, as a methodology of problem-solving, works efficiently in generating innovative ideas and identifying opportunities to help "reinvent business" (Brown, 2009). The various approaches to studying design thinking, however, make it difficult to define. Design thinking, therefore, is less likely to be fully understood by the public and practitioners (Kimbell, 2011). The conceptions of design thinking are not single, but are unifying and various (Mootee, 2013).

In the design discipline, researchers have begun to discuss the differences between design thinking and the thinking styles of other disciplines. Simon first introduced the concept of design science (Simon, 1969). Razzouk and Shute presented a map of a conceptual representation of content and process factors (Razzouk & Shute, 2012) based on Owen's map of fields in context and process differentiation (Owen, 2007). Even though mapping fields are not considered absolute and relative, it fundamentally shows that the importance of the provision of relationships' comparison by content and process as two dimensions among different fields (Owen, 2007; Razzouk & Shute, 2012). Four quadrants are shown on the map in a circle sequence. And design discipline locates in the fourth quadrant, which means its processes are synthesis and contents are real (Owen, 2007). Design thinking approaches are nurturing people to have the ability of analysis, synthesis and innovation to prepare them to deal with real-world matters. Nevertheless, communications and symbolism bring thinking and working style in design disciplines a symbolic component (Razzouk & Shute, 2012). Besides, design

disciplines use analysis to present the synthesis since it also has an analytic component in its thinking and working patterns (Owen, 2007).

There are a lot of theoratical models of design thinking in popularity nowadays. The two most famous design process models are double diamonds and five stages. First introduced by the British Design Council in 2005, the Double Diamond model provides a structured approach to design thinking by delineating the process into four key phases: Discover (problem identification), Define (problem framing), Develop (solution exploration), and Deliver (solution implementation) - collectively known as the 4D methodology. The two diamonds are metaphors for two divergent and convergent thinking circles. The Five stages model was established by the Hasso Plattner Institute of Design at Stanford. This model is popular for the five phases to empathize, define, ideate, prototype and test or implement. The empathize stage requires us to understand the problem empathetically, on this stage we should have the ability to empathise to be in the position of other people. The defining stage focuses on the problem statement, to identify a definition of the issue. The Ideate stage is a process to generate ideas and solutions for resolving the problem creatively. The prototype stage allows a quick and inexpensive test to mock up the performance of the solutions. The test stage generates results as the last step of the process, but the design thinking process is not implemented in certain order sequentially.

It is essential to know that design thinking is not a linear process. Mostly design thinking process includes a few rounds of divergent and convergent thinking. So the double diamonds might be triple diamonds, quadra diamonds or even much more iterative circles. And the five phases, stages, or modes do not have to follow any specific order and they often happen parallelly and repeat iteratively. This non-linear process is not always sequential. We may jump back and forth in these stages and go back to redefine the problem. It differentiates from the linear conventional problem-solving process for this important character. We go through the non-linear process to expand our knowledge of the problem situation (Simon & Newell, 1971) for a better understanding of the problem. Following the ambiguity rule (Meinel & Leifer, 2012b), we should keep flexibility in defining the problem, and keep refining our problem statement, which will enable us to resolve the actual problem instead of the

issues in our assumption when we understand the situation partially with limited information.

Design researchers' focus on the wicked problem has also contributed to the development of design thinking. When we face wicked problems, we may not able to find out an exemplified set of possible solutions (Conklin, 2006). Mootee claimed in his book Design Thinking for Strategic Innovation, depicted this intuitive and non-systematic process is confidential in emphasizing its application on identifying the real problem with a human-centric approach and implementing ideas by rapid prototyping (Mootee, 2013). To approach a more accessible tool kit to non-design discipline people, a few systematic processes which capture the core principles of the designer in problem-solving have been developed. Nonetheless, Mootee commented that “But design thinking is more than that” (2013).

Design Thinking is not merely a process for problem-solving, but the entire approach that designers use. It is a thinking style and an attitude, which is a core part of the design discipline, and which is developed by design students and designers who learn from their education and experience. Design thinkers do not only follow certain processes or use certain tools to achieve their results but are driven by the behaviours behind the design thinking approach (Cross, 2011). The behaviours of design thinkers in approaching problems include: *Human-centred focus, Holistic considerations, Non-linear process, Creative thinking, Use of cognitive tools, Intuition and subjective thinking, Learning-by-making, Exploring and discovering opportunities* (Ma, 2021). These behaviours benefit the problem-solving process. These behaviours enable them to use the process and the tools to formulate creative solutions that achieve results that exceed expectations. Martin stated on the Rotman School of Management's website that today's businesspeople don't just need to understand designers; they need to become designers themselves. He mentioned the importance of cultivating design thinkers (Martin, 2009).

3.1.1 Design Thinking in 1960s – 1980

The "design method movements" of the 1960s highlighted the design industry's aspiration to approach design with a more scientific perspective. Held in London in

September 1962, the Conference on Design Methods marked the emergence of design methodology as an independent scholarly field, serving as its foundational milestone. During this conference, there was a call for design processes and outcomes to be grounded in objectivity and rationality (J. C. Jones, 1966). Gregory suggested that science is a methodology for understanding the essence of things, while design is constructive, serving as a mode of action for inventing new things (Gregory, 1966).

In 1969, Simon published "The Sciences of the Artificial". He defined design science as an artificial science, distinct from the natural sciences, and characterized design as a way of thinking rather than a physical process (Simon, 1969). Although Simon did not explicitly use the term "design thinking," his theories have been widely cited in the design thinking literature. Simon (1969) posited that while the natural sciences examine 'what is,' design fundamentally addresses 'what ought to be.' His work contributed to the scientific and interdisciplinary foundations of design thinking, reflecting his own diverse academic background.

In addition to the concept of design science, this period also saw a growing focus on wicked problems. In Rittel and Webber discussed various dilemmas in planning theory and first introduced the idea that design is concerned with addressing wicked problems that science and engineering can not deal with (Rittel & Webber, 1973).

3.1.2 Design Thinking in 1980s – 1990

The 1980s witnessed substantial advancements in design methodology, accompanied by the creation of several influential journals that shaped the field's theoretical discourse. These included Design Studies, Design Issues, Research in Engineering Design, The Journal of Engineering Design, and The Journal of Design Management, which provided platforms for scholarly exchange and methodological development. While the articles in these journals were still explicitly grounded in scientific methods, there was a noticeable effort by design methodologists to distinguish the design discipline from science (Cross, 2001).

The epistemological foundations of design, distinct from those of the natural sciences, emerged as a significant scholarly discourse. Cross's (1982) foundational work "Designerly Ways of Knowing" articulated design as both an intellectual discipline

and professional practice, characterizing design thinking as a distinctive mode of cognition that informs and structures design activity. He introduced the concept of "designerly ways of thinking," emphasizing that design thinking is the cognitive style of designers. Cross's (1982) theoretical framework characterizes design practice through several distinctive features: the treatment of ill-defined problems, a solution-focused problem-solving orientation, constructive thinking processes, and the use of design codes that mediate between abstract requirements and concrete realizations. These codes function as a semiotic system through which designers both interpret ("read") and create ("write") material artifacts. Specifically, experience in a particular field enables designers to quickly identify problems and propose solutions. Generating, synthesizing, and evaluating a solution is often considered a key characteristic of design expertise. Designers should be able to evaluate conditions in specific situations and quickly adjust their actions accordingly. Cross believed that designerly thinking seems to be a characteristic of design thinking, primarily derived from design experience.

Criticism of Simon's concept of 'design science' also began to emerge. In 1983, Schön viewed design practice as a reflective conversation between a person and the various elements of a problem situation (Schön, 1983). Schön argued that Simon's notion of 'design science' was still rooted in solving well-formed problems, whereas design should address messy and problematic situations. He characterized design as a "reflective practice." Schön's ideas of reflective practice and context-dependent design theory inspired subsequent researchers to delve deeper into the concept of design.

The term "design thinking" was formally introduced into academic discourse through Rowe's 1987 seminal publication of the same name (Rowe, 1987). Following this conceptual milestone, the terminology gained widespread adoption within design research communities, eventually entering the field's collective lexicon as a fundamental concept (Razzouk & Shute, 2012). Over the following decades, numerous design thinking models emerged across various fields, each based on different observations of design contexts. This period also saw an increasing effort to define "design thinking" clearly and explicitly.

3.1.3 Design Thinking in 1990s – 2000

Schön's concept of 'reflective practice' was further developed during several 'design thinking research' conferences in the 1990s. In the first design thinking research conference in 1992, Cross mentioned that 'research in design thinking' focuses on understanding how people design (Cross, 1992). He published *Analysing Design Activities* with a few design researchers in 1996 (Cross et al., 1996). Cross argued that design is an independent discipline based on reflective practice and that as an independent discipline, design must develop its own theory and research approach (Cross, 1999b).

At the same time, with the shift in design's focus towards problem-solving, wicked problems gained attention. In his 1992 article "Design Thinking in the Wicked Problems," Buchanan linked Rittel's wicked problems with design thinking, redefining the role of the designer as design increasingly became a way of thinking (Buchanan, 1992). He viewed design thinking as a methodology for innovative solutions to wicked problems, further establishing problem-based design thinking research and practice. Buchanan considered the professional mindset of designers as a means of tackling wicked problems, which are fundamentally uncertain social system issues with no single solution and require substantial creativity to resolve. In 1998, Akin discussed that the field of design includes product design, engineering, as well as social policy and management. He introduced the idea of "descriptive model of design" and emphasized that design research should focus on the process of practice. Akin also noted that with the globalization of markets, the demand for addressing social and environmental issues has grown beyond the traditional scope of problem-solving (Akin, 1998). In 1999, Cross highlighted that design is not about finding the optimal solution to a given problem but is exploratory, with designers discovering new things rather than returning to familiar examples (Cross, 1999a).

3.1.2 Design Thinking in 2000s – 2010

With the introduction of the Design Thinking Research Symposium in 1999, design research began to focus on the role of representations in design thinking (Cross, 2018). In subsequent conferences, discussions expanded to include the need for design methodologies that study the activities within the design process, as well as the

consequences and impacts of these activities. During this period, discussions and explorations of design thinking representations started to emerge across various fields.

As a foundation in the history of design thinking theory, IDEO's business management theories have played a significant role. The company actively commercialized design thinking, becoming a pioneer in its education and promotion. In 2005, IDEO founder Kelley established the renowned Stanford d.school, which has become a leading center for academic research on design thinking. As a global leader in design, IDEO views design thinking as an innovative work method and design as an innovation management strategy (Brown, 2008).

Brown (2008), then CEO of IDEO, contributed one of the field's most influential works through his seminal article "Design Thinking." He conceptualized design thinking as a human-centered innovation methodology that synthesizes three core elements: user needs, technological feasibility, and business viability, mediated through designerly approaches. Brown's commercial orientation articulated design thinking's strategic value in organizational innovation, framing the process as an iterative system of overlapping spaces. This theoretical framework subsequently informed prominent operational models, including IDEO's 3I model (Inspiration-Ideation-Implementation) and the UK Design Council's Double Diamond framework (Discover-Define-Develop-Deliver).

The term "design thinking" quickly gained popularity across various fields. Dunne and Martin discussed its application in business, viewing it as an essential skill for managers to address organizational problems with uncertainty (Dunne & Martin, 2006). Other researchers noted that the innovation model based on design thinking is highly flexible and adaptable (Beckman & Barry, 2007). In design thinking theory, the works by Martin and Brown offer crucial insights into the application and theoretical foundation of design thinking in management innovation (Brown, 2009; Martin, 2009).

In addition to business management, design thinking has also garnered attention in the computer field. Huang used data structures and algorithms from computer technology to simulate designers' sketching processes, aiding in the generation of

creative concepts (Y. Huang, 2008). Brooks, speaking from the perspective of a computer scientist, discussed the insights gained from several conferences on design thinking. He argued that effective design is at the core of all work, whether in software development, engineering design, or architectural design (Brooks Jr, 2010).

3.1.3 Design Thinking in 2010s - 2020

The growing popularity of the term "design thinking" sparked considerable debate, with many arguing that the capacity to design is not an exclusive talent or skill but rather something that can be learned and practiced to improve problem-solving in various professions (Davis, 2010; Cross, 2011).

Dorst views design thinking as a creative activity. In his 2011 publication "The Core of Design Thinking and Its Application," Dorst explained that the core of design thinking is the frame creation, exploring the relationship of design practice and the practice of organizations in five different levels (Dorst, 2011). Dorst sought to identify specific elements within design practice. For example, he highlighted how professional designers use design thinking to create new problem frames, break conventional thinking patterns, and continuously seek innovative solutions through experimentation.

To explore more about on the design process and frame, many researcher focused on implementing design thinking as a cognitive model in design applications. Razzouk's team described design thinking as a systematic process that integrates analysis and innovation (Razzouk & Shute, 2012). Dalsgaard argued that pragmatism and design thinking converge, providing a well-rounded and coherent explanation of the core issues addressed by design thinking. He explored how key concepts in design thinking align with John Dewey's pragmatism, finding that pragmatism can inform and inspire the theoretical development of design discourse (Dalsgaard, 2014). Additionally, he conceptualized design tools based on pragmatism, identifying the key role of tools in design and creative methods (Dalsgaard, 2017). Haupt's (2018) theoretical investigation developed an extended information processing model of design cognition, analyzing both the preliminary phases of design activity and twelve distinctive psychological attributes characterizing expert designers' engagement with

their external environment. This framework advanced understanding of cognitive strategies underlying design innovation. Concurrently, technological progress in computational analytics has enabled new research directions (Haupt, 2018). Rahman and colleagues pioneered a data-driven approach through an integrated platform combining clustering algorithms with design process modeling, demonstrating how machine learning can illuminate previously opaque aspects of design behavior (Rahman et al., 2019).

The transdisciplinary adoption of design thinking has established it as a transformative innovation strategy across diverse domains. Scholarly consensus recognizes its capacity to reconfigure conventional innovation paradigms through human-centered methodologies (Liedtka, 2015). Cognitive research demonstrates its efficacy in mitigating decision-making biases while enhancing innovative outcomes, with institutional adoption evidenced by Stanford University's Executive Education Initiative, which has systematically trained organizational leaders in design thinking implementation (Royalty et al., 2015).

Sector-specific applications reveal its adaptive potential: Olsen's work in food systems highlights its empathic and collaborative value creation (Olsen, 2015), while Altman et al.'s healthcare research demonstrates improved service innovation through patient-provider centered frameworks (Altman et al., 2018). Bhushan further substantiates its methodological robustness, showing how its structured yet flexible approach successfully resolves complex, multidisciplinary challenges in hospitality education contexts (Bhushan, 2019).

3.1.3 Design Thinking in 2020 – now

Design thinking's benefits are increasingly recognized by researchers. Some researchers discussed how design thinking serves as an effective tool to bridge technology and innovation, providing opportunities for the commercialization of technology (Lynch et al., 2021). Some noted that design thinking enables the construction of more efficient management models and frameworks, stimulating organizational innovation potential and more effectively achieving specific goals (Santa-Maria et al., 2022).

As design thinking becomes more popular across various fields, educators are also increasingly discussing its application. Cross primarily discussed the return of professional knowledge in design to designerly ways of knowing and thinking (Cross, 2006). Today, design thinking is widely applied in education, including workshops and short-term courses, practical projects, and experience sharing.

Design thinking aligns with the current need for nurturing innovative talents, providing new directions for design education. When focusing on how students develop skills within courses, researchers have observed that design thinking is transmitted as tacit knowledge during the design process. Šuligoj's (2020) interdisciplinary investigation examined the cognitive and experiential dimensions of critical thinking across academic disciplines, with particular attention to its relationship with design thinking competencies. The study's correlational analysis revealed significant associations between students' epistemological beliefs about critical thinking and their demonstrated design thinking capacities, suggesting that critical thinking dispositions may serve as a substantive predictor of design thinking performance in educational contexts (Šuligoj et al., 2020). Dzombak discussed unpacking capabilities in the design thinking process, attempting to derive core problem frameworks and solutions from critical thinking, design thinking, and systems thinking (Dzombak & Beckman, 2020). Shanta aims to help students develop innovation and teamwork skills, encouraging them to use design thinking to solve real-world problems (Shanta, 2022).

Beyond the knowledge of design disciplines, educational research also focuses on improving teacher capabilities, refining teaching methods, and enhancing learning experiences by adhering to the principles of design thinking. Park emphasized the importance of using project-based learning in design studios to train students in design thinking (Park & Kim, 2021). Lin's (2021) empirical investigation examined how integrating engineering design processes within STEM project-based learning curricula influences the development of engineering design thinking competencies among pre-service technology teachers. The study contributes to the growing body of research on pedagogical strategies for fostering designerly cognition in STEM education contexts (Lin, 2021).. Balakrishnan emphasized that it is crucial for design

educators to use design thinking learning strategies to stimulate creativity, especially in design education (Balakrishnan, 2022).

Theoretical Framework

From the initial comparison with natural sciences while contemplating design science, to the later reflections on the characteristics and representations of design thinking, and finally to the broad application of design thinking across various fields, the history of design thinking encompasses a multitude of theories. Researchers from different disciplines have provided diverse interpretations, and there isn't a single standardized definition of the term design thinking. The table below presents a theoretical framework that outlines the theories throughout the history related to design thinking.

TABLE.4 Theoretical Framework

Theory	Concept
Design Science	Design science as an artificial science contrasting with natural sciences, emphasizing design as a way of thinking rather than a physical process.
Wicked Problems and Design Thinking	Addressing and exploring wicked problems—complex, ill-defined issues without clear solutions. Linking Rittel's wicked problems with Simon's design thinking, viewing design thinking as a methodology for innovative solutions to complex problems.
Designerly Ways of Knowing	Design thinking as a cognitive style unique to designers, focusing on solution-centred, constructive thinking and the use of codes to translate abstract requirements into concrete solutions.
Reflective Practice	Design practice as a reflective conversation between the designer and the problem situation, emphasizing reflection-in-action and context-dependent design theory.
Human-Centred Innovation	Design thinking as a human-centred approach to innovation, integrating customer needs, technological possibilities, and business sustainability through iterative processes.
Popular Model: IDEO's 3I	An iterative system with overlapping spaces for innovation, focusing on inspiration, ideation, and implementation.
Popular Model: Double Diamond	A framework dividing the design process into four phases: Discover, Define, Develop, and Deliver.
Popular Model: Five Stages	The Five Stages of Design Thinking, developed by Stanford d.school, include Empathize, Define, Ideate, Prototype, and Test. This iterative process emphasizes understanding users, clearly defining problems, generating ideas, creating prototypes, and testing solutions to develop effective and user-centred innovations.
Pragmatism and Design Thinking	Exploring how core concepts in design thinking resonate with John Dewey's pragmatism, informing the theoretical development of design discourse. Then many applications appear in various fields.
Design thinking and Design Tools	Conceptualizing design tools based on design thinking from a pragmatism perspective, emphasizing the key role of tools in design and creative methods.

Applying Design Thinking in Education	Emphasizing the return of professional knowledge to designerly ways of knowing and thinking, aligning design education with the need for nurturing innovative talents. Emphasizing the use of design thinking learning strategies to enhancing creativity in design education.
Applying Design Thinking in Healthcare	Applying design thinking in healthcare to enhance innovation, efficiency, and effectiveness by focusing on patient and provider needs.
Applying Design Thinking in Business and Technology	Viewing design thinking as a tool to bridge technology and innovation, providing opportunities for the commercialization of technology.
Applying Design Thinking in Reducing Cognitive Bias	Using design thinking to help decision-makers reduce cognitive biases and improve innovation outcomes

3.2 What is Design Thinking

The implementation process distinguishes the design thinking approach from traditional problem-solving approaches. While various design thinking process models have been developed, it is noteworthy that they often adhere to the fundamental structure of the conventional problem-solving process. To effectively apply design thinking in problem-solving, it is crucial to grasp its core concepts. These concepts include holistic consideration, iterative processes, creative thinking styles, and the use of cognitive tools. The following paragraphs will delve into a detailed explanation and discussion of each principle.

3.2.1 Designer's Perspective on Problem-Solving: Holistic Consideration

One of the key aspects of design thinking that designers must focus on is the foundation of how they approach problems. Embedded within the designer's thought process lies a holistic consideration that encompasses a human-centred focus, empathy, and consideration of stakeholders. By thinking about problems from this holistic perspective, our approach to problem-solving becomes more responsive to the genuine needs of humanity, bringing us closer to addressing real human concerns.

Human-centred Focus

Since design became a discipline with its own independent methodology, it has focused on human needs. Originating in 1958 with Professor John E. Arnold's establishment of the Stanford University design program, this approach to creative problem-solving in technical and business domains is fundamentally rooted in the principle of human-centered engineering design. This work coincided with the rise of creativity techniques and the subsequent design methods movement in the 1960s, which garnered significant attention from many design researchers. In his foundational articulation of design science, Simon (1969) established a fundamental epistemological distinction: while natural sciences investigate "what is," design inquiry concerns itself with "what ought to be" (Simon, 1969). Although early design research predominantly documented particular artifact creation, parallel scholarly efforts examined the fundamental nature of design activity itself. This trajectory

evolved into a robust research tradition conceptualizing design as a distinctive form of complex human practice, as evidenced by seminal contributions from Rittel and Webber (1973) on wicked problems, Schön (1983) on reflective practice, Krippendorff (1989) on semantic turn in design, Buchanan (1992) on design as a liberal art, and Cross (2001) on designerly ways of knowing (Rittel & Webber, 1973; Schon, 1983; Krippendorff, 1989; Buchanan, 1992; Cross, 2001). Design is about decision making in the “real” world (Nelson & Stolterman, 2003).

As design thinking evolved, many researchers emphasized the importance of human-centredness in design. Early researchers highlighted user-centred design, which was closely related to the experimental psychology popular at the time (Norman, 1995). In the fields of computing and interaction design, Bannon introduced a human-centred perspective in 2005 (Bannon, 2011). Within business contexts, Brown and Wyatt positioned human-centered design as a core tenet of design thinking practice, emphasizing its strategic value for organizational innovation (Brown & Wyatt, 2010). This professional perspective was subsequently institutionalized through the International Standards Organization's (ISO, 2010) formal guidelines, which codified human-centered design as a systematic approach requiring: (1) empirical understanding of users, tasks, and environments; (2) participatory engagement throughout development cycles; and (3) iterative refinement via user evaluations. Giacomin's (2014) phenomenological analysis further revealed how human-centered methodologies employ both verbal and non-verbal interaction techniques to uncover latent user needs, desires, and meaning structures - distinguishing it from traditional market research approaches (Giacomin, 2014). The term "human-centred design" became widely used, with researchers in various fields gradually recognizing that the focus of the design process is not on products or services but on people, their needs, and preferences (Young, 2010; Glen et al., 2015).

IDEO significantly advanced the concept of human-centredness, making the promotion of human-centred design one of its missions. In 2009, IDEO launched the HCD Toolkit, the first book to explain how and why human-centred design can influence the social sector (IDEO, 2009). In 2015, they compiled their design process into a step-by-step guide that includes 57 easy-to-use design methods and practical cases of human-centred design. They promoted this book as a guide to solving

problems like a designer (IDEO, 2015). As IDEO developed and disseminated human-centred design methods, making them more accessible to beginners, the approach gained wider recognition. More people became aware of the human-centred design method for problem-solving, which led to greater attention to human dynamics, interactions, and needs.

Design thinking's human-centred focus is central to its methodology, emphasizing empathy and a deep understanding of users' needs, experiences, and emotions. This approach involves immersing oneself in the users' environment, actively engaging with them through interviews, observations, and ethnographic research to gather valuable insights (Brown, 2009; Meinel & Leifer, 2020). While the user-centric paradigm in design thinking demonstrably enhances solution appropriateness (Liedtka, 2014), recent critiques argue this focus may sometimes limit radical innovation potential (Jahnke et al., 2020). Nevertheless, Carlgren et al.'s (2016a) multi-case analyses confirm its consistent value in balancing novelty and feasibility, particularly in complex organizational ecosystems (Carlgren et al., 2016a).

The redesign rule emphasizes that all design is a continuous process of iteration, adapting to changing technologies and environments while consistently fulfilling human needs (Meinel & Leifer, 2012; Leifer et al., 2016). This notion is critical because it acknowledges that designs must evolve in response to shifts in user expectations, technological advancements, and societal changes.

Human-centred design also employs tools such as personas and user journeys to predict user behaviors and needs effectively. Personas and user journeys serve as critical user-centered design tools that operationalize design thinking's empathic principles. As research-based archetypes, personas synthesize behavioral patterns into representative user profiles, enabling designers to transcend subjective assumptions and maintain authentic user perspective (Huỳnh et al., 2021). Complementary to this, user journeys systematically map interaction chronologies, revealing both friction points and latent opportunities across the experiential continuum (Khasanah et al., 2019). When employed synergistically, these tools create a robust framework for sustaining user focus throughout the design process,

resulting in solutions that demonstrate significantly improved usability metrics (L. Nielsen, 2018).

Empathy

Empathy is a cornerstone of design thinking and a crucial strategy for identifying and meeting design requirements. By putting themselves in the users' shoes, designers can gain a profound understanding of their thoughts, behaviors, and experiences. This involves considering what users think, do, see, and feel to uncover their true needs and desires (Kouprie & Visser, 2009; Carlgren et al., 2016b). Employing empathy allows designers to connect deeply with real human needs, making their solutions more relevant and effective. Techniques such as journey mapping, persona creation, and empathy mapping help designers visualize and understand users' experiences and emotions. This empathetic approach enables designers to create solutions that not only solve problems but also resonate on a personal level with the users, fostering a sense of trust and satisfaction.

Empathy drives the design process by encouraging designers to be open-minded and to suspend their own biases and assumptions. It requires active listening and observing without judgment (Carlgren et al., 2016a; Hashim et al., 2019). This mindset allows designers to uncover hidden insights and to understand the context in which users operate, leading to more thoughtful and effective design solutions.

One practical method for cultivating empathy in design is through empathy interviews, where designers ask open-ended questions to users and actively listen to their responses. These interviews are designed to elicit stories and emotions, providing deep insights into users' experiences and needs (Marufu & Merwe, 2019). Another method is shadowing, where designers observe users in their natural environments to see how they interact with products and services in real-time. This observational research helps designers gain a firsthand understanding of user behaviors and challenges (Hashim et al., 2019; Montero, 2022).

Empathy mapping is another valuable tool that helps designers organize and synthesize the information gathered from user research. An empathy map typically includes four quadrants: what users say, what they do, what they think, and what they

feel. By filling out these quadrants, designers can identify patterns and themes, leading to a more comprehensive understanding of the user (Liedtka, 2014).

Empathy not only improves the design process but also fosters a culture of collaboration and innovation within teams. When designers approach problems with empathy, they are more likely to build strong, trust-based relationships with users and stakeholders (Peng & Kueh, 2022). This cooperative methodology guarantees the integration of varied viewpoints, resulting in solutions that are both more comprehensive and innovative.

Stakeholders Consideration

Human-centred design advocates for inclusivity and accessibility. This approach fosters the development of universally accessible products and services, intentionally designed to accommodate users across the full spectrum of abilities (Bannon, 2011; Brownson et al., 2021). This aspect of design thinking is crucial in ensuring that innovations are not only effective but also equitable, providing value to a diverse range of users (Lamirande, 2022; Rossi, 2023). By advocating for inclusive design practices, design thinking contributes to a broader understanding of user needs and fosters a more equitable distribution of resources and opportunities within society (Lamirande, 2022). By engaging deeply with users and continuously refining designs, this methodology ensures that innovations are not only creative but also relevant and accessible to a diverse audience (Rossi, 2023).

When designing, it is essential to consider all stakeholders involved in the process. Stakeholders include not only users but also buyers, producers, competitors, and others who may be impacted by the design. This comprehensive consideration ensures that the design is viable and sustainable within its broader context (Altman et al., 2018). By engaging with a wide range of stakeholders, designers can gather diverse perspectives and identify potential challenges and opportunities (Rossi, 2023). This holistic approach aligns with systems thinking, which views problems as part of a larger, interconnected system (Buchanan, 2019). Understanding the roles and interests of various stakeholders allows designers to create solutions that are more balanced, inclusive, and sustainable (Cezarotto, 2023). It also helps in foreseeing and

mitigating any adverse effects the design might have, ensuring a more harmonious integration into the existing ecosystem (Sidabutar et al., 2023).

Stakeholder analysis is a critical step in the design process that involves identifying all parties affected by the project and understanding their needs and concerns. This analysis helps prioritize stakeholders based on their influence and interest in the project, guiding the design process to address the most critical aspects first (Carlgren et al., 2016b). Engaging stakeholders early and often through workshops, focus groups, and feedback sessions ensures that the design aligns with their needs and expectations (T. M. Jones et al., 2017).

Incorporating stakeholder feedback into the design process can lead to more innovative and practical solutions. For instance, insights from production teams can uncover manufacturing constraints that may influence design decisions, while feedback from marketing teams can help tailor the design to better resonate with target audiences (Woo et al., 2022). By considering the entire ecosystem in which the design will operate, designers can develop more suitable solutions.

Discussion

Holistic consideration is the way designers approach a design problem. Designers focus on human needs as the primary consideration, observing human activities and behaviors using empathy to accurately target and address those needs. During the journey of identifying the real needs of specific user groups, designers also take into account other groups involved in the problem. Since our target users will interact with these stakeholders, gathering information from a variety of sources enables us to empathize with our target users in various scenarios and gain a more multi-dimensional understanding of them.

Additionally, our design solutions will impact stakeholders beyond the target users, who are also human and whose perspectives align with our human-centred focus. By integrating these three perspectives—human-centred focus, empathy, and stakeholder consideration—designers can identify the relevant factors influencing both problem definition and solution development. This comprehensive approach

allows us to address real human needs in a holistic way, ensuring our solutions are meaningful, effective, and sustainable.

Holistic consideration requires designers to balance multiple, sometimes conflicting, interests and priorities. It involves making trade-offs and compromises to achieve the best possible outcome for all stakeholders. This complexity necessitates a flexible and iterative approach to design, where solutions are continuously refined based on feedback and changing conditions.

The designer's way of considering problems through a holistic lens involves a deep commitment to understanding and addressing human needs, employing empathy to connect with users, and engaging with all relevant stakeholders to ensure comprehensive and sustainable solutions. By embracing these principles, designers can create innovative solutions that resonate with users, satisfy stakeholders, and contribute positively to society.

3.2.2 Designer’s Problem-solving Process: Iterative Process

The design process involves formulating and refining solutions through systematic evaluation against both predetermined objectives and unforeseen consequences that emerge during development. The problem-solving process in design thinking is distinguished by its non-linear nature, which sets it apart from traditional linear problem-solving methods. Unlike linear approaches that follow a predefined sequence, design thinking involves continuous iteration, moving from the initial stage to the targeted stage. Designers, known for their inherent curiosity, exhibit flexibility in their problem-solving approach. As they encounter new information about a situation, their perception of the problem evolves. This often leads to a sense of dissatisfaction with the current solution, driving designers to explore better alternatives. Through iterative cycles of refinement, designers continually evolve their solutions while simultaneously redefining the problem, resulting in more innovative and effective outcomes.

Evolution of Design Solutions through Verification

Iteration is a crucial process for improving user interfaces and visual designs. Designers gather feedback from various sources, including crowd feedback systems and online communities, to refine their work (Crain & Bailey, 2017; W. Xu et al., 2024). Studies have shown that iterative design can lead to significant improvements in usability from the first to the last iteration (J. Nielsen, 1993). To enhance the iterative process, designers can combine feedback review with reflection activities, which help them recall goals, question choices, and prioritize revisions (Yen et al., 2024).

After implementing a design solution, designers receive feedback that informs them about its effectiveness. Unsatisfied with the initial solution, designers iterate the design to achieve a better fit with user needs. Learning from trial and error, designers continuously improve their designs, leveraging each iteration to refine their understanding of the problem and explore new possibilities (Marks & Chase, 2019).

In the process of verifying design solutions, designers go through a rigorous cycle of evaluation and refinement. They gather feedback from various sources, including user testing, expert reviews, and market analysis (Müller & Thoring, 2012; Zeh, 2015). This evaluation offers meaningful perspectives on the design solution's advantages and limitations, directing creators toward enhancement opportunities. Designers carefully analyze this feedback, identifying areas for enhancement and modification. They then iterate on the design, incorporating changes based on the feedback received. This iterative process of verification ensures that the design solution evolves to better meet human needs and preferences over time (Liedtka, 2018).

Evolution of Design Problems through Redefinition

Upon receiving feedback, designers gain additional insights into the problem, prompting them to redefine it. Exceptional designers possess the willingness and ability to rethink and redefine problems, often uncovering new insights and opportunities that differ from their initial assumptions. This cyclical approach to

refining the problem statement enables designers to gain greater insight into the challenge domain and discover more impactful resolutions.

Designers tend not to directly address core paradoxes but instead focus on surrounding issues, seeking clues in the broader context. From this exploration, new frameworks often emerge to address the core paradox (Dorst, 2006). When creating these frameworks, expert designers engage in a nuanced analysis, similar to phenomenological methods, where "themes" are used to interpret complex situations (Cross, 2006). In complex problem contexts, exploring and creating themes helps illustrate this process (Razzouk & Shute, 2012). Themes serve as tools for constructing meaning and are often unclear in their placement within the problem or solution space until a framework is established. Extracting themes from complex situations is seen as an insightful invention and discovery process. In design practice, themes on the periphery of a problem can trigger new frameworks that offer novel ways to approach the core paradox (Dorst, 2006). Although creating new frameworks is crucial in professional design, it often appears to be an informal activity. Designers emphasize the importance of "richness" in problem areas and the value of first-hand experience, suggesting a deliberate strategy rather than a random process, despite its seemingly vague and coincidental nature (Cross, 2011).

Research emphasizes the importance of problem exploration and redefinition in the design process. Information gathering is crucial for adequately defining problems and generating appropriate solutions (Bardwell, 1991). Through problem exploration, designers can uncover new perspectives, leading to diverse ideas and potential solutions (Chin & Chia, 2004). This process involves intentional and unintentional changes in problem understanding, allowing designers to gain fresh insights and identify key areas for intervention. Additionally, problem finding emphasizes the importance of reframing situations to create novel perspectives (Magistretti et al., 2022) .

Revising design challenges constitutes an essential phase in the solution-finding process, allowing designers to reveal latent difficulties and potential avenues. By revisiting the problem definition, designers gain fresh perspectives and insights that may have been overlooked initially. This process of problem redefinition often

involves conducting additional research, gathering new data, and engaging stakeholders in collaborative discussions (Woo et al., 2022). Designers then synthesize this information to refine their understanding of the problem and identify key areas for intervention. Through this iterative process of problem redefinition, designers are able to develop more targeted and effective solutions that address the root causes of the problem (Taura & Nagai, 2011).

Problem-solution Coevolution through Experiential Learning

In the iterative process, both the design problem and solution evolve together, constituting a continuous learning process (Dorst & Cross, 2001). This experiential learning occurs through hands-on experimentation, as designers actively engage in "learning by doing" (Anzai & Simon, 1979). As designers iterate through solutions, they gain new experiences and insights, which inform their understanding of the problem and drive further innovation (Mummah et al., 2016).

As designers engage in experiential learning through the iterative process, they not only refine their understanding of the problem and solution but also cultivate a deeper sense of empathy and connection with end-users. Through hands-on experimentation and direct interaction with stakeholders, designers gain invaluable insights into the needs, preferences, and behaviors of the target audience (Ravasi & Lojacono, 2005). This empathetic understanding allows designers to develop solutions that are truly user-centred, addressing the underlying needs and aspirations of the people they serve. By integrating empathy into the iterative problem-solving process, designers can create more meaningful and impactful solutions that resonate with users on a profound level, ultimately driving positive change and fostering a sense of trust and loyalty among stakeholders (Newton et al., 2020).

Discussion

The iterative nature of design thinking facilitates a symbiotic relationship between problem and solution, where each informs and influences the other. Through iterative cycles, designers acquire new experiences from solutions, leading to a deeper understanding of the problem. This continuous refinement and evolution ultimately drive innovation and enable designers to develop more effective solutions.

The iterative nature of design thinking not only allows designers to refine their solutions but also encourages them to explore new possibilities and push the boundaries of creativity. By embracing failure as an opportunity for learning and growth, designers can overcome obstacles and unlock new insights that lead to breakthrough innovations. Additionally, the collaborative nature of design thinking enables designers to leverage the diverse perspectives and expertise of multidisciplinary teams, resulting in more holistic and impactful solutions. As designers continue to iterate and evolve their solutions, they contribute to a culture of innovation that drives positive change and transformation in society.

And the iterative problem-solving process in design thinking empowers designers to address complex and ambiguous challenges with confidence and creativity. By breaking down problems into smaller, more manageable components, designers can develop targeted solutions that effectively address the root causes of the problem. This iterative approach also fosters a culture of continuous improvement, where designers are constantly seeking ways to refine and enhance their solutions based on feedback and real-world testing. As a result, design thinking enables designers to develop solutions that are not only innovative and effective but also sustainable and scalable, driving long-term impact and value creation.

3.2.3 Designer's Mindset and Attitude: Creative Thinking Style

Designers have a distinct approach that makes them particularly skilled at solving problems creatively. While most people rely on their experience to tackle issues, this knowledge can sometimes box them in, limiting their creativity. Designers, however, constantly push to break through these mental barriers, working hard to free their minds from such constraints. They critically question assumptions and remain dedicated to uncovering the truth. By trusting their intuition and embracing subjective thinking, they're able to come up with fresh ideas quickly. The process of solving problems, especially through iteration, often doesn't produce clear or easy solutions, requiring a tolerance for uncertainty. Designers are prepared to take on the risks that come with proposing new ideas, even when these ideas might face criticism. They don't easily abandon unconventional concepts, even if it takes extra time and effort to explore them. Their confidence and persistence help them push through difficulties,

increasing the likelihood of discovering and successfully implementing creative solutions.

Pursuing Thinking Out of the Box

The pursuit of "thinking out of the box" encapsulates the essence of creative thought and innovation. When we laud individuals as creative, it's typically due to their ability to conceive and actualize ideas that push the boundaries of their previous knowledge (Hemlin et al., 2008). This journey often entails embracing intuition and subjective perspectives, which can lead to groundbreaking insights and solutions. However, novel ideas frequently encounter resistance and criticism upon their inception (Mueller et al., 2012). In the process of pursuiting creative ideas, designers often find themselves challenged. To effectively embark on this journey within the realm of design thinking, it necessitates the adoption of some attitudes (Gabora & Kaufman, 2010). These include the willingness to question assumptions, embracing sensible risks, taking responsibility of one's ideas, tolerate ambiguity, and cultivating a sense of self-efficacy (R. Sternberg, 2007). These attitudes are beneficial for nurturing creative thinking style, enabling designers to break free from conventional constraints and explore innovative ideas in problem-solving. Thus, fostering an environment that encourages and supports ideas that beyond previous knowledge is important for fostering creativity in design process (Haller & Courvoisier, 2010).

Spirit of Questioning Assumption

Assumptions are deeply ingrained patterns of thought that shape our perceptions, behaviors, and decision-making processes (Anderson, 1960). They are often based on past experiences, cultural norms, and societal expectations, and can influence how we interpret and respond to new information and situations. And they unconsciously exist in human’s mindset (R. J. Sternberg, 2020). However, while assumptions can provide a sense of security and stability, they can also act as barriers to creativity and innovation. When designers rely too heavily on assumptions, they may overlook new possibilities and opportunities. Assumptions can blind designers to alternative perspectives, limiting the ability to think critically and creatively about complex problems (Yang et al., 2022).

Individuals with a creative thinking style understand the importance of questioning assumptions in the problem-solving process (R. J. Sternberg, 2001). They recognize that assumptions are not absolute truths but rather subjective interpretations of reality (R. Sternberg, 2007). By questioning assumptions, they seek to challenge the current status and push the boundaries of what is possible.

One of the key benefits of questioning assumptions is that it allows individuals to approach problems with an open mind, free from biases and preconceived notions. Instead of accepting things at face value, they actively seek out new information, perspectives, and insights (Henriksen et al., 2017). This openness to alternative viewpoints enables them to see the problem from multiple angles and consider a wider range of potential solutions.

Questioning assumptions encourages individuals to think critically about the underlying implications of a problem. By examining the assumptions that underpin their thinking, they can uncover hidden biases, contradictions, and inconsistencies (Mueller et al., 2012). This deeper level of analysis enables them to develop more holistic understandings of complex issues, building the foundation for innovative problem-solving approaches.

Questioning assumptions fosters a creative mindset of experimentation, and learning. It encourages individuals to embrace uncertainty, ambiguity, and failure as natural parts of the creative process (Manalo & Kapur, 2018). Rather than fearing failure or rejection, they see it as an opportunity for growth and discovery. This mindset shift can empowers designers to take risks, explore new ideas, and learn from their experiences, ultimately driving meaningful change and progress (Sawyer, 2019).

Overall, the spirit of questioning assumptions is a powerful catalyst for creativity in problem-solving. By challenging previous knowledge and experience, individuals can embrace uncertainty and find new opportunities.

Courage for Taking Sensible Risks

Designers need to confront challenges in their process, and a novel idea may encounter numerous sensible risks during its proposal and implementation.

Sometimes, these ideas might even receive ridicule and denial from others. However, these creative ideas can implement through sensible risk-taking (Mueller et al., 2012; Tyagi et al., 2017).

Taking sensible risks plays a vital role in nurturing creativity and innovation in problem-solving. It's not just about facing risks but about embracing them thoughtfully, despite the potential for failure or criticism. Sensible risk-taking involves resilience, perseverance, and the ability to navigate obstacles to achieve one's goals and builds confidence (Beghetto et al., 2021).

Designers often find themselves in situations where they must take measured risks to explore new ideas and concepts. These risks may involve challenging the assumptions in mindset, pushing boundaries of their knowledge and pursuing unconventional approaches (Tyagi et al., 2017). Sensible risk-taking enables designers to overcome the fear of failure and embrace the possibility of making mistakes (Shen et al., 2018). Failure is an inevitable part of the creative process, and designers must be willing to accept it as a natural and necessary aspect of experimentation and exploration (Carlgren et al., 2016a). By viewing failure as a learning opportunity rather than a setback, designers can push the boundaries of their creativity and discover new solutions to complex problems (Manalo & Kapur, 2018).

Sensible risk-taking also empowers designers with confidence to stand firm in their convictions and defend their ideas, even in the face of criticism or opposition (Beghetto et al., 2021). In the design field, creative ideas are often met with skepticism or resistance from stakeholders or clients who may not fully understand or appreciate their innovative potential (Ramaswamy & Gouillart, 2010). In such situations, designers must take sensible risks to advocate for their ideas and persuade others of their value, even if it means facing rejection or criticism. Designers may find new opportunities in this process. It enables them to step outside their comfort zones, embrace uncertainty, and push the boundaries of their creativity.

In conclusion, taking sensible risks is essential for designers seeking to innovate and push the boundaries of creativity in problem-solving. It empowers them to embrace risks thoughtfully, overcome adversity, and pursue their ideas with confidence and

conviction. By cultivating a mindset of sensible risk-taking, designers can unleash their full creative potential in the design process.

Willingness for Taking Self-responsibility

Willing to take self-responsibility means the readiness to assume responsibility for one's decisions and to evaluate based on personal values (Maier, 2019). Individuals should have ownership over their ideas, and a responsible attitude towards themselves when executing tasks (R. Sternberg, 2007). Self-responsibility is about taking ownership of one's actions and decisions, regardless of the outcome. Taking self-responsibility empowers designers to take ownership of their creative endeavors, driving them towards success and excellence in problem-solving. It requires designers to be accountable for their ideas and have ownership for their decision in design process.

Also, taking self-responsibility encourages designers to seek opportunities in problem-solving. This proactive mindset enables designers to drive their projects forward and make meaningful contributions to their teams and organizations. Instead of waiting for instructions or guidance, designers take proactive steps to identify challenges, set goals, and pursue solutions independently (Steen, 2013).

Self-responsibility fosters a sense of ownership and pride in one's work, motivating designers to strive for excellence and continuously improve their skills and capabilities. By taking ownership of their creative endeavors, designers become personally invested in their projects, leading to greater dedication, commitment, and accountability (Demirkan & Hasirci, 2009). Self-accountability enables designers to confidently embrace risks and pursue novel concepts, relying on their own discernment rather than external validation, thereby fostering the assurance to tackle challenges and break creative barriers with bold determination.

In conclusion, self-responsibility is a fundamental mindset for designers in problem-solving. By taking ownership of their ideas, decisions and actions, designers demonstrate confidence and commitment to their work.

Perseverance in Ambiguity

Ambiguity is a natural part of the creative process, marked by uncertainty and unpredictability. Those involved in creative work must learn to tolerate this ambiguous stage, as innovative ideas often need time to develop and be tested (R. Sternberg, 2007). At the start of a creative endeavor, there is typically a period of uncertainty. Designers need the perseverance to endure these early stages, demonstrating the resilience required to push through the challenges that arise before achieving a breakthrough (Sweetman et al., 2010). This ability to navigate ambiguity helps designers stay focused on their objectives, allowing them to overcome obstacles and ultimately arrive at innovative solutions (Tierney & Farmer, 2011).

When embarking on a new project, designers frequently encounter unclear paths and uncertain outcomes. This ambiguity can lead to doubt and frustration (Karwowski, 2011). However, these moments are crucial for growth and exploration. Designers must embrace the uncertainty, remain committed to their vision, and persist despite the challenges (Hass et al., 2019). Adopting a growth mindset is key, as it allows designers to see setbacks not as failures but as opportunities for learning and progress (Beeftink et al., 2011).

Resilience is essential for persevering through ambiguity. Designers need to develop strategies to manage stress and doubt effectively, enabling them to maintain focus even when faced with difficulties (Brun, 2016). Patience is equally important; creative breakthroughs often require time and iterative effort. By staying committed, even when progress is slow, designers can ultimately achieve their goals. Embracing ambiguity is critical for success in problem-solving and innovation. By accepting uncertainty, designers can navigate the complexities of the creative process and reach innovative solutions (Beghetto et al., 2021).

Strong Self-efficacy

Self-efficacy denotes the confidence designers have in their unfinished works and tasks during the process. It is a belief in oneself and a sense of confidence in one's capability to tackle difficulties and to devise and execute creative solutions (Bandura & Wessels, 1997).

This is crucial for designers, as strong self-efficacy will support them until their work is completed smoothly. Those possessing high levels of self-belief tend to establish ambitious objectives, dedicate increased effort, and demonstrate perseverance when encountering difficulties (Karwowski, 2011). Having strong self-efficacy enables designers to maintain a positive attitude towards their work, even when faced with difficulties. It provides them with the confidence and belief in their abilities to overcome challenges and achieve their goals, fostering resilience and perseverance in the face of adversity (N. Huang et al., 2020).

With strong self-efficacy, designers are enabled to take risks and pursue innovative ideas with confidence (Tierney & Farmer, 2011). Self-efficacy plays a crucial role in shaping designers' beliefs, attitudes, and behaviors in the creative process. It influences how designers approach tasks, handle challenges, and persevere in the face of adversity.

Instead of being deterred by fear of failure or criticism, designers with strong self-efficacy are more likely to take initiative and explore new possibilities with enthusiasm and optimism (Beeftink et al., 2011). Designers may seek out and utilize available resources effectively, maximizing their potential for success and achievement in problem-solving. It empowers designers to seek feedback, learn from experiences, and adapt their strategies to overcome challenges and achieve their goals.

By fostering confidence, belief, and resilience in their abilities, designers can overcome challenges, navigate uncertainty, and achieve success in the creative process (Liedtka, 2018). Strong self-efficacy is a critical mindset for designers in creative problem-solving and innovation.

Discussion

In creative thinking, certain mindsets play crucial roles. Thinking outside the box and questioning assumptions require us to push beyond the boundaries of knowledge and experience. Intuition and subjective thinking arise naturally from this process. Together, these attitudes help cultivate a culture of innovation and creativity within the design field.

Challenging assumptions encourages designers to question conventional wisdom and explore unconventional ideas. This mindset promotes curiosity, leading designers to seek out alternative perspectives and uncover hidden opportunities. By questioning the assumptions, designers can break free from traditional thinking and create innovative solutions.

Taking sensible risks is essential for overcoming obstacles in the creative process. It empowers designers to explore new possibilities, even when faced with uncertainty or criticism. With the courage to step outside their comfort zones, designers can pursue bold ideas that drive innovation.

Self-responsibility drives designers to take ownership of their creative work, fostering accountability and commitment. By taking initiative, designers are more likely to see their projects through to success.

Perseverance in the face of ambiguity allows designers to navigate the uncertainties inherent in the creative process. This requires resilience and determination to stay focused on their goals, even when faced with setbacks. By persevering, designers maintain the momentum needed for breakthroughs and innovative solutions.

Strong self-efficacy gives designers the confidence to overcome challenges and succeed in their creative efforts. This positive mindset helps them tackle difficulties with resilience and determination, keeping them motivated and driven towards success.

These mindsets collectively foster a creative thinking style in design process. By embracing these attitudes, designers can break free from their knowledge and experience to explore new possibilities.

3.2.4 Designer’s Problem-solving Aids: Use of Cognitive Tools

Cognitive tools are essential in enhancing designers' ability to solve problems. These tools support and improve the thinking process by providing structure and clarity. For example, mind maps help organize thoughts, while sketches and prototypes turn abstract ideas into visible forms. By using sketches and prototypes, designers can

express their ideas more clearly and communicate effectively with others involved in the problem-solving process. Additionally, testing solutions through prototypes allows designers to validate their ideas, gaining new insights into both the problem and possible solutions. In essence, using cognitive tools boosts the problem-solving process by enabling tangible expression, effective communication, solution verification, and experiential learning.

Tangible Communication

Prototypes play a crucial role in design communication by enhancing understanding and facilitating collaboration. As a form of communication, prototypes serve as tools to increase learning and demonstrate decision-making (Lauff et al., 2018). They help stakeholders communicate and collaborate more effectively (Lauff et al., 2020). Similarly, sketches are also valuable for communication. They allow designers to explore and uncover unintended consequences through a reflective conversation with the situation, a key aspect of design thinking (Schön, 1983). This process involves a dialogue where reflective criticism, analogical reasoning, and reinterpretation occur, stimulating creativity and enabling designers to share their design solutions from different perspectives (Goldschmidt, 2004).

Prototypes are essential for conveying the core aspects of a design to others, fostering a shared understanding and promoting collaborative problem-solving. When ideas are transformed into tangible prototypes, they create a common language that enhances communication and cooperation among stakeholders (Lauff et al., 2020). This tangible approach allows stakeholders to engage more deeply with the design, offering informed feedback that leads to iterative improvements (Piya & Ramani, 2014). As a result, prototypes assist in both conceptualizing and refining designs while encouraging teamwork.

Tangible expression is fundamental for designers to clearly articulate their ideas, turning abstract concepts into concrete forms. Sketches and prototypes are frequently used to visualize and communicate these ideas. The ability of prototypes to make ideas tangible allows designers to overcome language barriers and focus on critical aspects of their solutions (Zeh, 2015). This approach facilitates the communication

of sensory and experiential attributes, enabling stakeholders to interact directly with design concepts (Lauff et al., 2020).

Through an iterative process of developing multiple prototypes, designers gain a deeper understanding of their concepts and refine their solutions (Härkki et al., 2016; Corremans et al., 2018). Translating abstract ideas into tangible forms enhances designers' ability to visualize and explore innovative solutions (Baskinger & Gross, 2010).

Effective communication is vital to successful design, yet conveying complex ideas solely through words can be challenging and prone to misinterpretation. Tangible expression offers a powerful means of clear communication, overcoming language limitations and fostering deeper understanding among stakeholders (Lauff et al., 2020). By converting abstract ideas into tangible forms such as sketches and prototypes, designers provide stakeholders with artifacts that can be seen, touched, and interacted with. This approach bridges the gap between the designer's vision and stakeholders' understanding, enabling them to grasp the design's intricacies and offer informed feedback (Deininger et al., 2019). The tangible quality of sketches and prototypes serves as a common visual language that enhances productive discussion and teamwork throughout the design process (Goldschmidt, 2004).

Verification of Solution

Iterative prototyping is crucial for evaluating the feasibility, functionality, and usability of design solutions in real-world contexts (Lauff et al., 2018). Novice designers, in particular, benefit from this approach as they refine their solutions through prototypes, aligning with best practices that emphasize early stakeholder engagement (Deininger et al., 2019). This early involvement is key to developing more effective solutions, as prototyping encourages learning from early failures (Piya & Ramani, 2014; Manalo & Kapur, 2018).

By systematically evaluating prototypes and incorporating user input, designers progressively enhance their concepts to guarantee the end product aligns with users' requirements and preferences (Zeh, 2015). Creating prototypes improves clarity in discussions and choices during design development, leading to more successful

project outcomes (Camburn et al., 2017). It adds value at every phase of the design process, supporting learning and informed decision-making (Hansen et al., 2021). It reflects the importance of a continuous improvement mindset in successful design practices.

Learning by Doing

Learning by doing is a powerful educational approach that builds functional skills and knowledge by engaging learners in doing tasks (Anzai & Simon, 1979) . Unlike traditional methods, this approach addresses the issue of inert knowledge by allowing learners to directly apply what they learn, thus managing real-world complexity more effectively (Aleven & Koedinger, 2002). Despite its proven effectiveness, the learning-by-doing approach can further enhance the learning process by ensuring that the principles learned are directly relevant and immediately applicable (Sheshinski, 1967).

Designers particularly thrive on experiential learning, gaining essential insights through hands-on experimentation and prototyping (Coutts et al., 2019; Petrakis et al., 2021). The iterative process of making and testing prototypes allows designers to refine their ideas and improve problem-solving skills. By engaging in this cycle, designers develop a deeper understanding of the design problem and user needs, which leads to more innovative solutions (Petrakis et al., 2021). Embracing a culture of experimentation also fosters continuous improvement and drives innovation within the design field (Berglund & Leifer, 2013). Through this process, designers not only enhance their skills but also build resilience and adaptability, crucial traits for navigating the ever-changing landscape of design. Viewing failure as a learning opportunity, they can unlock new perspectives and create solutions that have a meaningful impact on society (Neeley et al., 2013).

Discussion

The utilization of cognitive tools in the problem-solving process enables designers to traverse the complexities of design challenges effectively. By fostering tangible expression, facilitating effective communication, enabling solution validation, and promoting experiential learning. Verification of solutions through prototyping

ensures that the proposed designs align with the desired outcomes and meet the users' needs by early failure.

Using cognitive tools in problem-solving benefits designers to address complex challenges with greater clarity and precision. These tools help transform abstract ideas into tangible forms, facilitating clear communication and collaboration with stakeholders. Prototyping is essential for validating solutions, ensuring that designs are aligned with user needs and intended outcomes. By adopting an iterative approach, designers continually refine their prototypes, fostering innovation and expanding the possibilities in design through learning by doing.

Conceptual Framework 1 Core Concepts of Design Thinking

The main difference between traditional problem-solving approaches and the design thinking approach is in the implementation of the process. Design thinkers understand these core concepts of design thinking, to make the problem-solving process different from when using traditional problem-solving approaches and find innovative solutions successfully.

A conceptual framework for principles of applying design thinking is generated. CF1 includes the core concepts in the application of the design thinking approach. It is used to find information for the four research questions.

TABLE.5 Conceptual Framework 1

Holistic Consideration

Principle	**Holistic Consideration**
Source	It related to designer's way of considering a problem

Human-centred focus	Considering problem from human needs
Empathy	Standing on someone else's points
Considering stakeholders	Consideration of stakeholders related to the problem

Iterative process

Principle	**Problem-Solution Co-iteration**
Source	It related to designer's problem-solving process

Redefine the Problem	Evolution of design problems through redefinition
Iterate the Solution	Evolution of solutions through verification

Creative thinking style

Principle	**Creative thinking style**
Source	It is related to the designer's attitude towards problem-solving thinking, which is characterised as thinking out of the box

Pursue thinking out of box	It means to break the limits of one's knowledge and experience, exploring innovative and unconventional approaches to problem-solving
Spirit of Questioning Assumption	Mindset of challenges existing knowledge and experience to find new perspectives amd possibilities
Courage for Taking Sensible Risks	Demonstrating the bravery and resilience needed to confront obstacles and pursue innovative solutions despite risks and uncertainties
Willingness for Taking Self-responsibility	Taking ownership and accountability for one's ideas, actions and decisions
Perseverance in Ambiguity	Displaying resilience and determination in navigating through uncertain and unclear situations, staying focused on goals despite challenges
Strong self-efficacy	Having confidence in oneself to overcome obstacles, tackle difficulties, and succeed in achieving goals

Use of Cognitive Tools

Principle	**Use of Cognitive Tools**
Source	This principle related to tools used by designers in problem-solving

Tangible Communication	Utilizing tangible artifacts, such as prototypes or visual aids, to facilitate clear and effective expression and communication of ideas, fostering shared understanding among stakeholders

Verification of Solution	The method of assessing the feasibility and effectiveness of proposed solutions through testing and validation processes, ensuring alignment with user needs
Learning by Doing	Engaging in hands-on experimentation and prototyping to acquire insights, refine skills, and develop innovative solutions through experiential learning

3.3 Chapter Summary

This chapter delves into the history of design thinking, tracing its evolution from its early roots to its current status as a critical methodology in various fields. It explores the development of the term “design thinking,” highlighting key concepts shaped its definition and application over time. Important understandings within the concept of design thinking are discussed and conceptual framework 1 is generated.

Chapter 4 How to Nurture Design Thinking

After understanding what design thinking is, it is also crucial to understand how design thinking is nurtured. First of all, we need to know that design thinking is not only an explicit knowledge, but also a tacit knowledge in our design process.In this chapter, we review some of the design thinking teaching methods that are often used abroad. And we explain the different levels of understanding of a concept, which are articulative understanding, applicable understanding and internalised understanding.

4.1 Design Thinking is Tacit Knowledge

Design knowledge can be categorized into explicit and tacit forms. Explicit knowledge is easily codified and shared, while tacit knowledge is more abstract and experiential (Thoring et al., 2022). Design knowledge can be categorized into four distinct forms: tangible objects, intuitive understanding, formalized information, and theoretical principles. Tacit knowledge plays a crucial role in design thinking, involving processes like empathizing, ideating, and prototyping (Müller & Thoring, 2012). While tacit knowledge is often thought to be ineffable, recent research suggests that some aspects can be articulated through expertise in verbal expression, models, and gestures. Understanding these knowledge and their interplay is essential for design education and research, as well as for developing systems to support design processes (Müller & Thoring, 2012; Thoring et al., 2022).

Tacit knowledge is a crucial concept in design research, encompassing skills and experiences acquired through practice rather than direct instruction (Moore & Muller, 2002). It is often described as knowledge that resists codification and is embedded in action or doing (Gascoigne & Thornton, 2014). Designers and researchers face challenges in capturing and understanding tacit knowledge due to its abstract and often inarticulable nature. Tacit knowledge plays a significant role in design, where intuition and judgment are essential (Wong & Radcliffe, 2000).

Design thinking is predominantly considered tacit knowledge, which is difficult to articulate and best understood through action and demonstration (Moore & Muller, 2002). Implicit understanding emerges through social interaction and discourse rather than existing as an inherent occurrence. Understanding and retaining tacit knowledge is particularly important for small manufacturing enterprises to prevent loss of valuable expertise (Wong & Radcliffe, 2000). This type of knowledge is embedded in daily product use and design development, requiring designers to involve users in nontraditional forms of explanation to uncover it. The design thinking process creates various types of knowledge, including physical artifacts, tacit gut feelings, codified knowledge, and testable theories (Thoring et al., 2022). Educating aspiring leaders in design thinking fundamentals - including user-centered approaches, problem definition, visual representation, iterative testing, and inclusive collaboration - proves

essential for navigating volatile business environments (Schumacher & Mayer, 2018). In design process, designers aquire tacit knowledge by combining theoretical and empirical research, questioning, and reflection can help their decision-making processes (Cross, 2011). These processes are inherently experiential and context-specific, making them challenging to teach through conventional methods alone.

4.2 Pedagogy for Teaching Design Thinking

To understand how design thinking is taught in universities in China, it's important to first consider global practices and how the core principles of design thinking are applied elsewhere. This global perspective offers valuable insights that can be tailored to the domestic context, making the teaching methods more relevant and effective. Research on design thinking pedagogy has identified various approaches and methodologies that have been successful in different educational settings.

4.2.1 Pedagogy for Teaching Holistic Consideration

Holistic consideration in design thinking involves looking at the problem and its context from a comprehensive perspective, considering all factors that might affect the outcome. Teaching this requires educators to encourage students to think beyond the immediate problem and explore the broader context, including social, cultural, and environmental factors. This can be achieved through case studies that highlight the importance of considering various elements and their interconnections. Interactive workshops and discussions can further enhance students' ability to think holistically, ensuring they develop solutions that are not only innovative but also sustainable and ethical.

Human-centredness approaches are increasingly being incorporated into design education to foster empathy and address social challenges. Teaching human-centredness provides students with methods to tackle complex problems while emphasizing the human perspective throughout the design process (Gill & Thomson, 2017). To effectively teach human-centred focus, design education should move away from teacher-centred pedagogies towards learner-centred approaches that

incorporate ethnographic studies, action research, and empathy (Garreta-Domingo et al., 2018). Service-learning offers synergistic opportunities to create human-centred design experiences by pairing students with real users and communities (Zoltowski, 2012). The application of human-focused design principles supported teacher training initiatives in adapting to online instruction during the COVID-19 crisis (Garreta-Domingo et al., 2018). The method emphasizes developing understanding, addressing teaching challenges, and creating virtual collaborative learning networks. These strategies help prepare students to address social issues and develop the competencies needed for design for social change.

Research on design education highlights the critical role of cultivating empathy in students. Various pedagogical methods have been developed to achieve this. For example, immersive professional learning opportunities combined with design thinking processes have been proposed as effective ways to build pedagogical empathy (Crichton & Carter, 2017). Another approach involves transformational teaching and the pedagogy of discomfort, which challenges students' assumptions and actively engages them in empathic design (Gudur, 2023). Additionally, the need for a structured toolbox to enhance students' empathic abilities is emphasized based on a five-year teaching experience (Gagnon & Côté, 2014). Inclusive design's signature pedagogies are also applied in high schools to develop critical thinking and empathy in students (Nicholl, 2017). These approaches collectively aim to deepen students' understanding of user needs, encourage reflection, and promote empathy-driven design practices. Common themes across the studies include experiential learning, challenging preconceptions, and developing skills in observation, listening, and storytelling to create more empathetic and effective designers (Montero, 2022).

Recent research highlights the importance of incorporating stakeholder engagement in design education. Participatory design methodologies have been shown to enhance student empathy and integrate social and technical aspects of design (Boradkar & Dhadphale, 2019). Design-led multidisciplinary innovation programs have evolved to consider the priorities of multiple stakeholders, including students, partner organizations, society, and academia (Bailey et al., 2019). In aerospace engineering education, integrating stakeholder requirements throughout the design process is crucial, though often overlooked in capstone projects (Coso & Pritchett, 2015).

Service design pedagogy, with its focus on collaborative activities and wider value considerations, has been identified as a potential means to enhance product innovation education by promoting sustainability principles and methods (Ding et al., 2023). These studies collectively emphasize the need for design education to adopt more inclusive, stakeholder-focused approaches to better prepare students for real-world challenges.

4.2.2 Pedagogy for Teaching Iteration

Iteration is a fundamental aspect of design thinking where the understanding of the problem and the development of the solution evolve together. Teaching this concept involves engaging students in iterative processes where they continuously refine both their understanding of the problem and their proposed solutions. Educators can use project-based learning to immerse students in real-world challenges, guiding them to iteratively test and refine their ideas. Encouraging reflection and feedback throughout this process helps students learn that problems and solutions are not static but dynamic and interdependent.

Iteration is a crucial aspect of design education, involving cyclical processes of idea generation, evaluation, and improvement (Yen et al., 2024). Various pedagogical approaches have been developed to foster iteration skills in design students outside China. These include alien-centred design, which emphasizes user needs and teaching iterative problem-solving by a systematic methodology based on established design axioms (Mendoza-Garcia & Cardella, 2014). Empirical studies have shown that iteration is unavoidable in instructional design processes, with different design styles leading to successful outcomes (Verstegen et al., 2006). To support novice designers, systematic methods combined with specific measures to manage iteration are recommended (Verstegen et al., 2008). Representations of iterative activity, derived from empirical data, can serve as valuable pedagogical tools for engaging students in discussions about effective iterative behaviors (Adams, 2002). These approaches aim to enhance students' understanding and application of iteration in design processes.

4.2.3 Pedagogy for Nurturing Creative Thinking Style

Cultivating innovative thought patterns proves essential in teaching design methodology, requiring learners to transcend conventional boundaries, question established perceptual blocks, and investigate alternative perspectives. Techniques such as brainstorming sessions, mind mapping, and role-playing can stimulate creative thinking. Additionally, exposure to diverse perspectives through interdisciplinary collaboration can inspire creativity. Educators can create an environment that celebrates curiosity and experimentation, allowing students to take risks without the fear of failure. By nurturing a mindset that embraces creativity, students can develop the ability to generate innovative solutions to complex problems.

Recent research on creative thinking in design education emphasizes experiential learning and interdisciplinary approaches (Samaniego et al., 2024). Key techniques include interdisciplinary projects, artistic practices, and digital tools, focusing on skills like originality and flexibility. The Educational Design Ladder model has been proposed to structure multidisciplinary Design Thinking programs (Wrigley & Straker, 2017). Design thinking in pedagogy emphasizes human-centred problem-solving and can enhance creativity and 21st-century skills development (Meyer & Norman, 2020). Non-traditional pedagogies are being explored to address the challenges of technological and social transformations in design education (Abd Manan et al., 2022). In architecture design studios, creativity is stimulated through specific criteria, idea generation techniques, and tailored pedagogies (Park & Lee, 2022). These studies highlight the importance of fostering creativity from an early age and adapting design education to meet contemporary needs. However, there is a need for more research in specific regions to enrich the global educational landscape in creative thinking and design (Samaniego et al., 2024).

4.2.4 Pedagogy for Using Cognitive Tools

Cognitive tools play a crucial role in design thinking education. They are essential in design thinking as they help in organizing thoughts, visualizing ideas, and facilitating problem-solving. Teaching students to effectively use these tools involves introducing them to various methods such as concept mapping, prototyping, and design software. Some pedagogies, such as workshops and hands-on sessions can

help students become proficient in these tools, enabling them to better structure their thinking and communicate their ideas. By integrating cognitive tools into the design thinking process, educators can enhance students' ability to tackle complex problems methodically and creatively.

Some researchers explored the pedagogies for the use of cognitive tools. These tools can be used for assessing design knowledge and skills, such as concept maps and justified graphs (Orhun, 2004). Integrating information and communication technologies as cognitive tools can shift teaching practices from teacher-centred to learner-centred approaches (Wang, 2014). For distance learning in design education, cognitive immersive experiences can be facilitated through online tools, supporting formal, informal, and social learning (Crain & Bailey, 2017). Cognitive tools can be classified into various functions, including information seeking, presentation, knowledge organization, integration, and generation (Haupt, 2018). While these tools offer significant benefits, it is essential to consider their design and implementation to avoid placing undue cognitive bias on learners (Liedtka, 2015).

Design education outside China emphasizes developing students' understanding of prototypes through various approaches. Teachers increasingly emphasizes prototyping as a communication tool, particularly in cross-cultural and distance learning contexts. Prototypes help students explain, persuade, and justify design decisions (Balakrishnan, 2022). However, beginning designers frequently fail to recognize prototypes' value as communication instruments, highlighting the need for enhanced teaching approaches (Deininger et al., 2019). Distance education programs have explored new methods for students to create and manipulate form remotely, such as converting sketches into tangible scale models (Prats et al., 2009). Various prototyping approaches, including spatial, multi-material, and physical prototyping, have been evaluated to support learning diverse competencies (Schaeffer & Palmgren, 2017).

4.2.5 Importance of Effective Pedagogy for Teachers in China

Drawing from these international insights, educators in China can adapt and implement similar pedagogical strategies to teach design thinking effectively.

Emphasizing experiential and studio-based learning can help students internalize design thinking principles. Providing opportunities for interdisciplinary collaboration can further enhance their problem-solving skills and creativity.

Design thinking pedagogy is gaining importance in Chinese education across various disciplines, from general education to law and K-12 (Li & Fu, 2020; Xu et al., 2023; Xu et al., 2024). It is seen as a valuable approach for developing critical skills such as empathy, creativity, and innovative problem-solving. In higher education, design thinking courses are being integrated to enhance students' practical skills and interdisciplinary collaboration. Some educators view design thinking as a means to build capabilities, foster a participatory approach to global issues, and develop a mindset. In legal education, it is perceived as an alternative to traditional methods, preparing students for future challenges in the profession (P. Xu, 2023). For K-12 education, design thinking is seen as a driver for educational innovation and development of young people's innovation abilities (Li & Fu, 2020).

Understanding the pedagogy of design thinking from a global perspective provides valuable insights for teaching it effectively within the domestic context. By adopting experiential, studio-based, and interdisciplinary learning approaches, educators can equip students with the skills and knowledge needed to excel in design thinking. Embracing a culture of experimentation and leveraging digital tools can further enhance the learning process, preparing students to tackle complex challenges with creativity and innovation.

4.3 Dimensions of Understanding Design Thinking

Design thinking is a multifaceted approach to problem-solving that encompasses various dimensions of understanding and application. It involves collaborative work and interdisciplinary approaches to address complex challenges (Koria, 2015). In educational settings, design thinking fosters problem-finding, framing, and solving skills, which are increasingly demanded of college graduates (McLaughlin, 1987). Design thinking is a complex cognitive process that characterizes designers' approaches to problem-solving and creativity (Cross, 2011).

Understanding concepts can occur at multiple levels of complexity. Klausmeier (1992) proposed four levels: concrete, identity, classificatory, and formal. Other researchers also identified several stages, including image making, formalizing, and inventizing (Guizzardi, 2005; Ball & Christensen, 2019). These studies highlight the importance of recognizing various levels of conceptual understanding in different domains. Research has shown that students may progress through these levels at different rates (Klausmeier, 1992; Guizzardi, 2005). Identifying and describing these levels can inform the development of instructional materials and assessment tools, ultimately enhancing concept teaching and learning (Wang, 2014).

The dimensions for this research include articulative, applicable, and internalized understanding, each representing a different level of comprehension and engagement with design thinking principles and practices. Recognizing and fostering these dimensions in educational settings is crucial for developing proficient and innovative designers. By focusing on these distinct aspects, educators can create a more robust learning experience that equips students with the necessary skills to navigate and excel in complex design challenges.

4.3.1 Articulative Understanding

Initial understanding refers to the ability to construct early knowledge based on existing experiences and knowledge. In this research, articulative understanding refers to the ability to clearly express and communicate the principles, processes, and outcomes of design thinking. This dimension involves not only verbal and written communication but also the use of visual representations to convey ideas (Rouse, 2013). Educators can enhance articulative understanding by encouraging students to engage in discussions, present their work, and create detailed documentation of their design processes. By articulating their thoughts and rationale, students deepen their comprehension and are better prepared to collaborate with others, share their insights, and advocate for their design solutions. Articulative understanding in design thinking involves the clear communication of design principles, processes, and outcomes through verbal, written, and visual means (Dorst, 2011).

4.3.2 Applicable Understanding

Applicable understanding refers to the comprehension and application of concepts in relevant contexts. It involves the ability to establish meaningful connections between new information and existing knowledge (Perkins, 2008). In information studies, understanding is emerging as a key research frontier, with two modes identified: hermeneutic and epistemological (Gorichanaz, 2018). In conceptual modeling, both information systems and application domain knowledge play crucial roles in schema understanding tasks, with knowledge being important for all task types, while the influence of application domain knowledge varies depending on the task (Khatri et al., 2006). This approach contrasts with traditional rote learning, focusing instead on building new knowledge from experience and prior understanding.

In this research, applicable understanding is the capacity to apply design thinking principles in real-world contexts. This dimension focuses on the practical implementation of theoretical knowledge and the ability to adapt and utilize design thinking methods to address specific challenges. Educators can foster applicable understanding through hands-on projects, case studies, and problem-based learning activities that require students to employ design thinking in tangible situations. By doing so, students learn to translate abstract concepts into actionable strategies, enhancing their ability to solve complex problems and create meaningful innovations in diverse settings.

4.3.3 Internalized Understanding

Internalized understanding refers to the process by which individuals incorporate external social and cultural knowledge into their cognitive structures (Marti, 2013). This concept is rooted in Vygotsky's theory of internalization, which posits that mental functions develop through social interactions (Symons, 2004). The internalization of psychological state dialogue fosters interpersonal comprehension, especially in how children form notions about peer relationships (Rizzo & Corsaro, 1988). Internalization is viewed as a transformative process rather than mere transmission, involving the construction of subjective experiences from imported social material (Lawrence & Valsiner, 1993). This process is considered intentional and potentially transformative, rather than rote mimicking.

Design thinking has emerged as a valuable approach for fostering innovation and problem-solving skills in education. Developing a design thinking mindset involves internalizing key attributes such as empathy, holistic thinking, and creative confidence (Vignoli et al., 2023). Educators can support this internalization through experiential learning environments that encourage reflective practice and repeated application of design processes (Groeger & Schweitzer, 2020).

In this research, internalized understanding means the deep, intuitive grasp of design thinking principles that becomes second nature to the practitioner. This dimension goes beyond explicit knowledge to include the subconscious integration of design thinking into one's mindset and approach to problem-solving. Educators can support the development of internalized understanding by creating immersive learning experiences, encouraging reflective practice, and providing opportunities for repeated application of design thinking processes. As students internalize these principles, they develop a natural proficiency and confidence in their ability to think creatively and iteratively, enabling them to tackle challenges with an intrinsic design thinking mindset.

Conceptual Framework 2 Levels of Understanding

From the unfamiliarity of the knowledge of design thinking to deeply understand of it, the levels of understanding are presented. This conceptual framework depends on learning theories and cognitive science. The behaviors and cognitive performance of each level shows what information we are going to find from participants.

From research questions 3 and 4, we want to know students' understanding of design thinking. These are the understanding levels: articulative understanding, applicable understanding and iternalized understanding.

TABLE.6 conceptual framework 2

Level 1: Articulative Understanding

Level 1	**Articulative Understanding**
Description	Start to aware the existence of the knowledge, early stage

Behaviors	Memorize explicit knowledge
	Describe explicit knowledge or general idea

	Articulation
	First trial
Cognition	Reproductive thinking
	Learnt facts and rules but not really able to apply
	Short-term memory
	Awareness of the existence of the knowledge

Level 2: Applicable Understanding

Level 2	**Applicable Understanding**
Description	Deeper stage, the knowledge is transferred into practice

Behavior	Transposition (apply knowledge to new contexts)
	Able to teach others
	Effective communication (clarity, coherence, ability to convey the concept to others in an understandable way)
	Apply in problem-solving
	Use appropriate strategies to bridge the gap between contexts
	Reinforced practice
	Enhancing the transferability and utility of knowledge (skilled performance)
Cognition	Productive thinking
	Sensitization of related environment
	Long-term memory
	Comprehension
	Flexibility and adaptability of thinking
	Recognizing the transferable elements of the knowledge
	Monitoring one's own thoughts (reflection)
	Making connections to other knowledge
	Recognize misconceptions

Level 3: Internalized Understanding

Level 3	**Internalized understanding**
Description	skills, attitudes, thoughts, and knowledge become parts of students' characteristics

Behavior	Habituation
	Behavior change
Cognition	Affect Instinct/ Intuition
	Affect Attitude
	Affect Mindset/ Cognition
	Affect belief/ inner life/ confidence

4.4 Chapter Summary

This chapter explores the pedagogy of design thinking concepts in conceptual framework 1 in various countries outside China, and the levels of understanding essential for mastering it. The chapter delves into three levels of understanding in design thinking as conceptual framework 2 in this research: articulative, applicable, and internalized.

Chapter 5 Research Methodology

This chapter shows this research's methodology and research design. It shows the rationale of the research methods and explains the reason why the methodology and methods are selected, how the research methods contribute to the study. The contents of this chapter include (1)qualitative research methodology, (2)sampling method, (3)data collection, (4)data analysis and (5) information needed to answer research questions.

5.1 Qualitative Research Methodology

This research utilizes a qualitative research methodology. Given the core features and benefits of qualitative methods, this approach is well-suited for exploring the answers to the research questions of this study.

Key Features and Benefits of Qualitative Methodology

Qualitative research is often exploratory, aiming to understand phenomena in-depth and generate new insights or theories. It investigates not only the objective nature but also the subjective meaning of behaviors, such as personal descriptions of attitudes, drives, and behaviors . The exploration in qualitative studies aims to understand what individuals say and do in various contexts and societies .

A key characteristic of qualitative research is its inductive approach, where patterns, themes, and theories emerge from the data rather than being imposed from the outset. Unlike quantitative research, which works with predetermined variables , qualitative research explores new variables or theoretical concepts through empirical studies . This approach employs various evidence-based materials - such as case analyses, personal narratives, reflective accounts, direct interviews, behavioral observations, historical records, interpersonal exchanges, and visual documentation - to reveal both typical and complex life experiences and their significance (Xu, 2023).

Qualitative inquiry fundamentally seeks to comprehend how individuals interpret and experience their personal realities and social contexts. Data collected from empirical resources can present individuals' perceptions, helping researchers understand the meanings and interpretations that participants assign to their experiences and actions. This methodology gives voice to participants, allowing them to share their stories and experiences in their own words, leading to more authentic and meaningful findings.

Qualitative methodology emphasizes the importance of context in understanding phenomena. Researchers consider the environment, culture, and specific circumstances surrounding the subject of study. By collecting rich and detailed data, qualitative research provides deep insights into the phenomenon being studied. The

researcher aims to acquire the most comprehensive set of available data (Lofland et al., 2022), analyzing and synthesizing it to answer qualitative research questions with descriptive data.

Why Use Qualitative Methodology in This Study

Given the research aim to gain a deeper understanding of nurturing design thinking in universities in China, qualitative methodology is essential to achieve the research objectives. The researcher needs to conduct empirical studies into teaching activities in design subjects to find answers to research questions.

To answer the four questions of this study, descriptive answers must be obtained from teachers and students in design subjects. The data required includes teachers' and students' understanding of the concept of design thinking, teachers' implementation of the pedagogy, and the students' impacts by design thinking in the problem-solving process.

This study needs to gain more insights into design thinking education in universities in China, requiring an investigation into participants' backgrounds, individual differences, and changes during the design process. Qualitative research methodology offers extensive opportunities to achieve this goal, providing a comprehensive understanding of the context and experiences of the participants.

5.2 Sampling method

This section outlines the sampling method of this research. The purposive sampling method is adopted, with an explanation of why it was selected and how it benefits the study. The sampling criteria are detailed and the research samples are introduced.

5.2.1 Purposive Sampling

Purposive sampling is a type of non-random sampling method commonly used in qualitative research. This method helps to quickly identify samples that meet specific requirements and make the best use of available resources.

One of the essential elements of purposive sampling is the selection of cases with rich information central to the study's purpose, providing a wealth of data (Coyne, 1997). By choosing information-rich cases, purposive sampling maximizes the utility of available resources (Patton, 2002). It requires identifying and selecting individuals or groups with particular expertise or experience related to the phenomenon being studied (Cresswell & Plano Clark, 2011). Sampling criteria are crucial for using the purposive sampling method to identify suitable samples. For this study, we should select design subjects where teachers and students have experience in design thinking education as samples.

Another crucial element of purposive sampling is the availability of researchers and samples, which benefits the research by providing access to rich, in-depth data. Samples should be chosen based on the researcher's time, location, interests, and energy, as well as the availability of the samples (Schatzman & Strauss, 1973). It is important that participants are available, willing to engage, and able to articulate, communicate, and reflect on their experiences and thoughts (Bernard, 2017). In this research, the availability of resources and the willingness of participants are key considerations when selecting samples.

5.2.2 Sampling Criteria

According to the research aim, design subjects from higher educational institutions that related to design thinking are selected as research samples and categorized into three clusters.

In order to answer research questions 1 to 4, the data collection should conducted with teachers and students in project-based subjects. These design subjects are named as cluster 1. From these, we can identify teachers' understanding of design thinking and their pedagogies. We can also identify students' understanding and how students'

understandings are internalized in their problem-solving approaches. To know more about teachers' understanding of design thinking, we select lecture-based subjects as cluster 2.

In clusters 1 and 2, design thinking is regarded as an important teaching component. However, design thinking is not only taught as explicit knowledge. Even without explicitly teaching design thinking, it can be nurtured through design practice. To understand how design thinking is nurtured in practice, we select a few project-based subjects were selected as cluster 3. These courses do not explicitly mention teaching design thinking in curriculum.

To collect rich data, the availability of documents and participants are also essential for this research. For project-based subjects, it is important that both educators and students are readily available and willing to participate in the research. For lecture-based subjects, ensuring access to relevant documents is essential.

The table below outlines the sampling criteria. The selection of design subjects for data collection in this study must adhere to the following criteria.

TABLE.7 Sampling Criteria

Categories	Sampling Criteria
Cluster 1	Design thinking is explicitly mentioned as an important teaching component in the course plan; Teachers will instruct students to finish a design project in the course; Teachers and students are willing to participate.
Cluster 2	Design thinking is explicitly mentioned as an important teaching component in the course plan; Teaching design thinking theoretically through lectures.

Cluster 3	Design thinking is not explicitly mentioned as an important teaching component in the course plan; Teachers will instruct students to finish a design project in the course; Teachers and students are willing to participate.

Based on the sampling criteria, we identified a total of 23 design subjects for data collection. Cluster 1 includes 10 project-based courses, while Cluster 2 comprises 10 lecture-based courses. Additionally, three more project-based subjects were selected for Cluster 3.

5.2.3 Research Samples

Twenty-three design subjects were selected as research samples. In the following sections, we will introduce how these subjects were categorized into the three clusters.

Cluster 2 consists of 10 lecture-based courses related to design thinking, such as online courses from MOOC platforms, which present the same theory of design thinking as project-based courses in universities, and the documents are highly accessible. Cluster 1 comprises 10 project-based courses that include design thinking as one of the core components. However, design thinking is more than a term or concept to teach; it is also a problem-solving approach in design practice. To gain further insight into how design thinking is nurtured, 3 project-based design courses without teaching design thinking were selected as cluster 3. They are listed as the following tables. For the information and details, please check appendice 1.

Samples in Clusters 1 and 3

The courses in clusters 1 and 3 were identified through online searches and direct contact with schools and instructors. The researchers reached out to approximately 50 schools to find courses that explicitly mentioned teaching design thinking and provided the instructors with details about the study. After assessing the willingness

of both instructors and students to participate, and following further screening and communication, ten design courses from the cooperating schools were selected for the research.

Here is a table presenting the research samples from clusters 1 and 3. These samples consist of project-based design subjects offered by the following universities.

TABLE.8 Research Samples of Clusters 1 and 3

Category	University
Cluster 1	Shanghai Jiao Tong University
	Shanghai University of Engineering Science
	Fujian Normal Uninversity
	Tsinghua University
	Guangzhou University
	Zhejiang University of Technology
	Jiangsu Ocean University
	Southwest Jiaotong University
	Luxun Academy of Fine Arts
	Wuhan University of Technology
Cluster 3	Beijing Institute of Fashion Technology
	University of Science and Technology Beijing
	Guangdong University of Technology

The background fields of these courses, as well as the study year and professional background of the participating students, can be found in appendice 1. We have ensured the ethical protection of the personal information of these participants. Throughout this study, their names, genders, majors, design experience, and other personal details will be anonymized.

Samples in Cluster 2

Cluster 2 consists of lecture-based courses related to design thinking. Since universities in China offer design thinking courses not only to enrolled students within design schools but also on Massive Open Online Course (MOOC) platforms, we identified these as valuable resources. Additionally, some university instructors independently offer their design thinking courses on MOOC platforms. These courses are freely accessible, and their documents are available, providing rich data for addressing research question 1. Therefore, we selected lecture-based design subjects from MOOC platforms as part of our research samples.and the availability benefits this study, the samples of cluster 2 are selected from MOOC platforms.

Cluster 2's lecture-based courses are sourced from Chinese university MOOC platforms. First, appropriate MOOC platforms were identified. The selection criteria were: (1) high click rates, (2) high usage rates, being recommended and discussed on many university websites and learning platforms, and (3) a large number of courses. A total of 11 platforms were selected, as shown in the table below. These platforms are well-known and widely used, with each platform offering open courses in collaboration with universities. Many courses are consistent with those offered at universities.

TABLE.9 Selection of MOOC Platforms

MOOC Platform	Name in Chinese	Website
icourse163	爱课程网	http://www.icourse163.org
XuetangX	学堂在线	http://www.xuetangx.com/
ChineseMOOC	华文慕课	http://www.chinesemooc.org/
CNMOOC	好大学在线	http://180.76.151.202/
UoocOnline	优课在线	http://www.uooconline.com/
Zhihuishu	智慧树	http://www.zhihuishu.com/
PmphMOOC	人卫慕课	https://pmphmooc.com/

Chaoxing	超星慕课	http://mooc.chaoxing.com/
CCtalk	CCtalk	https://www.cctalk.com/
Open163	网易公开课	https://open.163.com/
TecentKeTang	腾讯课堂	https://ke.qq.com/

By initial searching for “design thinking” on these 11 platforms, a total of 2,169 courses were found. The second step is screening. Through manually reading their titles, teaching objectives, content directories, and course syllabi, 152 courses related to design thinking were identified. Among these, there are not only many courses from design schools but also a significant number from business innovation management and engineering, with a smaller number from humanities, social sciences, and education. In total, 91 courses are offered by design schools. The following table presents the searching process in the MOOC platforms.

TABLE.10 Searching Process in MOOC platforms

MOOC Platform	Initial Search	Screening	From Design School
icourse163	1259	102	61
XuetangX	124	17	10
ChineseMOOC	0	0	0
CNMOOC	2	2	0
UoocOnline	130	7	6
Zhihuishu	34	12	5
PmphMOOC	0	0	0
Chaoxing	0	0	0
CCtalk	60	4	4
Open163	527	8	6
TecentKeTang	33	0	0
In total	2169	152	**91**

From these 91 courses, our research selected 10 design thinking courses for further investigation. The selection criteria were: (1) the courses comprehensively cover design thinking content with complete teaching materials, and (2) the entire course content is fully accessible. The table below lists the universities that offer these ten design subjects in cluster 2. Appendice 1 provides detailed information about these ten selected courses.

TABLE.11 Research Samples of Cluster 2

Category	University
Cluster 2	Zhejiang University
	Beijing University of Posts and Telecommunications
	Xi'an Polytechnic University
	Tsinghua University
	Nanjing University of the Arts
	Capital Normal University
	Geely University of China
	China University of Mining and Technology
	Yanshan University
	Xiangtan University

Recruit Students Participants

After establishing contact with teachers at these universities, the first step in the research process was to recruit participants from their classes. Two methods were used to recruit students for the study:

1. **Initial Recruitment via Social Media:**

   The first method involved creating a short message introducing the research study and the researcher. This message was then sent to students by their teachers via social media. The message was crafted to be both informative and engaging, and

it was also designed as an attractive booklet. The content of the message was as follows:

> The Design Education & Creativity Lab at The Hong Kong Polytechnic University is conducting a research study on the teaching and learning of design thinking in design schools on the Mainland. The aim is to explore teachers' pedagogies and students' learning experiences of design thinking in project-based subjects. We are looking to recruit five student participants. We will conduct two one-hour interviews in the middle and at the end of the course. To gain a deeper understanding of the learning process, we will have weekly follow-up communication through WeChat. The researcher, Miss Li Yating, is a PhD student at The Hong Kong Polytechnic University and a graduate of the Information Art and Design Department at Tsinghua University. She is also open to sharing design and work experiences beyond the research.

Despite the initial outreach through this booklet, sent either before or during the first week of class, some students were hesitant to participate. This led to the implementation of a second recruitment method.

2. **In-Person Presentation:**

   In cases where the initial message did not result in sufficient participation, the researcher conducted a short presentation about her learning and working experiences, aimed at engaging the students directly. During the first week of class, a 20-minute presentation was delivered via Tencent Meeting, where the researcher shared her experiences and insights with the students. The presentation was followed by a Q&A session, allowing students to interact with the researcher. Teachers also assisted in recruiting students who showed interest in the presentation. This approach proved to be an effective way to motivate students and increase their willingness to participate.

As a result of these efforts, 93 students were successfully recruited for the study. Each design subject had at least five highly motivated students willing to participate.

5.3 Data Collection

The data are collected by qualitative research methods. This section introduces the data collection methods and process. Also the triangulation in data collection.

5.3.1 Data Collection Methods

This research uses qualitative research methods. Documentation techniques and Semi-structured interviews are the main data collection methods. The experience sampling method is also used to assist the data collection.

In clusters 1 and 3, the data collection methods include documentation, semi-structured interview, and experience sampling method. Because of the data were collected mostly in the pandemic period, we only have a little chance for non-participatory observation. And participants' demographic information will be collected, which can be used in data synthesis. Since the data in cluster 2 are videos and reading materials, document analysis techniques will be applied in the data collection stage. The table below presents the data collection methods in this research.

TABLE.12 Data Collection Methods

Cluster	Data Source	Data Collection Methods			
		Documentation	Semi-structured Interview		Experience Sampling Method
			mid	final	
1	Teachers	✓		✓	✓
	Students	✓	✓	✓	✓

2	Teachers	✓			
3	Teachers	✓		✓	✓
	Students	✓	✓	✓	✓

The following paragraphs explains the rationale of these three research methods. Also, the reason for method selection and how these methods function in this study are elaborated.

Documentation

Reviewing documents that offer information to the research questions is called the documentation research method. This method is used to collect data from recorded human communications (Babbie, 2020), such as books, videos, photos and notes.

The process of documentation is divided into the following steps. Firstly, the collected documents should be verified. The researcher should check the document's type, who offers it, when, where and why it was written and recorded, the author, its title and its contents. Then, The document should be evaluated for how it is valuable for the research aim. After the evaluation, the researcher can decide how the document can be used in the data analysis phase.

One of the key benefits of the documentation technique is that it allows the researcher to collect a wealth of trustworthy information without having to interview numerous individuals. In this research, documentation will be conducted in both three clusters of design courses.

It is the selected method for collecting data from cluster 2. Because of the limited time and researcher of this study, documentation will be conducted in Chinese MOOC subjects to efficiently acquire qualified data for answering research question 1. Teachers' understanding of design thinking can be seen in the contents they present in the MOOC subjects, and these contents are arranged in the catalogue. The

documentation in cluster 2 will mainly focus on reviewing design thinking-related contents out of all the course materials.

A large number of documents will also be collected in the clusters 1 and 3, and the documentation allows us to clearly validate and categorize the materials. The main sources of documentation are (1) basic curriculum information documents; (2) the weekly schedule of the subject; (3) the teacher's teaching materials, such as PowerPoint files, recommended reading and references, previous student assignments, etc.; (4) the student's class notes; (5) the teacher's or students' photo or video records of the study process; (6) the student's documents produced during the problem-solving process of the design project, e.g. sketches, brainstorming notes, other design solutions not ultimately adopted, etc.; (7) student assignments or outputs other than the design project, such as documents from in-class activities; (8) the student's final design work, which may be in the form of a PowerPoint presentation.

Semi-structured Interview

Semi-structured interviews typically serve as the primary data collection method in qualitative research, usually prearranged at designated locations and times separate from normal activities. These interviews commonly follow predetermined open-ended questions while allowing for supplementary inquiries to emerge organically from the dialogue between researcher and participant (DiCicco-Bloom & Crabtree, 2006). The additional questions can dig into a deeper understanding of the information.

In this research, the semi-structured interview method serves as one of the primary data collection approaches. The interview protocols were designed based on the conceptual framework of the study. Initially, the interviews include predetermined open-ended questions, with additional follow-up questions posed during the interviews to delve deeper into information relevant to the research questions. These follow-up questions help to gain a more comprehensive understanding of teaching and learning design thinking.

For participants in clusters 1 and 3, semi-structured interviews are particularly suitable. These interviews will be conducted with both teachers and students within

these clusters. Students in clusters 1 and 3 will participate in two interviews: one during the middle and another at the end of the course. These interviews were conducted outside of the curriculum, ensuring that they did not interfere with classroom time. For teachers, due to their availability and willingness, each participated in a single interview. Additionally, we maintained ongoing contact with the teachers to inquire about the progress of teaching and learning throughout the course.

Experience Sampling Method

The Experience Sampling Method (ESM) represents a semi-naturalistic approach where researchers prompt subjects to report on their immediate experiences at unpredictable moments during daily life, usually spanning a week or more (Kubey et al., 1996). The objective of ESM is to gather self-reports that provide a representative sample of life experiences (Csikszentmihalyi, 1997). This method offers insights into individuals' behaviors, feelings, and mindsets, thereby enriching the context of the research.

In addition to the two primary data collection methods, the experience sampling method was selected as a supplementary approach. In the interviews, students often relied on recalling memories from the day. However, memory can be unreliable, with many details being modified or forgotten over time. Due to the resource constraints of this study, direct observation was not feasible, so the experience sampling method was employed to capture information that might be difficult to obtain through interviews, helping to better understand the dynamics of the learning process.

In this study, the experience sampling method was primarily conducted through several WeChat conversations. Students were also encouraged to write reflective journals to further document their experiences.

Demographic Information Collection

The collection of demographic information is beneficial for this research. In the pilot study, it was discovered that the preparation of this information facilitates communication in the interview. And it is also useful for ongoing communication in

the research to foster relationships with the participants and thus increase their willingness to participate. The demographic information of participants will be used in the data synthesis stage to understand the reason the findings appear.

Considering that the collection of basic information about the participants is beneficial for this research, the researcher will collect them in the data collection stage. The demographic information will be collected in many ways, such as inquiring about the participants in interviews or informal communication and collected from the documentation. This collection of basic information includes the participants' educational background, their working experience, and their prior experience of being taught design thinking.

5.3.2 Data Collection Process

We collected data from teachers and students in these 23 design courses between September 2022 and December 2023, using multiple methods. In clusters 1 and 3, data collection was based on documentation techniques and semi-structured interviews. We also used the experience sampling method, which gathers information at different time points during the course to avoid memory discrepancies in the final interviews. In cluster 2, we employed the document analysis.

A total of 13 educators and 93 students from clusters 1 and 3 participated in the research. The demongraphic information of students is shown in the appendix 2. We conduct one interview with each educator and two interviews with each student during the course. We conducted a total of 190 interviews, each lasting approximately one hour. Of these, 13 interviews were with teachers, and 177 interviews were conducted with students.

We also collected abundant documents such as course materials, student notes, reflective journals, assignments, sketches, and different versions of design works. Also, we communicate with students regularly on WeChat to understand their learning process.

Here is an overall chart of the data collection (take an 8-week subject as an example).

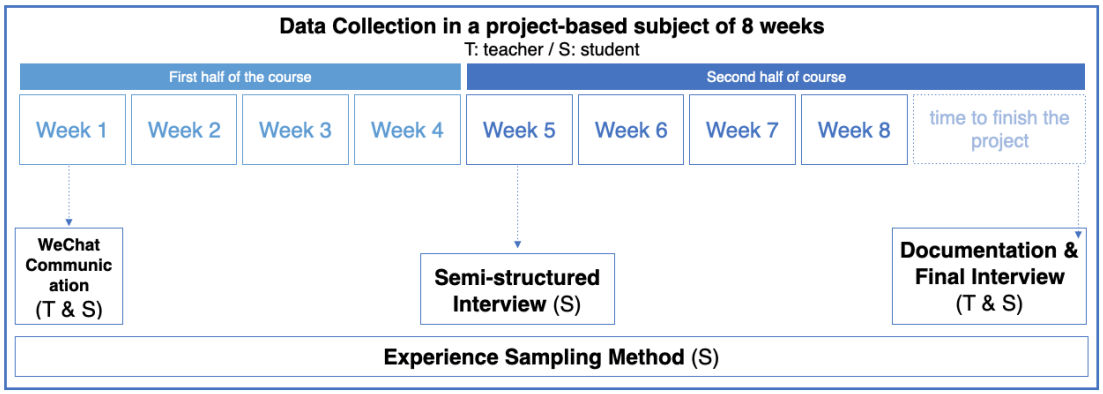

FIG. 3 An example of data collection process

5.3.3 Pilot Study

A pilot study is a small-scale trial run designed to pre-test the techniques and protocols in a research design that will later be applied to larger-scale research (Baker, 1994). Prior to conducting primary investigations, extensive research projects often implement preliminary trials that may incorporate both numerical and observational methodologies (Van Teijlingen et al., 2010).

Conducting a pilot study for this research is beneficial for three reasons:

- Pilot studies help test the feasibility and acceptability of the research design. By conducting a pilot study, researchers can assess whether the research design is appropriate and identify potential practical problems before proceeding with the main research.
- The pilot study can help researchers estimate the time and effort required to complete each stage of the research, allowing them to better plan and schedule the research.
- Additionally, preliminary data can be collected through the pilot study.

It is essential to test the research design in pilot studies. Based on the four research questions in this study, the most appropriate samples for the pilot study are those in Cluster 1, as the data collected from these samples can address research questions 1, 2, 3, and 4. Samples from Cluster 2, which are lecture-based subjects from MOOC platforms, can only address research question 1. Cluster 3, which shares the project-based delivery style of Cluster 1 but does not include design thinking in the

curriculum, cannot address research question 1. However, the information that Cluster 3 provides for research questions 2, 3, and 4 can also be collected from Cluster 1. Therefore, samples from Cluster 1 were selected to test the overall research design's appropriateness.

The pilot study for this research was conducted at Shanghai Jiao Tong University and Shanghai University of Engineering Science, which were the first to start classes among the 13 project-based subjects in Clusters 1 and 3.

Shanghai Jiao Tong University

The subject is in the field of product design. The course started on 30 September 2022, with classes held every Friday. The course duration is 16 weeks. According to the curriculum, the subject begins with a design theory component, followed by sketching exercises on product design in the middle of the course, and design practice in the second half. Students are grouped voluntarily before undertaking the design project, which is presented in week 16. The teacher allows students to continue revising their work after week 16.

Shanghai University of Engineering Science

This subject includes students from multiple backgrounds and is not specifically set for any particular field. The course started on 1 November 2022, with classes held every Monday. The course duration is 8 weeks. According to the curriculum, the subject begins with a design theory component and in-class discussions, followed by a study trip in the middle of the course, and a practical design project starting in the fifth week. Students are grouped voluntarily before carrying out the design project, which is presented in the 8th week. The teacher permits students to continue revising their work after week 8.

From September to December 2022, we conducted this pilot study with the two courses in Cluster 1 to assess the feasibility of the research design, particularly the data collection methods. Through the pilot study, we confirmed that the study design and data collection methods were feasible. After the pilot study, we refined the interview questions to make them easier for participants to understand. These refined questions were then implemented in the other 11 courses in Clusters 1 and 3.

Feasibility of the Research Design

The pilot study demonstrated that the research methods used in the research design were adequate. The data collected in Cluster 2 through documentation, semi-structured interviews, and the experience sampling method were able to answer all four research questions. The interview protocol effectively obtained the necessary data, and the pilot process allowed us to develop better interview questions for subsequent data collection.

Additionally, the pilot study confirmed that the conceptual framework was applicable to this study. The data collected from both teachers and students reflected the understanding of design thinking in Conceptual Framework 1. Furthermore, students' understanding of design thinking could be categorized into three levels: articulation, application, and transformation, as described in Conceptual Framework 2. The data could be coded using this conceptual framework to conduct thematic analysis.

Insights for Improving Interview Questions

The pilot study provided valuable insights for refining the interview questions:

(1) **Iterative Development of Interview Questions**

While the interview protocol was feasible, some questions were challenging for participants to understand, resulting in additional time spent explaining these questions during interviews, which prolonged the data collection process. Throughout the interview process, the researcher became more aware of which questions were more accessible to students. The researcher recorded effective

interview questions during the interviews, and in subsequent semi-structured interviews, difficult questions will be improved, and effective ones will be retained.

(2) **Need for Additional Data Collection**

In project-based learning, students were grouped in the middle and later stages to complete the design project. If data is collected from only some students, particularly those in the same group, it may result in a biased understanding of the subject's overall profile. For example, after data collection at Shanghai Jiao Tong University, the majority of students' data came from the second and third groups, while only one student provided data from the first group. By contacting two other students from the first group for interviews, the researcher was able to obtain additional information and relevant documents.

(3) **Increased Use of the Experience Sampling Method**

The experience sampling method proved beneficial for capturing participants' learning processes. For instance, at Shanghai Jiao Tong University, data collection was compared between students who participated in the experience sampling method from the beginning and two new students who were recruited as supplementary data. The new students only had one interview, which relied on their memory of the entire subject, making it difficult to observe changes in their learning process. In contrast, students who participated in regular WeChat communication and had two interviews provided more detailed information, allowing us to observe how their understanding of design thinking evolved throughout the course.

5.3.4 Data collected from teachers

Answers to research questions 1 and 2 can be obtained from the teacher. The data collection methods are used to collect data from teachers include (1) documentation and (2) a semi-structured interview.

Documentation (Teachers)

In this section, we collect materials from teachers that can be used for documentation. The documents collected were originally in Chinese. We translated the necessary information into English and included the original Chinese content as footnotes in this thesis. Below is a list of the data that will be gathered from teachers:

Documentation for Teachers' Materials from Clusters 1 and 3

The documents provided by the teachers can be categorized into the following main areas:

- **Basic Curriculum Information Documents:** These include general information about the course, such as the course syllabus and learning objectives.
- **Weekly Schedule of the Subject:** This outlines the sequence of topics and activities planned throughout the course.
- **Teacher's Teaching Materials:** These consist of PowerPoint presentations, recommended readings, references, and examples of previous student assignments.

From these documents, we can discern the subject's objectives and teaching structure. The teacher's understanding of design thinking and their pedagogical approaches are also reflected in this documentation.

Documentation for Cluster 2

For cluster 2, the primary focus is on identifying the teacher's understanding of design thinking. These insights can be gathered from the discussions of design thinking

within the course. Each course in cluster 2 includes its own introduction and content catalog. Documentation will begin by reviewing these tables of contents and identifying sections that are strongly related to the concept of design thinking.

Semi-structured Interview (Teachers)

Each teacher participated in a semi-structured interview, conducted in Chinese. Before conducting the interviews, we developed an interview protocol to determine the starting questions and potential follow-up questions. These questions mainly focused on the teacher's understanding of design thinking, the course's objectives for student development, curriculum arrangement, design thinking pedagogy, any assignments during the course, and the requirements for the final design project. Based on these focal points, we created an interview guideline, organizing the questions in a general order, though the sequence might change depending on the flow of the interview.

We used different interview protocols for teachers in cluster 1 and cluster 3. The two distinct interview protocols can be found in Appendix 3. For cluster 1 teachers, we began by asking how they understand design thinking and why these design thinking concepts are important in the course. For cluster 3 teachers, we first asked about their course objectives, the skills and qualities they aim to develop in students, and the reasons behind their course arrangements. Finally, at the end of the interview, we asked additional questions to cluster 3 teachers regarding their understanding of design thinking.

5.3.5 Data Collected from Students

Answers to research questions 3 and 4 can be acquired from the students. This section presents how the data collection methods are utilized to collect data from students. The main techniques include (1) documentation, (2) two semi-structured interviews and (3) experience sampling method. Experience sampling method are also adopted in the data collection process, the data are collected in different time points.

Documentation (students)

We collect materials from the students that can be used for documentation. The list below outlines the documents collected from students:

Documentation for Students' Materials

The main categories of documents that students may provide are as follows:

- The student's class notes
- The students' photo or video records of the study process
- The student's documents produced during the problem-solving process of the design project, such as sketches, brainstorming notes, and other design solutions that were not ultimately adopted
- Student assignments or outputs other than the design project, such as documents from in-class activities
- The student's final design work, which may be in the form of a PowerPoint presentation

The documents collected from students in Clusters 1 and 3 fall under these categories. Since these materials are in Chinese, they will be translated into English for citation in this thesis.

Semi-structured Interview (students)

Two interview protocols were designed for students: one for the mid-course interview and another for the final interview. These interviews are conducted in Chinese, allowing us to capture the changes and details in the learning process. The interview protocols were refined during the interview process, with adjustments made to the questions to better suit the responses of design students. Both interview protocols are provided in appendix 4.

The mid-course interview typically takes place during the middle of the course. In addition to understanding the teacher's course progress and what students have absorbed from the lessons, we also explore the students' understanding and

application of design thinking at this stage. In many cases, students have not yet started their design projects at this stage. Therefore, we ask them about their initial ideas for the design project.

The final interview is conducted after the course has ended and the assignments have been submitted to the instructor. Some courses allow students an additional 2-4 weeks to complete their work. During this period, while students may not attend regular classes, they often remain in contact with the instructor for guidance. In the pilot study, we found that asking students directly, questions with terminology such as "What is design thinking?" was difficult for them to answer. Therefore, in the final interview, we first ask students to recall the course process, discuss the problems their design aimed to solve, the design process itself, and the factors they considered. After students have reflected on their entire design process, we then ask them about the design thinking concepts they applied and what they believe designers should focus on during the design process. Follow-up questions are used to confirm that the students' understanding of design thinking comes from this course.

Before the interviews, instructors inform students that the interviews are unrelated to their course grades. During the interviews, the interviewer does not comment on the course or the students' work. At the start of the interview, students are reminded that the interview content will not be shared with their instructor and is not connected to their course grades. This approach is intended to provide students with a safe, reassuring, and comfortable environment for the interview.

Experience Sampling Method (students)

The Experience Sampling Method aims to gather more detailed information from the learning process and to understand the students' learning dynamics throughout the course. This approach is primarily implemented through two interviews, regular WeChat communication, and reflective journals in which students regularly record their learning experiences. Students also provided their sketches, unfinished works, and prototypes from the design process at regular intervals.

During the implementation of the Experience Sampling Method, we paid close attention to students' learning opportunities and time. To ensure that students had sufficient time for learning without adding extra pressure, we collected the following data at various points:

Semi-structured Interview (mid)

This interview was conducted in the middle of the course. At this stage, students may not have started working on their design projects or may still be in the ideation phase, making it challenging to assess how they will apply design thinking. In such cases, we asked students about their intentions for the design project, their current plans, and any concerns they had. Out of 93 students, 9 were unable to participate in the mid-interview due to time constraints, but we maintained contact with them through WeChat during the course. Ultimately, 84 students participated in the mid-interview.

Semi-structured Interview (final)

This interview was conducted at the end of the course. Some courses allowed students to complete their projects a few weeks after the last class. Therefore, this interview took place after students had finished their entire project. All 93 students participated in the final interview.

WeChat Communication

Communicating with students via WeChat allowed the researcher to obtain additional relevant information. WeChat communication brought the researcher closer to the participants and provided real-time insights into the course process, along with access to some additional documents and details about student learning. We had multiple WeChat conversations with all 93 students during the course to understand their progress and their understanding of design thinking.

Study Diary/Reflective Journal

We also encouraged students to maintain a weekly log of their learning through a study diary or reflective journal. These logs provided more context and added to our

understanding of the students' learning experiences. However, not every student was willing to do this. Some students felt that keeping a journal was disruptive to their focus due to their tight schedules, so we did not require them to do so. We collected reflective journals from most of the students.

Documents from the Design Process

The documents from the design process included students' class notes, in-class exercises, unfinished works, alternative design solutions they considered, and prototypes leading up to the final design. We collected process documentation from every student.

Collection of Demographic Information (students)

To efficiently gather demographic information and prior experience with design thinking from students, a template was developed for this study. In the pilot study, I found that asking students for basic information individually through WeChat communication was inefficient. To address this, a template has been designed to gather their demographic information more effectively. The Demongraphic information of students is shown in appendice 2. And some questions are intended to identify whether the students have previously studied design thinking, which will help in preparing for later interviews. This information will be collected during the data collection stage, through interviews and during the course process. This form applies to all the students in clusters 1 and 3.

TABLE.13 Temlpate for Collection of Demographic Information

Questions for Demographic Information	
Q1	What’s your name?
Q2	What’s your gender?
Q3	How old are you?
Q4	Educational background • Are you an undergraduate or postgraduate?

	• Which study year are you in? • What's your major? (If you are a postgraduate student, please also write down the university and major in your bachelor's degree.)
Q5	Work experience • Do you have work experience? • What is the content of the work? • How long is your work experience?
Q6	Have you ever taken subjects teaching design thinking before?
Q7	Have you ever studied design thinking from some source?

5.3.6 Triangulation

Data triangulation is a method used to enhance the validity and reliability of findings by cross-verifying data collected from multiple sources or methods. It involves comparing and contrasting different sources or methods of data collection to identify converging or diverging patterns, thereby increasing the trustworthiness of the research outcomes.

In this study, method triangulation was employed, with each design subject utilizing more than two data collection methods. Specifically, semi-structured interviews and documentation were employed across all subjects, with non-participatory observation used in some cases. Multiple data collection methods were applied for each participant to ensure the credibility and confirmability of the data. This approach provided a more comprehensive understanding of the phenomena under investigation and reduced the potential bias associated with relying on a single method.

Additionally, data triangulation was implemented within each design subject, with data collected from multiple participants. The study included a total of 23 design courses, each comprising several participants. This approach ensured that the data obtained were not solely dependent on individual perspectives but reflected a broader consensus within each subject. Data were also collected from three distinct clusters

of design courses: lecture-based courses explicitly teaching design thinking (Cluster 2), project-based courses explicitly teaching design thinking (Cluster 1), and project-based courses not explicitly teaching design thinking (Cluster 3). By incorporating data from diverse clusters and multiple participants within each cluster, the study achieved data triangulation, thereby enhancing the credibility and reliability of the research findings.

The investigator triangulation will be conducted in the data analysis stage. Another experienced researcher will be invited to discussed weekly of the collected data. By frequently discussion of the research findings can reduce bias in the data analysis in order to make this study more credible.

5.4 Data Analysis

Since the data collected in this research are descriptive, the thematic analysis method is appropriate for analyzing the data. Following the data collection stage, the data will be categorized using coding techniques and analyzed through thematic analysis. The rationale for using thematic analysis, its relevance to this research, and the use of the software MaxQDA for conducting the analysis will be discussed in the subsequent section.

5.4.1 Preparation for Data Analysis

Preparing raw data for analysis stands as the cornerstone of any research endeavor, serving as the crucial preliminary step that lays the foundation for insightful analysis and meaningful conclusions. It encompasses a range of procedures aimed at refining raw data into a format conducive to rigorous examination. One of the primary objectives is to ensure the accuracy, completeness, and consistency of the data, thereby minimizing the risk of erroneous interpretations and conclusions. Moreover, preparing raw data for thematic analysis plays a pivotal role in enhancing the efficiency and efficacy of subsequent analysis processes, streamlining the identification of patterns, trends, and insights within the data.

In the context of this research, this preparation step assumed importance in light of the ethical imperatives surrounding participant confidentiality and privacy. Following the completion of semi-structured interviews and document collection, stringent measures were implemented to safeguard the anonymity and integrity of participants' personal information. This entailed the meticulous anonymization of data, wherein participants' names and any identifiable information were replaced with pseudonyms or removed altogether. By anonymizing the data, researchers aimed to mitigate the risk of inadvertently disclosing sensitive information and safeguarding the privacy rights of participants. This ethical imperative underscores the conscientious approach adopted in data preparation, wherein the principles of respect, beneficence, and justice guided every stage of the process. Furthermore, the anonymization of data served to enhance the objectivity and impartiality of subsequent analysis, ensuring that interpretations and conclusions were based solely on the merits of the data itself rather than extraneous factors such as the identity or characteristics of participants.

MaxQDA Software

MaxQDA is a computer-based analysis of qualitative and mixed-methods data, text and multimedia materials designed for academic, research and commercial organisations. MaxQDA can be used for qualitative, quantitative and mixed-methods research. MaxQDA has a wide range of functional properties and the ability to process large volumes of interview material and documents relatively quickly. It is suitable for the thematic analysis of a large number of multiple data sources in this study.

Additionally, the choice to utilize MaxQDA as the platform for thematic analysis further underscores the meticulous approach to the preparation of data collected in this research. MaxQDA's robust features and user-friendly interface make it an ideal tool for managing and analyzing qualitative data, offering researchers a comprehensive suite of tools for coding, organizing, and interpreting data. By importing anonymized data into MaxQDA, researchers were able to conduct systematic and in-depth analyses, uncovering underlying patterns, themes, and relationships within the dataset. MaxQDA's flexibility and versatility proved

instrumental in exploring the complexities and nuances inherent in qualitative data, enabling researchers to derive rich and nuanced insights from the dataset. Moreover, MaxQDA's collaborative features facilitated seamless communication and collaboration among researchers, fostering an environment conducive to rigorous analysis and scholarly exchange. In essence, the meticulous approach of preparing data, coupled with the utilization of advanced analytical tools such as MaxQDA, exemplifies the commitment to excellence and integrity that underpins this research endeavor, ensuring that the findings are robust, reliable, and ethically sound.

5.4.2 Thematic Analysis

Thematic analysis represents a methodological approach for identifying, exploring, and interpreting significant patterns (termed "themes") present in qualitative datasets (Braun & Clarke, 2012). Thematic analysis emphasizes identifying and classifying both overt and underlying ideas within identified patterns, going beyond mere quantification of surface-level terms. This process typically involves generating codes that encapsulate discovered themes, which are then applied to original data as categorical labels for further examination (Guest et al., 2011). Codes are used to present, identify, and link to raw data for further analysis.

This research adopted the thematic analysis method. The use of thematic analysis has the benefit that it allows for the identification of patterns within the data that relate to participants' real-life experiences, opinions, and actions (Braun & Clarke, 2012). It is compatible with generating the answer to the research questions. In addition, the data collected in this study are from different sources of empirical study. Thematic analysis has the flexibility to analyse data collected from participants of different samples, and codes can be tagged on each data source, making it efficient and easy to analyse the data to meet the study objectives. Therefore, it is useful and convenient for analysing information that meets the objectives of the study.

Thematic information for each research question can be derived from the data collected from the three clusters. Research question 1 can be addressed using data from clusters 1 and 2. However, since the teaching documents in cluster 3 do not explicitly state that design thinking is taught, even if design thinking concepts are

mentioned, the data on teachers' understanding of design thinking from cluster 3 is not applicable for this question. Research questions 2, 3, and 4 can be answered using information from clusters 1 and 3.

Cluster 2 consists of lecture-based courses, where teachers' pedagogy cannot be fully identified. Additionally, since cluster 2 involves online students whose identities are unknown, it is not possible to answer research questions 3 and 4 based on this cluster. Below is a table summarizing the information available for each research question from the respective clusters.

TABLE.14 Information available for each research question

Research Question (RQ)		Cluster 1	Cluster 2	Cluster 3
RQ1	Teacher's understanding of DT	✓	✓	
RQ2	Teacher's pedagogy of DT		✓	✓
RQ3	Students' understanding of DT		✓	✓
RQ4	Impact on student's problem-solving approach		✓	✓

In the thematic analysis for this study, the coding scheme was developed based on four research questions, with specific concepts and themes subsequently added. To streamline the coding process and make the MaxQDA interface more efficient, short terms were utilized in the coding system. This brevity allows for easier navigation and analysis within the software.

For example, the coding system includes terms such as "Peda" for pedagogy, "HC" for human-centred focus, "CogTools" for the use of cognitive tools, "CTS" for creative thinking style, and "TOB" for thinking outside the box.

- **Research Question 1**: Utilizes Conceptual Framework 1 to identify teachers' understanding of design thinking, forming the basis of the coding system.

- **Research Question 2**: Codes teachers' understanding of design thinking along with their pedagogical approaches, while also incorporating students' perceived pedagogy into the coding system.

- **Research Questions 3 and 4**: Employ a shared coding system that integrates both Conceptual Frameworks 1 and 2. Conceptual Framework 1 is used to identify students' understanding of design thinking, while Conceptual Framework 2 assesses their levels of understanding.

The table provided outlines the coding scheme used in this research. The next section will provide a detailed explanation of the specific information required for each research question.

TABLE.15 Coding scheme in this research

Research Question	Information Needed for the Research Question	Coding System for Each Research Question
RQ1	Teacher's Understanding of DT	Conceptual Framework 1
RQ2	Teacher's Pedagogies of DT Students perceived pedagogies	Peda for CogTools Peda for Iteration Peda for CTS Peda for HC
RQ3	Students' articulation of DT Students' application of DT	Conceptual Framework 1 Conceptual Framework 2
RQ4	Impact on student's problem-solving approach	

5.5 Information Needed to Answer Research Questions

To effectively find answers for the research questions, it is important to clarify what information we need from the collected data. The information needed encompasses diverse dimensions, including but not limited to, educators' understanding and pedagogies for teaching design thinking, students' comprehension and transformation in problem-solving, and the impact of design thinking education on educational practices and student outcomes. By synthesizing insights from educators and students, researchers can gain a full picture of the intricacies surrounding design thinking education. Thus, the gathering of comprehensive and nuanced information serves as the cornerstone for addressing the research questions and advancing our understanding of design thinking education in practice.

Information Needed for Research Question 1

To explore how teachers understand design thinking, we will use Conceptual Framework 1, which presents the key concepts of design thinking. By analyzing teachers' interviews and the materials they provide, we can map their understanding against this framework. It's important to note that while teachers might not always explicitly mention a concept, they may still convey it through their pedagogical practices. These implicit expressions should be carefully coded and considered in the analysis for this research question.

Analyzing the data provides valuable insights into how educators understand and apply design thinking. By examining this information, researchers can identify the key aspects of design thinking from teachers’ understanding and how they integrate these concepts into their instructional practices.

This analysis sheds light on the diverse interpretations and applications of design thinking within the educational context of universities in China. Understanding the educational backgrounds and professional experiences of these educators is crucial, as these factors significantly influence their approach to design thinking. By exploring their educational and professional journeys, researchers can better

understand the factors that shape their perspectives on design thinking and how these perspectives are reflected in the design subjects they teach.

Additionally, considering a broader range of backgrounds and contexts, such as institutional development, cultural influences, and technological advancements, can deepen our understanding of how design thinking is perceived and implemented in education. This comprehensive analysis offers a pathway to understanding the complexities surrounding educators' understanding of design thinking in universities in China. By exploring the intricacies of their backgrounds, experiences, and perceptions, researchers can gain valuable insights into the pedagogical strategies used in this research.

The information gathered from this research question serves as a foundation for research question two. Based on teachers' understanding of design thinking, they develop and extend various pedagogies.

Information Needed for Research Question 2

To answer Research Question 2, it is essential to identify the pedagogies that correspond to the teachers' understanding of design thinking. These teaching methods reflect how teachers implement their understanding of design thinking within the curriculum. To gain a more comprehensive understanding of how these pedagogical strategies are executed, we will also gather insights from students on how they perceive and receive these teaching methods. Understanding how students internalize these methods will provide valuable information on the effectiveness and implementation of the teachers' pedagogies.

Investigating the specific pedagogies employed by teachers to teach design thinking is crucial. Educators may use a range of instructional methods, such as project-based learning, collaborative problem-solving tasks, case studies, and experiential learning activities, to engage students in the design thinking process. By analyzing the diverse strategies adopted by teachers, researchers can determine the effectiveness of different approaches in fostering students' design thinking skills.

Moreover, understanding the role of assessment in design thinking pedagogy is vital. Assessment methods, such as portfolios, presentations, peer evaluations, and reflective journals, are used not only to evaluate students' understanding and application of design thinking principles but also to shape their learning experiences. Investigating how these assessment practices align with pedagogical goals and influence students' learning experiences provides valuable insights into the effectiveness of design thinking instruction.

In addition to examining the curriculum design and pedagogy, it is important to consider the teachers' perspectives on teaching design thinking. This includes exploring whether they believe design thinking can be effectively taught, their approaches to teaching it, and the importance they place on certain concepts within the curriculum. These insights offer valuable context for understanding the rationale behind their instructional choices.

Finally, investigating the impact of contextual factors on teachers' pedagogical practices is essential. Factors such as institutional policies, resource constraints, and cultural norms can influence teachers' approaches to teaching design thinking. For instance, educators in resource-constrained environments may need to adapt their methods, while those in culturally diverse settings may need to consider how cultural perspectives affect students' engagement with design thinking. By exploring the interplay between these factors and pedagogical practices, researchers can gain a deeper understanding of the challenges and opportunities in teaching design thinking.

This research question's answer can serve as a foundation for the next one. In research question 3, we need to identify the design thinking understanding that students have gained from the course. Students must first receive the pedagogy before we can determine that their understanding comes from the course.

Information Needed for Research Question 3

We use Conceptual Framework 1 to gather the design thinking concepts that students learn during the course and identify which pedagogies these concepts stem from. The concepts collected from students represent a diverse array of perspectives, forming a rich database of students' understanding.

We also employ Conceptual Framework 2 in this question, as it allows us to connect with the previous research question's answers. This connection helps us identify which teaching methods are most effective and reveals the varying levels of students' understanding of design thinking within the course. Research question 3 delves into the depth of students' understanding of design thinking, which can be categorized into three levels: articulation, application, and transformation. At the articulation level, students possess a basic understanding of design thinking concepts and can articulate them to some extent. At the application level, students demonstrate the ability to apply design thinking principles in practical scenarios. Finally, at the transformation level, students exhibit a profound understanding of design thinking, enabling them to transform problems into innovative solutions through creative and empathetic approaches.

Understanding which aspects of design thinking are derived from the classroom is crucial. Each student brings a unique foundation, influenced by prior exposure to design thinking concepts. Some students may have received formal training in design thinking, while others may have acquired knowledge from alternative sources such as the internet or workshops. Additionally, students may vary in their familiarity with design principles, with some being novices in the field. We will only consider the understanding of design thinking from students within this study's design subjects for the findings.

We collect data from students at multiple points during the course, from the early stages to the middle, and again after the course concludes. This allows us to understand the teaching of design thinking within a dynamic context. This dynamic view helps us more clearly determine how students' understanding is formed and where it originates.

Understanding students' comprehension of design thinking is essential for effective design education. By delineating students' understanding into articulation, application, and transformation levels, researchers can gain insights into the depth and breadth of their understanding. Employing a conceptual framework of design thinking provides the necessary scaffolding to decipher students' perspectives and identify areas for further development. Moreover, exploring students' prior

knowledge and experiences enriches our understanding of how students engage with design thinking concepts.

Information Needed for Research Question 4

This research question is answered using Conceptual Framework 2 to explore the internalized understanding of design thinking and Conceptual Framework 1 to identify the impact of students' understanding.

Understanding the impact on students' problem-solving approaches is integral to assessing the efficacy of design thinking education. As students progress through their educational journey, they undergo profound changes in their problem-solving methods, attitudes, motivation, and self-confidence. While developing problem-solving skills is crucial, equally significant are the shifts in students' problem-solving attitudes and mindsets, which are essential for their holistic growth and development.

Although it might be unrealistic to expect a single course to significantly transform students' problem-solving abilities, it is important to recognize the incremental changes that occur over time. By closely examining the subtle shifts in students' problem-solving processes throughout the course, educators and researchers can gain valuable insights into the personal growth and development that students experience. These changes are influenced by the course content, the pedagogical strategies employed by the teacher, and the students' engagement with and reflection on the design challenges they encounter.

Students’ internalization of the design thinking approach in problem-solving extends beyond acquiring skills; it encompasses a broader range of cognitive, emotional, and behavioral changes. For instance, students might shift their perspective on difficulties, viewing them not as challenges but as opportunities for creativity and innovation. Similarly, their thinking patterns may evolve to become more flexible, adaptive, and divergent as they engage with design thinking principles and methodologies. Additionally, students' attitudes toward design may transform as they develop a deeper appreciation for the iterative and collaborative nature of the design process.

Through interviews, researchers can identify the nuanced shifts in students' attitudes, motivations, thinking patterns, and self-perceptions, as well as observe these changes in their work. It's essential to recognize that not all students will experience the same degree of transformation—some may show significant changes, while others may exhibit little to none. Exploring the reasons behind these variations can help researchers understand the factors that facilitate or hinder growth in problem-solving.

Moreover, it's important to acknowledge that students' transformation in problem-solving is not solely determined by the course content but is also influenced by various contextual factors. For instance, students' prior experiences, learning environments, and personal motivations may shape their receptivity to design thinking concepts and their willingness to engage in the problem-solving process.

5.6 Chapter Summary

This chapter describes the research methodology and research design of this study. This chapter first introduces the use of qualitative research methodology, followed by the sampling method, explaining how to select the 23 design courses for this study. It describes the process and methods of data collection, as well as the preprocessing and thematic analysis of data. It also mentions the information needed for the four research questions.

Chapter 6 Research Findings

This chapter presents the research findings. All research questions were answered after completing the data collection and analysis. All interviews and documents collected were in Chinese. In this chapter, this information is quoted in English, with the original Chinese in the footnotes. Next, we present our research findings in the order of the four proposed research questions (RQs):

- RQ1: How do educators understand design thinking?
- RQ2: What pedagogies are educators using to teach their understanding of design thinking?
- RQ3: How do students understand design thinking based on the pedagogies they have received?
- RQ4: How does students' understanding of design thinking affect their problem-solving?

6.1 Answers to Research Question 1

RQ1: How do educators understand design thinking?

Finding 1: All teachers demonstrated their understanding in subjects explicitly emphasizing design thinking (Clusters 1 and 2). Teachers had a different focus on teaching design thinking in their classes, and many teachers showed their understanding through a linear design process.

In subjects emphasizing design thinking (Clusters 1 and 2), all teachers demonstrated their understanding of the concept. They all expressed the importance of design thinking in their classes and during interviews. As mentioned in the curriculum, these teachers emphasized that nurturing design thinking is a crucial goal and teaching component of their courses. Although teachers all emphasized the importance of nurturing design thinking in the course, their focus on teaching design thinking varied.

All Teachers Demonstrated Understanding of Key Concepts in Design Thinking

All teachers appeared to believe that design thinking, as a problem-solving approach, comprises important concepts that students need to understand. All the subjects in Clusters 1 and 2 emphasized the use of design thinking to solve human problems and encouraged students to use design thinking to identify and address issues in daily life. They encouraged students to pay attention to everyday details and identify human needs. Many teachers mentioned building prototypes in the design process to express design ideas and test feasibility. The importance of innovation was frequently highlighted, with many teachers encouraging students to apply creative thinking throughout the design process. Some teachers also noted the significance of iteration.

While teachers' descriptions of these concepts varied, they consistently referenced all key aspects corresponding to the concepts in Conceptual Framework 1: holistic

consideration, iterative process, creative thinking style and the use of cognitive tools. The understandings that teachers displayed is elaborated in the following findings for this research question.

The emphasis on the understanding of design thinking for problem-solving varied across subjects. Depending on students' levels, course schedules and course objectives, teachers strategically incorporated their understanding of design thinking into their courses.

A Different Focus on Teaching Design Thinking

Based on differences in students' levels and the training objectives of these subjects, teachers placed a different emphasis on teaching design thinking in their classes. Some educators attempted to explain design thinking comprehensively from the perspective of the entire design process. In contrast, some educators focussed on limited aspects of design thinking, such as human-centred design and creative thinking.

Some teachers attempted to cover the key aspects of design thinking comprehensively, especially in Cluster 2. For instance, Zack covered human-centred design, identifying real problems, the iterative process and using prototypes for expression and verification. These concepts were explained with design cases in Zack's lecture, and he also explained why these concepts are important in design practice.

> *"By taking this course, you will understand the concept, history, and current state of design thinking, master the processes, frameworks, methods, and related tools of design thinking, and be able to combine the path of innovative design development to solve real-world problems, thereby gradually engaging in innovation and entrepreneurship practice." (Zack)*[1]

> *"The course covers topics such as technology, culture, art, human-centred design, business, and integrated design in 'innovative design,' as well as the*

[1] 通过学习本课程，你将了解设计思维的概念、历史与现状，掌握设计思维的过程、框架、方法及相关的工具，并可以结合创新设计发展路径，解决现实存在的问题，进而逐步开展创新创业实践。(Zack)

steps of 'need understanding - problem definition - ideation - prototype design - model iteration - result presentation' in 'design thinking.' Moreover, it incorporates domestic and international practices, with the teaching plan featuring distinct interdisciplinary, cross-field, and cross-border characteristics." (Zack)[2]

In some subjects, particularly in Cluster 1, teachers focussed on teaching one or two aspects of design thinking. For example, Leo's course mainly nurtured students to understand and analyse human needs.

"Mainly through design thinking methods, students analyze these matters. Once the analysis is done, they need to concretely define the target users." (Leo)[3]

However, some subjects focussed mainly on disciplinary knowledge, with design thinking discussed in only one or a few sections. For example, while Sandy's course title and outlines emphasized the design thinking approach, and human-centred approaches are mentioned, the main content often leaned towards unrelated topics such as brand building, gamified systems, the community economy and the opportunities and challenges of the AI era. Design thinking appears as a buzzword in course titles to attract interest, but the actual content may not align with the design thinking approach.

Demonstration of Design Thinking in a Linear Process

Within this research, many teachers showed their understanding of design thinking through a linear design process and emphasized the stages of design steps, with a few teachers highlighting the non-linear nature of these steps. Commonly, teachers presented the double diamond model and the five stages to explain design thinking, treating the steps as part of a standard design process. This phenomenon of explaining

[2] 课程涵盖了"创新设计"的技术、文化、艺 术、人本、商业及集成设计等内容，以及"设计思维"的"需求理解-问题定义-思维发散-原型设计-模型迭代-成果发布"等步骤，而且还结合国内外的实践，教学方案具有鲜明的跨学科、跨领域和跨国界特性。(Zack)

[3] 主要通过设计思维的方法，让他们去分析这些事情。分析好之后，就要求他们把目标用户实在的固定下来。(Leo)

design thinking through a linear process appeared in most lectures. These lectures often involved explaining the term “design thinking”, including its history, process, models and related tools. Notably, many teachers emphasized the design steps in a linear sequence.

This approach was not limited to lecture-based subjects in Cluster 2. In Cluster 1, most courses allocated a significant portion of their teaching time to lectures, often taking up half of the course duration or more. During these lectures, most Cluster 1 teachers also used a linear design process to explain design thinking. When guiding students through the design process, many teachers also followed these linear steps, such as first identifying design needs, then ideating, followed by prototyping and finally testing.

Finding 2: In Clusters 1 and 2, all the teachers emphasized human-centred focus, mainly emphasizing on user-centred approach. A few mentioned considering stakeholders, and some highlighted the importance of empathy in design.

Similar Understanding in Human-centred Focus

Related to a holistic consideration, the teachers' understanding has similarities in its human-centred focus. All the teachers in Clusters 1 and 2 mentioned the importance of human-centredness in design thinking, and many teachers stated that the core of design thinking is to meet human needs.

> *"Design thinking itself views problems from a human perspective. If it were technology-driven, this methodology wouldn't be necessary. Therefore, the core of design thinking is user-centred and human-centred." (Charlotte)*[4]

> *"Design thinking is a human-centred spirit and approach that takes into account human needs and behaviours, as well as technological or commercial feasibility." (Cholly)*[5]

Some teachers stated that when designers begin thinking about design, they should start from daily life and consider how to benefit people to determine which problems need to be solved.

4 设计思维本身是站在"人"的视角看问题，如果是技术驱动，就不需要这套方法论。所以设计思维最核心的就是以用户为中心，以人为中心。(Chris)

5 设计思维是以人为本的精神与方法，考虑人的需求、行为，也考量科技或商业的可行性。(Cholly)

"Design addresses the most fundamental practical issues that need to be implemented. These issues involve the most personal interests and the most immediate conflicts in our lives." (Erell)[6]

"The more important point is how we pay attention to the details of everyday life, identify critical problems, and find better ways to solve them." (Fritz)[7]

Varied Interpretations of Human-Centred Scope

Although they all mentioned a human-centred focus, they had different definitions of the scope of "human" in human-centred design. Most courses, when talking about human-centred design, refer to being user-centred, with the "design user" as the design object. They emphasized considering the user and the market, while requiring a precise target user group.

"It also emphasizes cultivating a basic habit of user thinking research and market research in them." (Erell)[8]

"The design work ultimately has to be acknowledged by its users to be considered successful or unsuccessful." (Mary)[9]

For example, George highlighted the importance of knowing who the design is for and emphasized the importance of preliminary research into users' needs to ensure the design is appealing to the target audience.

"Preliminary research is crucial, as well as the initial positioning: what kind of product am I going to make, who exactly is the target user of this product,

6 设计它解决的是最为基本的需要落地的实践的问题。这个问题涉及到我们生活中最切身的利益。和最切身的矛盾。(Erell)

7 更重要的点是我们怎么关注生活当中的点点滴滴，然后并且发现很关键的问题，并且如何更好的解决它。 (Fritz)

8 也在强调他们培养他们的一个基本的用户思维调研和市场调研的这样的一个习惯。(Erell)

9 设计的作品，最终是要被他使用的人肯定才能算。才能说是他是成功的或者是不成功的。(Mary)

what materials and price will it have, and what will it roughly be like as a final product in terms of price and quality." (George)[10]

However, only a few teachers mentioned that design should also consider stakeholders or expanded the scope of design objects to include people related to the user. For instance, Chris specifically emphasized that design thinking should consider stakeholders.

"Stakeholders are very typically user-centred tools. Before embarking on specific primary research, we often have to analyse what people or organisations have a close stake in the whole, to facilitate the selection of specific research subjects." (Chris)[11]

Emphasizing the Use of Empathy

Some teachers mentioned the importance of applying empathy in design. When talking about empathy, Zack mentioned the importance of applying empathy to understand the real needs of users. He added that understanding users' deeper needs allows designers to compensate for their initial lack of understanding.

"Often the apparent behaviour of the user does not align with the underlying needs. Understanding is not just about understanding the user's behaviour, but also about understanding the user's real needs. Satisfying the deeper needs of the user grounds the design and makes up for the designer's lack of understanding of the target user." (Zack)[12]

Teachers had a similar understanding of the application of empathy. They unanimously agreed that understanding others' perspectives by putting oneself in

[10] 前期的调研是很关键的，还有前期的定位，我到底做一款什么样的产品，这款产品的用户到底是哪一个精确的人群，他到底是采用什么样的材质，什么样的价格，然后它大概最后变成一个商品，大概是什么样一个价位，什么样一个品质。(George)

[11] 利益相关人是非常典型的以用户为中心的工具。在展开具体的初级研究之前，我们往往要分析什么人或组织于一体具有密切的利益关系，便于选择具体的研究对象。(Chris)

[12] 用户的表面行为与潜在需求往往并不一致。理解，不仅仅是理解用户的行为，更需要理解用户的真实需求。满足用户的深层需要，让设计有根据，弥补了设计师对目标用户的了解不足。(Zack)

their shoes is crucial. They believe it is necessary to analyse the characteristics, psychological cognition, behaviours and needs of target user group to understand those different from the designers themselves. For example, in her class, Bella emphasized that students need to understand the other person's perspective.

> *"I convey this message: you need to try to empathize and understand from the other person's perspective." (Bella)*[13]

> *"Designers create user personas by integrating basic indicators and identifying specific consumer groups. They should also conduct a thorough analysis of group characteristics, psychological cognition, behaviors, and needs. User personas should be immersive, empathetic, and authentic, described with keywords to derive design concepts and create designs from the consumer's perspective." (Jenny)*[14]

[13] 我传递出来这个信号，你们要试图感同身受对方的角度啊。(Bella)

[14] 设计师制作用户画像，除了整合基本指数，圈出特有的消费群外，还应该对群体特征、心理认知、行为和需求进行缜密分析。用户画像要有代入感，要有同理性、真实性，并且用关键词来描述，导出设计概念，从消费者角度去创意设计作品。(Jenny)

Finding 3: In Clusters 1 and 2, many teachers emphasized prototyping to express and communicate ideas. Some mentioned using prototypes to verify solutions, while a few discussed learning from verification.

Shared Emphasis on Prototyping for Idea Communication

In relation to the use of cognitive tools, most teachers in Clusters 1 and 2 emphasized the importance of prototyping. Many highlighted how prototypes are crucial for conveying design concepts. Judy, for example, discussed prototyping as a tool for processing thoughts, generating inspiration, and evaluating ideas.

> *"Prototyping is a thinking tool. It is tangible, visual, and manageable. It can be used to showcase the outcomes of our thinking, spark inspiration, and evaluate the results of our ideas." (Judy)*[15]

> *"A prototype is a tool for them to present their concepts." (Mary)*[16]

> *"We particularly emphasize creating prototypes that don't need to be highly precise; as long as the idea is conveyed, that's enough. Prototypes allow for discussions among people from different disciplines and can then be tested with target users to assess usability and effectiveness. This iterative process highlights that hands-on practice is essential. Prototyping helps different disciplines understand each other, forming a common language that facilitates communication. The prototype is an excellent medium for this." (Chris)*[17]

[15] 设计原型是一种思考工具。它是具体的，视觉的，可操作的。利用它可以展示我们思考的结果，激发灵感，并评估思考的结果。(Judy)

[16] 原型就是让他们讲自己概念用的，是道具。(Mary)

[17] 我们特别强调做原型，不一定做得很精准，能把意思表达出来就可以，可以让不同学科的人进行商讨，然后再拿给我们的目标用户去测试是否可用和好用，然后再进一步去迭代开发。这个过程中我们会发现，动手实践是核心，要把它原型化，能让不同学科的人理解，这形成了一种共通的语言，大家都能用这样的语言去沟通，原型就是一个特别好的媒介。(Chris)

Different Requirements for Prototype Details

Many teachers talked about the importance of prototypes for tangible communication, but their requirements for the level of detail varied. Some teachers stressed the significance of creating high-fidelity prototypes to showcase the design's effectiveness. They emphasized developing precise skills, such as accurate sketching, modelling and using AI tools to produce detailed renderings. These teachers prioritized the refinement of students' work, possibly because class assignments were intended for competitions, exhibitions or to produce a comprehensive project portfolio. As a result, they required students to achieve a certain level of completion in their prototypes.

> *"In our courses, we continuously train students in their sense of aesthetics and design expression abilities, which are crucial for innovative thinking. Even if your ideas are excellent, if your expression is poor, people will be reluctant to see or listen to them. This would be quite detrimental." (Fritz)*[18]

> *"Recording and expressing the fleeting, continuously flowing experiences and ideas in your mind require some tangible skills at hand."(Allen)*[19]

Other teachers placed less emphasis on refinement and focused more on the quick and effective communication of concepts. These teachers did not restrict the level of detail or methods used for prototypes. They emphasized in interviews that students did not need to produce highly polished prototypes. Instead, the priority was on rapid idea expression.

> *" Whether using traditional mediums like sculpture and painting or artificial intelligence, it primarily serves as a way to present your thinking.*

[18] 那我们的课程当中就是也不断的训练他们的一个美感，或者说怎么样，设计表达的一个能力，也是创新思维一个比较重要的一个环节吧，我觉得虽然你的思想法很好，但是你表达很烂，但别人都不愿意看，不愿意听对。那也是很糟糕的嘛。(Fritz)

[19] 对于你脑海里面不停流动的这种转瞬即逝的经验体验创意，这些东西的记录和表达。那还是要有一点点手头上的东西。(Allen)

If you cannot clearly explain or use this medium to express your thoughts, it indicates a complete failure." (Erell)[20]

"Your hand-drawings reflect your thinking. I will have requirements, but it doesn't matter how poorly you draw; what matters is that it reflects your thought process and how you creatively solve the problem." (Helen)[21]

Testing Solutions through Prototypes

Some teachers highlighted the need to create prototypes to test the feasibility of solutions. After creating prototypes, some teachers emphasized the need to test them with users. For example, Mary introduced various types of prototypes and emphasized that prototypes are meant for user testing, while Zack suggested that through continuous improvement, designers can use prototyping tools to reduce the cost of design and thus increase the efficiency of iteration.

"I explained to them that a prototype is not just a physical model. I gave them several examples to broaden their understanding. Prototypes can include storyboards, models, open-source hardware, service blueprints, and even commercial mockups. So, I opened up their thinking and, during testing, allowed users to experience their work." (Mary)[22]

"Prototyping allows for quick idea realization and improves communication efficiency. It helps reduce production costs, increases efficiency, and enables faster iterations." (Zack)[23]

[20] 因为无论是使用雕塑，绘画传统的这种表现方式，还是说使用人工智能。那它首先是你思维呈现的一种方式。如果自己都解释不清楚，不能利用这种媒介表达你的思维的话，那说明这个是完全失败的。(Erell)

[21] 你手绘的体现了你的思维。我会有要求，你画出来的，你画的再差我觉得都没关系，它体现了你的思维，体现了你怎么解决这个问题的创意。(Helen)

[22] 我跟他们说了 Prototype 不仅仅是一个实体模型，其实 prototype 它包含的类型特别多。故事版、模型的开放式硬件，甚至像这种服务蓝图还有商业样式都属于 prototype。所以，先打开他们的思路，最后测试的时候就让用户去体验，他们就拿作品让用户去体验。(Mary)

[23] 原型设计可以快速实现想法，提高沟通效率。借助原型能节约制作成本，效率高效，速度更快的迭代。(Zack)

Learning by Doing

When discussing the validation of solutions, few teachers mentioned the importance of experiential learning during the design process. While only a few explicitly discussed this in interviews, it is possible that more teachers understood the concept of learning by doing but did not mention it explicitly. For example, David stated in the interview that making prototypes is a learning-by-doing process. Through this process, designers gain a more in-depth understanding and build their thinking step by step.

> *"First, learning to create prototypes is a valuable learning process. During this process, you understand and comprehend. Through these steps, you can gradually advance and develop your thinking process step by step." (David)*[24]

[24] 我们说"先学做"，这个是一个很好的学习过程。在"学做"的过程当中。就知道就理解。通过这些步骤，能够把自己的思维的成长和发展的过程，一步一步推进出来。(David)

Finding 4: In Clusters 1 and 2, many teachers emphasized the importance of iteration in design. Among these teachers, most mentioned that iteration is for optimizing solutions. Only a few also highlighted that the iteration process allows for re-examination of the problem.

Emphasis on the Importance of Iteration

Many of the teachers in Clusters 1 and 2 emphasized the importance of iteration in design. They noted that design is inherently a lengthy iterative process and that quickly prototyping, re-interviewing users and iterating are essential steps in refining solutions.

> *"Design is actually a rather long iterative process." (Mary)*[25]

> *"Quickly prototyping, re-interviewing users, and then iterating are also crucial steps." (Leo)*[26]

For example, Helen noted that iteration a crucial method in the design process to keep the mind flexible, and she suggested it can happen at any design phase. She emphasized that iteration allows for continual adjustment and improvement. Like a ping-pong player continuously moving and adjusting, designers can iterate at every stage to stay dynamic and flexible.

> *"Design thinking involves constant iteration, and we can think of it like water—it's dynamic and very flexible. Design thinking keeps your mind in a flexible state, similar to a ping-pong player continuously moving and*

[25] 设计，它其实是一个比较长的迭代的过程。(Mary)

[26] 快速成型和再去采访用户，然后去迭代，也是很关键的内容。(Leo)

adjusting at the table. Its essence lies in the fact that you can iterate at every stage or any phase of the process." (Helen)[27]

A Prevalent Understanding of Iteration for Optimizing Solution

Among the teachers who emphasized iteration, a prevalent understanding was that iteration is for verifying design solutions. David mentioned that iteration involves refining and validating design concepts through continuous feedback and testing. This process helps to ensure that the design meets the required standards and effectively addresses user needs.

"The iterative mindset involves a process of developing from a conceptual idea to a planning stage and then to a concrete solution. It is not possible to create a high-quality, reliable outcome all at once. We can only achieve this through continuous validation and repeated discussions at each stage. By addressing the major aspects first and then gradually delving into the details, we can ensure that the entire development process is accurate and less prone to errors." (David)[28]

Fritz explained that updating solutions involves a continuous process of feedback and iteration. He compared the design process to a scribbled line that evolves through constant adjustments, rather than a straight line. Starting over is sometimes necessary, and Fritz introduced this non-linear process early in the course to help students understand the iterative nature of design.

"The updating of solutions is continuous. Each time they discuss their solution with us, I provide feedback or suggestions, which leads them to iterate. In the product course, I also tell them that the product design process

[27] 设计思维，它有不断的迭代，我们也可以把它理解成水，那这个水它是活的。它非常的灵活……所以设计思维，我觉得它会让你的头脑处在一种比较灵活的状态。像打乒乓球运动员不断的在桌子前面轻轻的跳跳来跳去的那种感觉。还有一个是，我觉得它的精华在于每一个阶段，或者是你在任何阶段你都可以迭代。(Helen)

[28] 迭代的思维就是从一个概念性的东西，再到一个规划性的东西，再形成一个具体性的东西的一个发展的阶段的一个过程。是这样的。不可能一下子就让他们去形成一个低保，高保证的东西，这是不可能的。我们只有通过不断的论证，不断的在每一个阶段里面去进行反复的讨论，解决了大的东西，慢慢往细节去不断的深入。之后才能够保障这整一个开发的过程是比较精准的，不会容易出错。(David)

is not linear. It is like a scribbled line that constantly evolves, rather than a straight line moving forward. The design process may require starting over, and this is an important concept I convey to them early in the course." (Fritz)[29]

Few Understand Iteration for Redefining Problems

Few teachers emphasized re-examination of the design problem during the iteration process. A small number of teachers, including David, mentioned the need to revisit and redefine the problem after iterations, thus identifying any mistakes in the initial problem definition.

"In teaching iteration in design, I stress to students not to expect success on the first try. Like in a video game, you won't clear a level immediately—you need multiple attempts. When facing obstacles, reconsider, and possibly start over, reassessing to correct any missteps or errors." (David)[30]

Although Helen mentioned the importance of revisiting pain points during design iterations to determine if they are real issues, she was not optimistic about encouraging students to do so.

"When a tangible product is presented, students will iterate and improve it. But when asked to revisit the pain point, they hesitate, fearing it will be time-consuming and they may not identify the real issue." (Helen)[31]

[29] 方案的更新是持续不断的，每次他们和我们交流方案时，我都会提出反馈或建议，这样他们就会进行迭代。在产品课程中，我也告诉他们，产品设计过程不是线性的，而是非线性的。它就像是我们乱画的线条，一直在不断迭代，而不是像线性过程那样，一条直线一直向前。设计过程中可能会需要重新开始，也是我在课程早期就向他们传达的重要概念。(Fritz)

[30] 设计方法的迭代的问题，我也是跟同学们是很强调的，就不要谋求一次过关。在这个过程当中，也是说就你打游戏也不会一次就能够过关。你要通过三分四次的通过。当你在做出来的一个方案的时候，在推导的过程当中，你推导不过去的时候，那你就得要把它推翻重来，重新梳理，好重新观察里面是不是有一些地方是走错方向了。或者是有一些前因错误了等等。那么去重新审视这一切。(David)

[31] 当一个实物出现的时候，他会去迭代它改进它。但你让他再回到去看这个痛点，这个问题是不是真正的一个问题的时候，他就会退缩，因为他觉得会花很多时间。他有可能也找不到真正的问题。(Helen)

Finding 5: Many teachers in Clusters 1 and 2 emphasized the importance of innovation and nurturing a creative mindset in design. Their perspectives varied: some focussed on viewing problems from new perspectives, a few highlighted the value of fostering a questioning attitude and others discussed the importance of self-efficacy, tolerance for ambiguity, resilience in facing challenges and taking responsibility for originality.

Pursuing New Perspectives through Creative Thinking

In Clusters 1 and 2, teachers frequently discussed creative thinking styles. Many emphasized the importance of innovation and creativity in design, while urging students to use creative thinking to uncover unique ideas and push the boundaries of their creativity. Jerry highlighted that creative thinking involves seeing familiar things in new ways, while George stressed that innovation requires generating unique and unconventional ideas.

> *"The nature of creative thinking means being able to see the same things as others but think of something different." (Jerry)*[32]

> *"Innovation and creativity involve coming up with unique and unconventional ideas." (George)*[33]

Teachers like Fritz believe that training in creative thinking should help students discover new perspectives.

> *"To cultivate students to view things from different perspectives and collaborate, cooperation should involve people with complementary*

[32] 创造性思维的求异性，是指与别人能看到同样的东西而能想出不同的事情。(Jerry)

[33] 所谓的创新创造力就是一些标新立异。(George)

strengths rather than similar ones. This instills a mindset of diverse thinking." (Fritz)[34]

A Questioning Attitude

There were different understandings on this point as well. Some teachers believed in truly discovering problems rather than staying within their imagination, while advocating for a questioning attitude towards established rules and authority and maintaining a critical spirit.

"Due to students being too compliant, you could explain from another perspective that their enthusiasm and ability to challenge authority are diminished. However, true geniuses and insightful individuals often inherently resist authority and established rules. This trait is relatively lacking among artists and designers." (Erell)[35]

"You need to truly engage by doing, not just hearing or seeing, to fully understand. I tell them that when you chat with others, you might hear and see, but you still lack part of the experience. Only by immersing yourself in the environment for a longer period or by participating as part of the family can you gain deeper insights. I emphasize that every time you conduct interviews or surveys, the methods and time invested will affect the outcomes. We must always maintain a spirit of questioning and critique regarding the results." (Mary)[36]

[34] 就培养他们去另外的视角去看待，进行合作嘛，合作肯定不能是相同的人进行合作嘛，那肯定是优势互补嘛，这是灌输他们的一个思维吧。(Fritz)

[35] 由于学生太乖了，你从另一个角度来解释，就是可能他们的积极性。那种反抗权威的能力在削减。但是恰恰我们讲那种真正的天才，真正的有识之士，他可能骨子里就是反权威的，反既定规则，那这一点在艺术家和设计师里面其实是比较欠缺的。(Erell)

[36] 你听到的。你知道了，你看到的，你了解了。只有你做的，你才真正的理解了。所以我就告诉他们，你们去跟别人聊天，你能看能听，但是你毕竟不是他，那就是值得质疑的。那除非你能深入到这个家庭，你做更长时间，然后或者作为这个家庭的参与者，你才能了解更多的内容。我就跟他们说，每一次不管是做采访还是做问卷，做的方法不一样，做的时候投入的时间不一样，它最后的产出肯定是不一样的。对于产出，我们始终要保持保留质疑和批判的这样的一个精神。(Mary)

Self-Efficacy

The importance of self-efficacy was also highlighted. Fritz suggested that developing confidence and experiencing success after overcoming difficulties can instil a lasting passion for design in students. This process enhances their resilience and demonstrates the effectiveness of their creativity, while helping to sustain their interest and commitment to learning about design. It also provides a sense of satisfaction when they overcome challenges in both their design work and personal lives.

> *"Having confidence and experiencing success after overcoming difficulties can foster a long-term passion for design in students. Additionally, it can enhance their resilience by showing that their creativity remains effective. This approach helps maintain their interest and ongoing learning about design, providing a sense of satisfaction when they overcome challenges in both design and their personal lives." (Fritz)*[37]

Tolerating Ambiguity

Some teachers discussed their understanding of design ambiguity; they viewed the early stages of design as inherently ambiguous and considered it a normal phase of the design process. Judy emphasized the ambiguity in design thinking and mentioned that the design process can be fuzzy and confusing, with variables throughout; design thinking itself requires keeping questions open and ambiguous.

> *"Design thinking is inherently ambiguous. Designers must anticipate that the design process will be unclear, even chaotic, with uncertainties throughout development. Design thinking itself requires first creating*

[37] 有了自信，通过克服困难并获得成功，这种培养模式可以激发学生对设计的长期热爱。同时，它也能培养学生的韧性，使他们认识到自己的创造力是有效的。这种经历不仅能激发他们对设计的兴趣和持续学习的热情，还能帮助他们在生活中遇到困难时找到解决办法，并从中获得满足感。(Fritz)

possibilities before selecting the best solution, keeping problems in an open and ambiguous state." (Judy)[38]

Judy also highlighted the importance of experimenting, encouraging students not to be afraid to move forward and take risks: design has to progress in ambiguity, and design problems are gradually clarified during the process.

"The problem in design becomes clearer as the process unfolds! There was no path in the world, but as more people walked, a path was formed." (Judy)[39]

Resilience in Facing Challenges

Some teachers mentioned the importance of cultivating students' willingness to face challenges. Fritz added that stimulating students' resilience is key to generating innovative ideas. By fostering resilience, students become better equipped to overcome obstacles and discover new possibilities. He noted that he encourages students to push through difficulties, leading to creative breakthroughs.

"Innovation is very challenging, and coming up with good ideas is also difficult. This is where resilience is crucial—being able to persevere through pain and continue exploring new ideas. Even after repeated setbacks, maintaining the determination to keep going is part of building resilience. Innovation, from creating something from scratch, is inherently tough. The early challenges they face can help them in their future careers and personal lives, teaching them not to retreat when encountering difficulties but to keep seeking new concepts. For those with high aspirations or leadership potential, this ability to persist despite challenges is essential." (Fritz)[40]

[38] 设计思维是有模糊性的。设计师要预知到设计过程会是模糊的，甚至是混乱的，开发全程都存在变数。设计思维自身要求先创造可能性，再优中选优，要让问题处于开放和模糊的状态。(Judy)

[39] 设计的问题，是在设计过程中逐渐清晰的！世界上本没有路，走的人多了，便成了路。(Judy)

[40] 创新是非常困难的，获得好的点子也同样不易。这就需要激发学生的韧性，特别是在面对困难时，依然要有坚持挖掘新事物的能力。尽管会经历不断的挫折，但韧性的培养使学生不轻言放弃。创新过程本身就非常艰难，从零开始发明新的东西更是挑战重重。前期的困难和挫折，能为他们未来的职业生涯和生活提供重要的经验，帮助他们

Take Responsibility for Originality

George emphasized the need for students to take responsibility for their originality and strongly encouraged them to create unique content while drawing inspiration from various design references. He stressed that developing originality is crucial, as relying solely on imitation prevents students from cultivating their own distinctive ideas and perspectives.

> *"Although there is a requirement for originality, since this is an introduction to professional courses, I need you to be innovative. Whether the form is good or bad, whether it looks attractive or not, or if it's simple or complex, I need to see your own thinking about it. I believe that gradually training students in this way will strengthen their understanding. Otherwise, if you start by merely imitating others, you will never develop your own unique ideas." (George)*[41]

在遇到问题时不会轻易退缩，而是继续挖掘新的概念。作为未来的领导者或具有高远目标的人，这种坚持和韧性是必不可少的。(Judy)

[41] 虽然我对你的作品有一定的要求，那就是需要独创性。刚进入专业课程时，我希望你能展现一些独特的创意。我不评价它这个功能好不好，或者说它长得好不好看，丑不丑，或者说简不简单，复不复杂，但是我需要是你自己对于它的一个思考。我觉得这样慢慢训练，可能会增强学生的理解能力。不然的话你一开始就照着别人的做，然后最后你永远出不了自己的东西。(George)

6.2 Answers to Research Question 2

RQ2: What pedagogies are educators using to teach their understanding of design thinking?

Finding 6: In project-based subjects that emphasize teaching design thinking (Cluster 1), all the teachers used pedagogies for design thinking. Most teachers' understanding of design thinking was integrated into various pedagogies, but few of these pedagogies focussed on the iterative process. Many subjects arranged the design practice as a one-round linear process.

All Subjects Include Design Thinking Pedagogy

In project-based subjects that emphasize teaching design thinking (Cluster 1), various pedagogical approaches have been adopted in all subjects. Most teachers' understanding of design thinking has been integrated into these pedagogies, which are fully implemented in students' design practices. Despite the extensive use of lectures in these courses, teachers also employed pedagogical strategies to guide students' practical work. Teachers mentioned many aspects of design thinking in interviews, but in practice, many focussed on one or two specific aspects. Most teachers emphasized human-centred design in their courses and encouraged students to understand and empathize with users' needs. They also focussed on prototype creation, while highlighting the importance of clearly expressing design concepts. A significant number of teachers sought to enhance students' creativity and foster a creative thinking style; however, few teachers emphasized the iterative process.

Various Pedagogies for Design Thinking

All teachers employed pedagogies related to holistic consideration. Human-centred design, a fundamental concept in design education, was heavily emphasized in most

subjects in Cluster 1. Most subjects included user research, some incorporated empathy training and a few involved stakeholder analysis. Pedagogies related to cognitive tools were also prevalent. In Cluster 1 classrooms, teachers stressed the importance of expressing design concepts through prototypes. Some teachers believe in developing skills in hand-drawing, modelling and other abilities, while stressing that prototypes should visually convey the design concept clearly. At a minimum, students were required to produce low-fidelity sketches, with some courses progressing to high-fidelity prototypes.

Many teachers also focussed on nurturing a creative thinking mindset for problem-solving. Recognizing the importance of innovation and creativity, they employed various methods to help students generate new design ideas. Our research found very few pedagogies related to the iterative process.

Lack of Time for Practice

Despite using various pedagogical methods, a significant portion of course time was devoted to lectures. In a typical study day, lecture sessions often spanned an entire morning or afternoon. In most Cluster 1 subjects, design thinking was first taught through theoretical concepts in lectures, followed by practical design activities. Teachers used lectures, cases and past student works to explain design thinking concepts, often featuring models from IDEO and Stanford.

We identified possible reasons for the lack of iterative process pedagogy based on the course arrangements and interviews. Project practice time is limited in many Cluster 1 courses, which makes it challenging to incorporate iterative processes. Lectures occupied half or more of the course time, with the remaining time dedicated to classroom activities or guided design projects. In some courses, lectures took up the entire class time, with students conducting design practice outside of class hours. Most teachers verbally emphasized the importance of iteration and state that students should refine their design solutions. However, due to limited practice time, few teachers arranged for students to undergo iterative processes, which resulted in the design process going through only one round in many course arrangements.

Practice in a Linear Design Process

Although some teachers mentioned the non-linear nature of design thinking in the interviews, design thinking pedagogy is applied in a linear process in many subjects. One approach involves arranging the practical part of the course to match the linear steps discussed in previous lectures. For example, after the completion of the lecture part, the first discussion might focus on reviewing students' user research to define the design target. Subsequent sessions typically involve brainstorming results and selecting solutions, followed by prototype creation and finally, presenting the final design.

Another approach involves conducting lectures and design projects simultaneously in a linear manner. Each week, students follow the design steps covered in that week's lecture. After completing a lecture on a specific design step, students immediately engage in the corresponding practical activity. For instance, the first two weeks are usually dedicated to user research. Students learn user research methods in the lecture and then identify their target users and needs in the practical session. After the first step of the design process is complete, students rarely redo the user research to modify the design goals and user needs.

Finding 7: Due to teachers' emphasis on considering human needs, each Cluster 1 subject includes pedagogies that help students consider users or stakeholders. Effective pedagogies facilitate interactions between students and their target users and stakeholders, while prompting reflection on real user needs.

Given the emphasis on a human-centred focus by all teachers and the focus on empathy by most of them, each subject in Cluster 1 incorporates pedagogies focussed on holistic consideration, such as user and stakeholder research. All teachers required students to begin their design process by considering human needs.

Facilitating Students' Interaction with Users and Stakeholders

In courses with opportunities for fieldwork, the effectiveness of teaching comes from extensive student interactions with design users and stakeholders, which proves many chances to understand the real needs.

One effective instructional method is field research, where students must leave the classroom and conduct research in real-world settings. Bella organized several research sites near the school for students to conduct their investigations. She set the design topics based on these research sites and arranged for students to research the users there. Students had to choose a direction from the given topics for their design projects. Importantly, students could easily contact their user groups at the designated locations.

> *"I generally choose interesting places for visits. For example, I took them to a well-known community building center in Shanghai and a space where*

social innovation cases are gathered for young people. I arranged for them to visit these places, and later, one group also visited a farm." (Bella)[42]

"Bella took us for real-world field research and allowed us to interact with designers and community members. Learning how they conduct research and engage with the community significantly improved our design work, as opposed to relying solely on data from papers which lack real-world interaction. " (Doris)[43]

Mary had her students conduct field research on elderly people living alone. She guided students to first learn about empathy maps and write interview outlines, then arranged for them to conduct research in a community she had pre-arranged.

"In this part, they interviewed elderly people living alone. Initially, they researched and understood the community where they would be conducting the interviews, and each group created a detailed interview outline specifying the issues to observe. They then conducted the interviews with the elderly, creating user personas and empathy maps. One group interviewed five or six elderly people and summarized their empathy map into a user persona, highlighting common issues faced by elderly people in their sixties or seventies, with loneliness being a significant concern. " (Mary)[44]

Another effective approach is bringing stakeholders into the classroom to provide students with opportunities to interact with real users. Charlotte and Chris invited stakeholders and experts to join the classroom workshops. After grouping students

[42] 我一般找的地方也会比较有意思。我带他们去了上海的一个比较有名的社区营造中心，然后还有一个把社会创新案例全部集合的很多年轻人的地方。把这两个地方给他们联系好了，带他们去看了一看，嗯，后来还有一组去了农场参观。(Bella)

[43] 但是，Bella 带我们去进行了真实的线下调研，和一些设计师或社区成员直接交流。设计师会讲解他们如何进行调研，以及如何与社区的人打交道。这种实践经历对我们的设计效果有很大帮助，因为这些数据都是从论文中摘取的，并没有真正的实地调研，因为不是自己接触的。(Doris)

[44] 这个部分就是通过访问孤寡老年人。前期他们对孤寡老年人，还对他们要采要进行采访的社区是做了一定的理解的，还查了一些资料，然后他们每个组都做了一个详细的采访提纲，他们要观察哪些问题。然后后面去采访老年人，然后就发现一些做了用户画像，这个地方让他们做了一个 empathy maping 吧。然后有一个组是把他们采访了五个，六个老年人，就把这个同理心地图这个东西给把它总结成了一个用户画像——六七十岁的老年人，他大概都要面临的一些问题。哪一个是比较重要的问题。(Mary)

by project, each group was paired with an expert and stakeholder, establishing connections through WeChat and on-site visits. This allowed students to ask questions directly and understand stakeholder needs.

> *"Since each theme and problem-solving activity is closely related to current social issues and public needs, the course includes workshops with multiple participants and experts. These workshops, conducted in a format of workshop, use perspectives from both the field and industry experts to calibrate students' problem-solving approaches. Additionally, there will be field visits and research to help students understand real social conditions and apply their professional skills to address them." (Charlotte)*[45]

Prompting Reflection on Real Human Needs

Not all courses have opportunities for field research. In courses without fieldwork, effective methods for helping students understand a human-centred focus and empathy involved prompting reflection on real human needs.

Fritz linked student projects to a competition for designing for children. All students had to participate, mostly conducting research through secondary information, but they had to consider children's needs during the process.

> *"The design task is to create a device for children to address inconveniences in their daily lives, with a clear goal for the design task and the aim of competing in a high-level competition." (Fritz)*[46]

Erell had students design for a fictional character, while encouraging them to think about the needs of the character they were interested in and explain their design choices during presentations.

[45] 因为我们每次选择主题和解决需求时，都紧密关注当前的社会议题和大众需求。课程中，我们会举办多方参与的工作坊，以专业领域和行业专家的视角来校准大家的问题处理。在这个过程中，我们还会进行实地考察和调研，帮助大家切实了解真实的社会情况，并运用自己的专业能力进行解决。(Charlotte)

[46] 设计任务就是给儿童设计一个什么装装置来解决他们生活当中的不便，那是有个目标清晰的设计任务的，并且它的目标是参赛到比较高阶的一个竞赛当中。(Fritz)

"If I directly discuss design thinking with them, using established design psychology or previous case studies, I worry that the approach might be too slow or face some generational gap. Later, I came up with a particularly interesting topic: I can ask each student to choose a film, literary work, or animation that has had a significant impact on their life, with the requirement that it must have some narrative meaning. Narrative meaning means that whether it's a film, animation, or literary work, it tells a story because stories leave an impression. In this process, they would naturally look for a piece of work from their childhood up to 18 years old that had the most impact on them. They would then select their favorite character from that work and design some accessories or clothing for them, whether it's a hat or a key prop from the literary work. This approach engages their interests and opens up the scope of their creations." (Erell)[47]

Without field research, teaching students design tools is also beneficial in developing their understanding. These tools can help students to reflect on human needs. For example, Leo introduced stakeholder maps as a tool in the classroom. Students used these maps in their design projects to consider the stakeholders involved.

"When focusing on user-centred design, there are indeed methods and tools that we provided. I insisted that everyone use these methods and tools, including initially observing stakeholders. I required them to conduct interviews with users to ensure they thoroughly researched their target users with this mindset." (Leo)[48]

47 我如果直接正面跟他们聊，比如说设计思维是什么样的，通过一些成熟的设计心理学。或者是一些以前面的案例跟他们这样说，我怕切入的会比较缓慢。或者是存在一定的代沟。后来就想了一个特别有趣的话题，我可以让每位同学自行拟定他们生活中的。或者是对他们影响特别大的一个电影或者是文学作品，或者是一个动画，但是要求是这个东西必须是有一定的叙事意义在里面的，所谓的叙事意义就是不论是电影也好，动画也好。文学作品也好，它里面都在讲一个故事，因为只要有故事就会有内容，它就会给人有印象。在这个过程中，他会比较自然的去找寻自己从童年到 18 岁，给自己最大影响的一部作品。同时在这个作品里面选取一个自己最喜欢的人。再给人做一定的服装的配饰，不论是帽子也好，还是说是推进这个文学作品其中的一个关键的道具也好。这样一下就把他们的兴趣调动起来。同时那他们所做的东西的面，一下就打开了。(Erell)

48 以用户为中心的话其实是有的，其实用的。当时给他们的几个方法和工具就强行让大家使用方法，工具，包括最开始看到的就是那个 stakeholder。让他们去强行的对用户进行访谈……这次我就强行的让大家一定要去调研一下你们的想要设立的目标用户。(Leo)

Less Effective Activities for Empathy and Human-Centredness

Some classroom activities were less effective in promoting empathy and human-centredness. Some teachers inserted activities during lectures, hoping students would understand human-centredness and empathy through these exercises, followed by reflective discussions.

For example, Bella conducted a gift-giving exercise, where students had to choose a gift for a peer's mother. The teacher believed this exercise would help students immediately relate to others and practise empathy.

> *"It's an experience of exchanging gifts with each other. For example, if you and I are classmates, and you need to give a gift to someone, like your mother, I would interview you about it. This process simulates empathy. It's a classroom activity where you can find an interviewee right there. After interviewing, I write down my insights, find out what your mother might like, and then get your feedback. After that, I might create a small model, though sometimes there are no materials available in class, so they would need to do it at home. Afterward, they would give more feedback. This approach allows for immediate, practical simulation of the design process in a short time frame, like an hour." (Bella)*[49]

David held an exercise where students brought and evaluated water cups, then voted for their favourites. The results were revealed to discuss the design value of highly rated cups.

> *"At the beginning of the course, we didn't focus too much on technical aspects. Instead, we started by discussing the product itself, such as using*

[49] 它是相互给对方做赠礼体验嘛。比如说我们两个是正好在那节课是同桌，比如说你最近要给一个人送礼物，随便什么人，你比如说你要给你妈妈送礼物，所以我就会去访谈你。其实这就是同理心的那个步骤，我觉得它就是用一个课堂上可以实现的方式让大家把这个同理心过一遍，因为你课堂上就可以找到访谈对象了。然后我访谈你以后我就写下来我的洞察，然后我去找你妈妈可能喜欢哪些东西，然后我又找你去做 feedback。然后做完以后我可能还做一个小的模型出来，但课堂上有的时候没有材料嘛，就让他们回去做。对，然后做完以后再听你的反馈意见。因为通过这种安排就可以找立马找到一个可以访谈的人。嗯，然后把这套流程做完。对，就是一个很容易很容易把这个选择过程模拟在课堂上面，而且时间又很短，一个小时。（Bella）

various types of water bottles. Each student brought their own, and we evaluated how different bottles made us feel, why they gave those impressions, and which ones were preferred through voting. This approach helped illustrate design value by comparing preferences and price, showing how a well-designed product can enhance functionality and user experience." (David)[50]

Mary acted as a consumer choosing a water cup to help students understand the diversity of perspectives.

"At that time, they didn't understand user personas. I prepared many different cups. They could scan and choose from these cups as consumers and fill out a form. Each person selected different cups and had different reasons for their choices. After this round of research where they acted as consumers, I had them review the data with me. They realized that even if they thought a cup was unattractive, many others chose it. By reviewing their reasons, they understood that different people have different perspectives." (Mary)[51]

Unfortunately, although the teachers intended to help students understand empathy through these activities, few students remembered what they learnt from these exercises.

[50] 在这个课程开始时，我们没有过多地讲解技术性内容，而是从产品本身出发来讨论设计。我们采用了常见的例子，比如水杯。每位同学都会带一个水杯来课堂，我们不会统一要求大家购买特定的水杯，而是鼓励他们带来各种各样的水杯。通过这些水杯，我们一起评估不同水杯给人的感觉，并探讨为什么会有这样的感觉。同学们可以写下他们的感受，也可以通过投票来选出自己最喜欢的水杯。水杯的主要功能是让人喝水，但我们可以通过投票询问同学们购买水杯时所花的价钱和其价值。通过这样的比较，同学们发现自己喜欢的水杯往往售价较高，这在一定程度上说明了设计的价值。在这些优秀水杯的设计中，我们探讨了它们在形式和机制设计上的特点，例如如何既能保温又能方便使用。(David)

[51] 他们那时候还不懂用户画像，我准备了好多的杯子。你要感兴趣，你也可以去扫描一下。各种各样的杯子，让他们自己扮演消费者填写了表格，最后他们每个人选的杯子都不一样，他们喜欢的杯子不一样，每个人的理由都不一样。 对，然后同时就是通过这一轮我先调研他们。等于说他们当消费者，我先调研他们，但是他们后来转过头来跟我一起一起看了这个文档的数据。他们就明白了。他们当时就觉得我觉得这个杯子好丑，为什么还有那么多人的选，还有那么多人选他，然后他们其实我后面让他们因为都写了原因的。选他的原因是什么？他就理解了，原来别人有不一样的想法。(Mary)

Lack of Guidance Hinders Effective Student Interaction with Users

A few classes provided opportunities for students to interact with real users, but this was less effective due to a lack of guidance from the teacher, which hindered effective interaction with users. Students struggled to complete user research independently at their current level. Although David also arranged field research, his student Sunny complained about the lack of guidance from the teacher. Without sufficient guidance, they conducted research on their own using previously learned methods, but the assignments ended as soon as they were submitted, without further support.

> *"Our process is basically formed by some habits that our previous course teachers helped us develop. Maybe because our teacher thinks we are already in our third year and have experience, he gives us a lot of freedom. Our previous teachers did provide a lot more guidance. With David, it's more about division of labor and cooperation within the group. He doesn't really teach us how to do things; it's all about our own understanding!*
>
> *This is the first time we've encountered this situation. Unlike other courses, where the teacher would provide some professional guidance and give feedback on our proposals. Usually, with every step we take, there's teacher involvement. This time, it's very different!" (Sunny).*[52]

[52] 我们基本上这个流程是之前我们课上的老师带我们形成的一些习惯。就可能因为 David 他也觉得我们反正也都大三了，然后经验是有的，就放手比较多这样。像我们之前老师指导的话确实比较多。到 David 这就是在小组组内的分工合作，很多知识都不会涉及到，并不会教我们怎么去做，全靠悟性！
我们也第一次遇见这种情况，像其他课就不会这样，老师也会做一些专业上的指导，我们出方案的时候也会给指导意见。基本上每推进一步都会有老师参与。这一次很神奇！(Sunny)

Finding 8: Given the emphasis on prototype application, most teachers in Cluster 1 required students to create prototypes. Pedagogies of urging students to consider the prototype's communication recipients enhanced tangible communication. Getting effective feedback from real users was beneficial for verifying solutions.

Most teachers emphasize the importance of creating prototypes to express design concepts and test feasibility. However, while many pedagogies focus on tangible communication, few emphasize verifying solutions. Effective pedagogies involve considering the intended recipients of the prototype, which improves tangible communication. Obtaining constructive feedback from real users is also crucial for refining solutions.

Considering the Prototype's Communication Recipients

Regardless of the medium and refinement level of the prototype, when teachers require students to consider who the prototype is intended to communicate with, the effectiveness of tangible communication improves. This approach helps students identify and address areas where their expressions may be unclear.

One example is organizing a design exhibition within the course, where students' prototypes are displayed for others to view. Mary held an exhibition of students' prototypes within the course. Her students Elaine and Chelsea noted that the audience's questions about unclear aspects of the prototypes helped them understand how to improve their design expressions.

> *"The first prototype was completed at the end of the previous course. During the class, the teacher provided some feedback, and we made iterations. Now, the second iteration has been taken for exhibition." (Mary)*[53]

53 第一次的原型是在上一个课程结束时完成的，在那个课堂上的老师给学生提出了一些建议，学生进行了迭代。现在第二版的迭代已经拿去展览了。(Mary)

"The exhibition made me think more deeply about the design. It prompted me to consider not only the visual appeal but also how those who have not received guidance might perceive my work and how to improve it. If I hadn't been there to explain how to proceed, they might not have known the next steps to take." (Elaine)[54]

"When I present my work, I realize that everyone has different points of resonance. I need to address a broader audience and consider public acceptance, rather than relying solely on my subjective feelings." (Chelsea)[55]

Another example involved combining competitions with students' design projects, where the final designs were presented to judges. Students had to articulate their designs and visually express their concepts, thus making their ideas tangible. Fritz noted that integrating competitions into the classroom can stimulate students' creativity. In this mode, students are motivated to be active in finding ways to achieve effective visual presentation and expression.

"Integrating a competition-based approach into the final project of the course stimulates their creativity. They will develop ideas, work through various stages, and focus on the final presentation, including visual expression and design documentation, as part of this comprehensive process." (Fritz)[56]

[54] 展览还是让我考虑的更深了一点。从画面的美观度。直观上面会考虑的更多一点。会考虑到他们那些没有指导过的人，他们会怎么想我设计的作品，然后要怎么改。假如当时我没有在展览旁边跟他们说要怎么操作，他们可能就不知道下一步要怎么做。(Elaine)

[55] 当我去展示我的作品时，我会发现每个人的感触点都不一样。我需要面对的是大多数人，可能还要考虑大众的接受，而不能只依赖我的主观感受。(Chelsea)

[56] 以赛促教的一个方式融入到这个整个的课程的最终的大作业当中，激发他们的创造力，然后他们会想方案想各种环节，包括最终的表达，呈现视觉的表达，呈现设计说明文档，这些一系列的一套的东西呈现。(Fritz)

Challenges in Design Expression Training

Some design expression training intended to help students understand tangible communication placed pressure on them instead. Allen attempted to train students in prototype creation by having them sketch on hands, aiming to give students firsthand experience in generating design concepts. However, during student interviews, many perceived this merely as training in sketching skills rather than using prototypes to express and communicate design ideas. His student, Andy, expressed concern about not being able to meet the teacher's expectations effectively.

> *"You should use computer-aided functions for this task, but you also need firsthand experience and a foundational understanding, as these are essential." (Allen)*[57]

> *"I stress the importance of sketching in every class, especially during the creative phase, even if students find it difficult. When rushed, they often use text instead of sketches. I urge them to sketch because designers are visual thinkers, and visualizing ideas is crucial for inspiration and clarity. Text alone can limit the team's understanding of the design." (Allen)*[58]

> *"The teacher is not to have that pencil kind of model drawing of the product to be drawn and then the physical one he is also expected to have. On my side, I have not learnt any design at all. I've never studied any design on my side. I'm not very good at drawing because I don't know how to do hardware and software. That was the part I was worried about at the time." (Andy)*[59]

[57] 这件事情可以交给计算机辅助功能来完成，但你自己也需要有第一手的体验和一定的经验，这是必要的、基础的，这些东西是必要的啊！(Allen)

[58] 我会反复强调，虽然你们可能画得不好，但在每节课上，尤其是在创意阶段，一定要多画画。然而，实际上，当学生感到着急时，他们往往开始用文字代替画图，因为他们真的不擅长绘画。我曾告诉他们，尽量画图，因为设计师是视觉工作者，你们的创意必须以视觉的方式展现，这样才能激发互相的灵感并实现设计。如果仅仅依赖文字，团队中的其他成员可能无法充分理解设计的细节和造型。(Allen)

[59] 老师要求我们画出产品模型图，还希望有实体模型。我完全没有学过任何设计相关的软件或硬件，所以画画也不好。这是我当时比较担心的部分。(Andy)

After extensive emphasis on drawing from the teachers, Veronica also expressed that she faced difficulties. She believed her drawing skills did not meet the required standard, which led to imperfections when conveying design concepts.

> *"From a technical perspective, one of our main difficulties is in presenting the product. Our team lacks expertise in sketching, so our drawing and modeling may not effectively convey the ideas we have in mind." (Veronica)*[60]

Getting Effective Feedback from Real Users

Although teaching methods involving prototype testing were rare, teachers in some courses provided opportunities for students to get feedback from real users on their prototypes, which was effective for understanding solution verification.

As mentioned, Charlotte paired each student group with an expert and a stakeholder. These experts and stakeholders reviewed the students' prototypes and provided feedback. Students frequently encountered these experts during the learning process, and because the teacher required students to present iterative reports in front of the experts, most students executed prototype iterations in such courses.

> *"We meticulously planned and arranged this course, contacted several partners in advance, and genuinely hoped that the schemes could be implemented or receive serious, real feedback from experts or enterprises in our project field, giving students real and honest feedback." (Charlotte)* [61]

Some teachers believe that prompting students to reflect on their prototypes is important. In some classes, teachers asked students to reflect on their prototypes and record the reflection. Mary asked students to verify the prototype in the exhibition to get feedback and record their reflection in a template. Mary said that this helps

[60] 从技术层面来看，我们面临的一个主要困难是产品的呈现。我们组在美工方面并不特别擅长，因此无论是绘画还是建模，都无法完美地表达我们心中的想法。(Veronica)

[61] 我们对这个课程进行了详细的安排规划布置，然后还有提前联系好几个合作方，然后也是真实的希望这些方案能落地或者是得到我们选题领域内的这些专家的，或者是这些机构企业的反馈，认真、真实的这些反馈内容给到学生们 (Charlotte)

students understand the use of prototypes for observe user needs. According to the reflections, many students, like Cindy, gained a better understanding of the target user and received feedback that helped refine their prototypes.

> *"Just encouraging them to reflect. You can use a template to record reflections; for example, when you interviewed them, and I roughly estimate that during the research, at this point you may not have been very clear about your target customer, but you should have had a general idea. Have you observed your users in this way? I know most people aren't very accurate because they are looking at it from their own perspective." (Mary)*[62]

> *" Encourage them to reflect on this. You can use a PowerPoint template to record reflections. For example, I estimate that during the research phase, you might not have a clear understanding of your target customer, but you should have a general idea. Have you observed your users through the prototyping method? I know most people are not very accurate because they are coming from their own perspective. I think this is a great way to gather feedback from others." (Cindy)*[63]

Challenges in Asking Students to Make Big Refinements

Although other experts were invited to give feedback, some students were reluctant to abandon their already made prototypes. Mary's student Melody stated that her teacher invited a professor to give advice in the exhibition, but because the work would have been substantially altered if she adopted the professor's suggestion, no revisions were made.

[62] 鼓励他们反思就可以了。你可以使用一个 PPT 模板记录反思；比如，我粗略估计，在调研期间，此时你可能还不是很清楚你的目标客户，但你应该有一个大致的概念。你是否通过原型这种方法观察过你的用户？我知道大多数人都不是很准确，因为他们都是从自己的角度出发的。(Mary)

[63] 展示我们的设计作品有督促作用，因为要展现给很多人看，所以我们会更努力地完善自己的作品。在展览过程中，我发现收集用户的体验和数据非常重要，因为自己看作品的角度是片面的，有时会陷入思维局限中。需要把作品展示给更多人看，收集他们的意见，才能得到更全面的观点，有利于设计的迭代。这也能让我更好地反思，了解自己作品的不足之处。我觉得这是一个很好的方式去收集别人的意见。（Cindy）

"During our project, Mary invited another professor to review our work. When he reviewed my presentation, he offered feedback that didn't align with my original intentions. He suggested changes, but I decided not to implement them. I felt that following his advice would have required significant modifications to my entire project, leading it away from the message I wanted to convey. So, I chose not to make the changes.." (Melody)[64]

[64] 在我们的项目中，玛丽邀请了另一个教授来审查我们的工作。当教授来看我们的演示并看了我的作品后，他给了我一些反馈意见。但是，我觉得他的建议与我的初衷大相径庭。他提出了一些修改意见，但我没有采纳。例如，如果我按照他的建议去做，我觉得我的整个项目就需要做很大的修改，这就会偏离我的初衷。因此我没有采纳他的建议。(Melody)

Finding 9: Although many teachers in Cluster 1 emphasized the importance of iteration, few pedagogies focussed on the iterative process. Most teachers highlighted its significance verbally, but few required iteration at different time stages. Mandating iteration helps students understand its role in optimizing solutions. While some teachers mentioned re-examining problems in their instructions, no effective pedagogies related to iteration were found in this research.

Mandating Iteration at Different Stages

Cluster 1 teachers often emphasized the iterative process but usually covered it in lectures. Many courses followed a linear design process in which prototype testing happens at the final design stage. After completing or testing their prototypes, the course ends, and most students only refined their original prototypes based on feedback and submitted them as final projects, but rarely created new iterations.

A few courses that mandated iteration significantly affected their students' understanding of the process. Charlotte, for instance, advanced the timeline for starting design projects and scheduled three mandatory presentations throughout the course. Each presentation required students to show iterative versions of their designs. These presentations were formal, with experts and stakeholders invited to review and provide feedback. This approach simulated a real-world design iteration scenario and transformed student projects from mere assignments to designs evaluated by the market. Despite the tight schedule, all students engaged seriously and received validation and feedback from real design courses, with everyone completing at least one iteration and some completing two. One of her students, Katy, expressed the perceived valued of this pedagogy.

> *"The course lasts for eight weeks, with each session lasting about half a day. Since it uses PBL (Project-Based Learning), after choosing a topic, each*

stage will have a corresponding output. In later sessions, students will report in groups." (Charlotte)[65]

"We iterate once a week. We have weekly reports, and the feedback we receive in class varies. Sometimes, the teacher's ideas conflict with ours. For instance, we initially approached it from a user's daily routine, but the teacher suggested focusing on a specific scenario for the user. This required several iterations, making our approach more specific and better at addressing the core issues." (Katy)[66]

Limited Effectiveness of Verbal Emphasis on Iteration

Verbal emphasis on iteration was less effective for fostering a true understanding of the process. Teachers who did not mandate iterations frequently reminded students to revise their work. For example, Fritz emphasized iteration every time he communicated with his students. However, without a mandatory requirement, many students remained reluctant to make substantial changes, often focussing only on improving the aesthetics of their prototypes. Fritz's student Gina mentioned that her understanding of iteration was making the design look more pleasing.

"The update of this programme is definitely something that's always been maintained, because the update of the programme is equivalent to every time they communicate with us about the programme, I've given them a definitive sentence or a suggestion that they're going to do an iteration of it." (Fritz)[67]

[65] 有八周的课程，八次课程，然后每次课程时间，大概半天时间，然后，因为是这个 PBL 的这个项目制教学嘛，所以大家选定一题之后呢，每一个阶段都会有一个阶段性的产出。 (Charlotte)

[66] 每周都会迭代一次。就是我们每周都会有汇报，然后课堂上给的意见就是。不一样嘛。可能会就是。呃，老师他这边的想法可能和我们这边想法有所冲突。他可能就觉得我们切入点，比如说。我们之前是从一个用户的一天去做。但后来他给的建议就是我们应该就是找一个切入点。有一个具体的场景给这个用户。这就是重建经历了好几次的过程。会更具体一些，而且。考虑问题的一些。角度会比之前。就是更能切入那个痛点。(Katy)

[67] 这个方案的更新肯定是一直一直保持的，因为方案的更新就相当于他们每次跟我们交流方案的话，我都给他们提出确定句或者建议他们会进行一个迭代。(Fritz)

"It still has to look good, it's not aesthetically pleasing enough, it has to be modified multiple times from the shape, and it feels like where exactly do you change it to make it look more more pleasing to others." (Gina)[68]

Challenges in Encouraging Students to Redefine Problems

Regarding redefining problems, many teachers provided direct feedback during project reviews, thus helping students reposition their problems to align with real needs. Students then learned to trust their teachers' expertise and follow their suggestions to revise, with less questioning, which resulted in limited training in digging deeper into the problem. Instead, students obediently modified their designs to meet their teachers' approval.

"It's like the teacher says it's too fancy, then we have to change it, then I have to iterate." (Felix)[69]

"The teacher's considerations are more comprehensive, and they may bring up perspectives that you hadn't thought of. You might initially think the teacher is wrong or you might not agree with them. However, I believe since this is a learning process, you need to absorb what they say. First of all, the teacher is the one grading you, and secondly, they are all highly educated, much more than I am. I feel I'm not at a level where I can completely disregard their input. Considering the reality, I can't afford to be rebellious; I'm being very pragmatic." (Fiona)[70]

A few teachers, however, avoided giving direct feedback on problem positioning. Bella, for example, used questions to help students understand that their perceived problem might not be the real issue needing a solution. During project reviews, she

[68] 还是要好看，就不够美观，从外形上要多次修改，觉得到底哪里改一改，让别人看着更加比较顺眼。(Gina)

[69] 就像老师说太花哨，那我们就要改，那我就要迭代。(Felix)

[70] 可能老师考虑的方面就是更全面，然后老师提出的一些角度，可能你想不到就觉得老师说的不太对，或者是不太认同，但是我觉得既然这是一个学习的过程，那就要吸取。首先就是老师他负责打分儿，其次就是就他们都是高材生，毕业就比我学历高多了，我感觉我还没有那种能强到把他们的一点都不听的程度。我从现实的情况考虑了一下，不敢有反骨，非常现实。 (Fiona)

frequently asked students why they were designing a particular item and for whom. However, she noted that few students engaged in this reflective process.

> *"Habits and their understanding of design are related. Many people start by proposing an idea and sometimes conduct shallow user research, but then they quickly focus on their final product, thinking it's good enough to discuss with the teacher. However, I believe discussing the final design directly is not as meaningful as starting from scratch with them—discussing why they are creating this, what it's based on, and what problems it can solve. This method can provide great support for achieving the goal." (Bella)*[71]

[71] 习惯有关，还是可能和他们对于设计的理解有关哦，就是很多人会一上来就提，我要做一个这个，然后偶尔也会有一些用户调研的部分，但是其实都很浅。然后他们就会直接去盯着他们最后那个东西去说，觉得还不错，我要跟老师交流什么什么的。但是事实上我觉得直接去讨论那个方案没有意义。嗯，我还不如跟他们就真的是从头开始讨论，从为什么要做这个东西，然后它是基于什么对象，然后能解决什么问题来讨论。所以我觉得这个方法是能够在这样的一个目的下起到一个很好的支持的作用。(Bella)

Finding 10: As creativity is emphasized, many Cluster 1 courses included pedagogies for developing students' creative thinking. Most teachers trained students through brainstorming. Effective pedagogies exposed students to diverse ideas and helped them overcome mental limitations.

As teachers emphasized, many Cluster 1 courses focussed on training creative thinking and had corresponding pedagogies. A common pedagogy involved incorporating brainstorming into the curriculum. Effective teaching methods can help students break through cognitive limitations by seeing different perspectives and promoting sensible risk-taking.

Extensive Integration of Brainstorming Pedagogy into Curricula

Many Cluster 1 teachers emphasized design innovation, encouraging students to engage in ideation practices such as brainstorming. Helen mentioned that she trains her students in class by brainstorming, hoping that when they look at one point, they can also think of other related points.

> *"I train my students' ability to innovate by using design thinking tools. For example, brainstorming. When using a specific aspect of traditional techniques, you can consider whether surrounding aspects can be altered. The core essence of this approach is still design thinking, using tools like brainstorming and mind maps." (Helen)*[72]

Allen mentioned that brainstorming in his class is a lightweight method, where even one person or a small group can generate novel ideas. Mary required each group to brainstorm and then present their creative ideas in front of the class. The requirement

[72] 我训练学生的创新能力是使用设计思维的一些工具。例如，头脑风暴。比如，你在使用传统工艺的某个点时，可以考虑其周围的几个点是否可以改变。这种方式的核心本质仍然是设计思维，运用一些工具，比如头脑风暴和思维发散图。(Helen)

was that no ideas can be like any of the others. This method of brainstorming engaged the entire class in the process.

> *"We did classroom brainstorming. It is a lightweight method that requires just one or a few people to generate ideas or at least directional concepts in a short amount of time. It can produce novel ideas that are still valuable in the future industry." (Allen)*[73]

> *"In each group presentation, other groups should listen to understand how others think. I ask them to record their creative ideas about the paper box on the blackboard. If someone has already presented a similar idea, they should not repeat it. Instead, if they have something innovative, they can add it to the list." (Mary)*[74]

Encouraging Students to Explore Different Perspectives

Among these pedagogies, effective ones for fostering creative thinking exposed students to diverse ideas and helped them overcome mental limitations. Some teachers sought to make students aware of their limitations and teach them how to collaborate with others to gain new perspectives.

For example, in Fritz's class, he required students to share ten excellent design cases they had collected and then explain why they found each case outstanding. After the first discussion, students were exposed to a multitude of ideas shared by their peers, some of which they had not considered before. In the second round, most students had a new understanding of the topic and a new definition of what constitutes excellent design.

[73] 课堂上用的这种脑暴还是就经典的这种脑暴……那么脑暴其实就是这样一种工作方式和能力，轻量化，只需要你自己一个人或者那么几个人短时间就可以产生一些这种东西，呃，或者一些至少方向性的东西啊，有可能会产生一些 novel 的东西。这都还是在未来的这个行业里面还是有价值的。(Allen)

[74] 每个组上来讲，另外的组就可以听着。让他知道别人是怎么想的，我让他们把自己的创意点就关于这个纸盒的创意点，当时有黑板都是写在黑板上面。是别人讲了的。别人的创意一点已经讲过了，你跟他雷同，那你就不要再写上去，如果你有创新的地方，你就可以继续弥补填下去。(Mary)

"I asked students to share examples of outstanding design cases. In the first class, with no specific guidelines, they presented around ten products, focusing mainly on aesthetics and novelty, with little attention to innovation, functionality, or technical complexity. After the course, I had them present again. This time, they showed a better understanding of what makes a design truly outstanding—recognizing that great design isn't just about aesthetics but also about solving important societal or everyday problems with a clear problem-solving approach." (Fritz)[75]

Bella assigned students to create a booklet of design methods in the form of cards to expand their thinking by exposing them to various professional design techniques. Different majors were grouped together for this task, which led to inevitable discussions and exchanges. Some students reported that learning about unfamiliar design methods from their group members opened their minds to new possibilities.

"When they move into their specific professional fields, I cannot cover every specific method for each profession because I am only an expert in one field, for example, medicine. Therefore, I prefer them to complete this part through group work. Group work also helps prevent the situation where I provide all the output and they have no input. It enables them to understand what they know and what they don't, allowing them to identify areas they are unsure about, which we can address together." (Bella)[76]

[75] 我让他们分享优秀设计案例。在第一堂课上，我特意没有提出具体要求。我要求学生收集十件左右的产品并进行展示。在最初的展示中，许多被选中的作品主要侧重于美学。他们强调设计语言和形式的新颖性，却很少考虑创新性、功能性和技术复杂性等方面。这种做法导致产品虽然新颖，但缺乏更深层次的考虑。课程结束后，我让他们再次分享了优秀案例。经过改进，他们对什么是优秀设计有了更好的理解。他们认识到，优秀的设计不仅要有美感，还要解决重要的问题--无论是社会问题还是与日常生活相关的问题。他们了解到，成功的设计以明确的解决问题的方法来解决重大问题。(Fritz)

[76] 当他们进入具体的专业领域时，我无法涵盖每个专业的所有具体方法，因为我只是一个领域的专家，例如医学。因此，我更希望他们通过小组合作来完成这部分内容。小组合作还有助于防止出现我提供所有输出而他们没有输入的情况。这可以让他们了解自己知道什么，不知道什么，从而找出自己不确定的地方，我们可以一起解决。(Bella)

During a field trip, students had the opportunity to discuss with industry designers. These interactions allowed students to gain perspectives they had not previously considered. Doris mentioned that she learnt to integrate other people's ideas through Bella's pedagogical choices.

> *"At the beginning, I was only thinking from my own perspective and did not consider looking at other designers' solutions. My approach was quite narrow. After reviewing other people's cases, I realized that their ideas could actually help the elderly and could integrate well with our solution without any conflict." (Doris)*[77]

Challenges in Promoting Sensible Risk-Taking

Some teachers encouraged students to take sensible risks in their design processes through verbal encouragement, but this approach was less effective. They frequently reminded students to push their boundaries and innovate, although students often hesitate to act. For instance, in Helen's class, students using AI received verbal encouragement not to limit themselves to AI-generated solutions. However, most students, once satisfied with their initial results, were reluctant to continue exploring further.

> *"Students often imitate well-known or lesser-known designs, indicating they believe there's only one way to solve a problem and are constrained by what they've seen. When asked to create a better design, they feel overwhelmed by the abundance of good existing designs, limiting their imagination and making them hesitant to innovate. They tend to think AI-generated solutions are sufficient, so I focus on encouraging and motivating them to push beyond these boundaries." (Helen)*[78]

[77] 我刚开始想的话，可能就是仅仅是单纯的从自己的角度出发，没有考虑到就是没有看其他设计师的一些方案。就可能比较狭隘吧！看了一下其他人的案例的话，就觉得这个其实可能也是能对老人有帮助的，然后也是能和我们这个方案是不排斥的，也是能很好融进我们这个方案的。(Doris)

[78] 比如说很常见的就是有一些同学在做设计的时候，有时候他们会模仿，比如说一个比较有名的设计，或者是不太有名的。这种时候我差不多认为是他。觉得在解决这个问题的时候，只有这个方法没有别的。的时候我认为他是被已经看到的东西给限制或者是控制了？或者是比如说我们要求你做一个更好的设计出来，他们觉得现在好的太多

Insufficient Pedagogies for Developing Key Qualities

While teachers recognized the importance of qualities like self-efficacy, acceptance of design ambiguity and responsibility, they often lacked corresponding pedagogies to develop these traits. Although many teachers highlighted the significance of these qualities in lectures, they only occasionally emphasized their importance in design practice and did not purposefully use pedagogies to cultivate them.

Tendency to Assess Creative Ideas from a Market Perspective

Many teachers emphasized the importance of market-oriented creativity, while encouraging students to develop innovative solutions with market relevance. They stressed that designers should explore new directions and products that are not yet seen in the market. During ideation and project reviews, teachers assessed students' ideas from a market perspective and highlighted that truly novel ideas are those that offer value to both the market and to users.

Fritz's course incorporated design competitions with a strong emphasis on commercial and market innovation. He often reiterated in class that "innovation is paramount" and that students must consider commercial market value and technical feasibility in their designs. This was a key requirement for the course projects.

> *"In this course, I emphasize the importance of considering both the commercial viability and technical feasibility of your product design. Innovation is key, but if your design lacks technical feasibility or practical use, it's less valuable. However, if the technology shows future potential and feasibility, it's a strong solution. We also cover different types of innovation, including business model and design-driven innovation." (Fritz)*[79]

了，他们已经觉得没什么可做了的时候，我认为是被已经被看到的东西所控制了。他们的想象能力我觉得还是有限。他不敢去动，他觉得那个 AI 给他的方案已经很好了，他一动全部就要变一变了，他就觉得不太好了。我只能用语言激励他们。(Helen)

79 你要考虑你的产品设计需要商业性，包括技术可落地性，这些都是我在课程当中灌输给他们的重要点。创新高于一切。当技术可落地性稍微欠缺时，我觉得不重要。但如果产品没用且技术可行性不高，我宁愿不要。如果技术在未来可行且有前景，那么这种方案也是很好的。这是我在课程中灌输给他们的。还有一种商业模式的创新，这也

Fritz also explained why he emphasized the market relevance of students' designs: He aimed to broaden students' perspectives and understanding by encouraging them to approach design from a market and industry level. Therefore, he had high market-level expectations for students' ideas from the early stages.

> *"I hope everyone looks at design from a higher perspective, considering the overall impact on the industry. Previously, teachers' lectures were too practical. I intervene early to cultivate students' perspectives and cognition, so they realize that design has a high standing in the social division of labor, not just an aesthetic role." (Fritz)*

Fritz had high expectations for market innovation from the early stages of reviewing students' projects. About 80% of the proposals discussed are rejected. By evaluating from a market perspective, he hoped students would recognize their current creativity limitations and understand the importance of market-level innovation.

> *"Learning to innovate courageously is painful. In this course, I place the highest evaluation on their innovation dimensions. About 80% of the proposals discussed with me are rejected for low creativity. This process helps them realize the importance of innovation and their own creative limitations, as imagination will eventually run dry." (Fritz)*

Like Fritz, teachers often evaluated creativity within a market context and compared students' ideas with others. However, few teachers addressed the need for students to overcome their own knowledge and experience limitations in the design process. The teaching focus was predominantly on creativity within a market context, with less emphasis on breaking through personal mindset constraints.

是我在课程中讲的。创新有很多种，包括商业模式创新、设计驱动创新、技术驱动创新，反正创新模式非常多。(Fritz)

6.3 Answers to Research Question 3

RQ3: How do students understand design thinking based on the pedagogies they have received?

Finding 11: Regardless of whether the courses explicitly emphasized design thinking, students in Clusters 1 and 3 showed a consistent understanding of design thinking concepts. All students gained varying degrees of understanding and could articulate at least one concept they learned from their teachers. Most students in Cluster 1 had applied design thinking, while all students in Cluster 3 had applied it. A small number of students also expressed that their understanding of design thinking had affected their problem-solving approach. Both clusters predominantly adhered to a linear design process during their arrangement for design practice.

Consistent Understanding of Design Thinking

Students in Clusters 1 and 3 exhibited a certain understanding of design thinking, despite differences in how design thinking was taught. In both project-based design courses, Cluster 1 students were explicitly taught design thinking, while Cluster 3 students were not. However, both groups achieved some understanding of design thinking.

Students' understanding of design thinking from these courses could be related to the concepts in our Conceptual Framework 1, which indicates the consistency in their understanding. When they described concepts related to holistic consideration, they mentioned similar ideas, such as the importance of human-centred design and empathy. When discussing the purpose of building prototypes, students consistently mentioned using prototypes to express design ideas and test feasibility. They also

understood that iteration could optimize design solutions and emphasized the importance of innovation and creative thinking for designers.

In Cluster 3's project-based design courses, the design process was also taught in a way that included stages such as user research, problem definition, ideation, prototyping and testing, which corresponded to the process taught in Cluster 1. Although Cluster 3 teachers did not explicitly state they were teaching design thinking, the process trained students to think about how to solve problems through design, which resulted in an understanding of design thinking similar to that in Cluster 1.

Varies Levels of Understanding Design Thinking

The students exhibited different levels of understanding of design thinking, as they could articulate, apply and indicate the impact of design thinking on their problem-solving methods. Many students in Cluster 1 could articulate their understanding of design thinking, with some able to apply it. The limited time allocated for design projects in Cluster 1 courses restricted students' opportunities to widely apply design thinking.

In contrast, all students in Cluster 3 were able to apply design thinking. The distinguishing feature of Cluster 3 courses was minimal lecturing and requiring students to engage in design practice from the outset. The ample project time allowed students to conduct multiple rounds of user research, create prototypes, test solutions and iterate designs. This extensive application enabled Cluster 3 students to achieve a higher level of understanding of design thinking. The students participating in the study from Cluster 3 tended to be the most diligent and high performing, which may have contributed to their high level of application.

Most students from both groups were able to apply human-centred design principles and use prototypes to express design ideas. Unlike Cluster 1 students, who primarily articulated the concept of iteration, many Cluster 3 students moved beyond mere articulation to the actual application of the iterative process. However, students' understanding of creative thinking remained limited, with many only able to articulate the concept. A small number of students mentioned that their understanding

of design thinking in the subjects affected their approach to problem-solving. We will discuss these in the findings for Research Question 4.

Practice in Linear Design Process

In Cluster 1, many students followed the linear design process introduced in class during their design practice. These students expressed approval of this step-by-step approach. Once they and their teachers identified a satisfactory solution, students rarely engaged in iteration, opting only for minor adjustments. Few students revisited the earlier user research stage to reconsider whether the definition of the design problem needed adjustment.

Cluster 3 students also did not mention applying a non-linear approach to design thinking. Although the subjects were also structured around a linear design process, the ample practice time allowed many students to reflect actively on previous design stages and iterate on their prototypes continuously.

Finding 12: In Clusters 1 and 3, many students, guided by their teachers, focussed on user needs in design. Most students could articulate and apply human-centred thinking, while empathizing the user's needs. A few also considered stakeholders.

Students in both Clusters 1 and 3 demonstrated a comprehensive understanding of holistic consideration, particularly focussing on user needs in design. Most students in both clusters could articulate and apply human-centred thinking and empathy, although few considered the broader implications involving stakeholders.

Articulation and Application of Human-Centred Focus and Empathy

In Cluster 1, most students, guided by their instructors, exhibited a deep understanding of human-centred focus and empathy. These students effectively articulated and applied these concepts within their design processes. One student highlighted her understanding of empathy in design thinking. She mentioned standing in her clients' shoes to see their needs.

> *"Design thinking, I believe, is about standing on the side of the group or clients you are designing for. It involves thinking from their perspective to understand what they need, recognizing the issues they may face, and helping solve those problems to make their lives better or address specific needs. This process of designing and thinking reflects the essence of design thinking." (May)*[80]

[80] 设计思维，我觉得，作为一个设计师应该站在需要设计的群体和客户的那一端去，在他们的角度去思考他们所需要的东西，然后需要去了解他们所可能存在的一些问题，站在他们的角度去帮助他们去解决。然后方便他们，无论是更好的生活还是就针对性的解决。就是，我需要在这一过程中去思考。这个过程和思考我觉得就是一种设计思维的一种体现。(May)

Despite the absence of explicit instruction in design thinking, Cluster 3 students also exhibited an understanding and application of human-centred focus and empathy. A student from Cluster 3 showed her consideration of student needs in her design.

> *"We primarily focused on functionality and student needs. Some students, for instance, really enjoy gardening. So, we created a garden on the rooftop where they can plant flowers and also enjoy the view. Since it's a girls' dormitory, many of the girls love flowers." (Rubby)*[81]

Limited Consideration of Stakeholders

While a few students in Cluster 1 addressed stakeholder considerations, those who did so demonstrated an understanding of the broader impact of their designs. One student remarked:

> *"After taking this course, I realized that one should not view design from a single perspective. It's important to start from the user's point of view, but you must also consider the entire industry chain. For instance, an architect should not only focus on the design but also consider the concerns of construction workers who will implement the plans. When designing something like a chair, you should not just focus on your own ideas but also consider the user's experience and think horizontally about different competing brands and the upstream and downstream industries. Understanding what your upstream suppliers and downstream manufacturers can provide is crucial. Design is not just a single entity; it is holistic and societal. Since design exists as a part of society, it's important to consider these external relationships and explore various perspectives." (Lily)*[82]

[81] 我们主要是针对功能性和学生的需求来设计。有些学生可能比较喜欢种花，所以我们就在楼顶建了一个花园，既可以供她们种花，也可以供她们观赏。毕竟是女生宿舍，喜欢花的女生还是很多的。(Rubby)

[82] 上完这门课我可能就觉得。不能站在某个单一的角度，我可能都说是可能要从你的用户来出发，你可能也是得考虑到你所处的产业的上下链。就是像前面说的。建筑设计师他可能和建筑工人的关心。同时也得考虑到那种工人去实施。实施你蓝图的问题。你得站在不同的方向去考虑不能。我设计一个椅子，我就。只管。发散自己的思维就可能我愿意去。考虑用户的。感受这也不一定去是够的你。横向的去考虑不同的你的竞争品牌去考虑你的上下游产

In Cluster 1, a few students applied stakeholder consideration. For example, Debby designed a magazine for children, and she not only considered children's needs, but also considered the taste of the parents who would pay the bill.

> *"Children's magazines need to consider not only the children's perspectives but also the parents' expectations, as parents want their children to learn something useful from the magazine. Therefore, it is essential to balance education and entertainment. The magazine should include engaging stories to capture children's interest while also offering informative content. For example, picture books should convey moral lessons through their stories, while science sections should present knowledge in a simple and understandable manner. This approach will help gain parents' approval and encourage them to purchase the magazine for their children." (Debby)*[83]

Like Cluster 1, the consideration of stakeholders was limited among Cluster 3 students. One student from Cluster 3 shared her consideration of stakeholders, as she considered residents' needs for convenience and a quiet environment, as well as the surrounding residents for their convenience to use facilities.

> *"We considered how to make people's activities more convenient and how to design the layout to avoid interfering with rest. For instance, since our building is located near a busy road with significant noise, it could greatly affect the rest of students in the dormitory. Therefore, we deliberately placed the dormitory rooms on the side of the building farther from the road to minimize noise disturbance. For pedestrian traffic, we also made the pathways more convenient. Additionally, we considered the needs of the surrounding residents. For example, we placed the gym and game rooms on the ground floor, making them easily accessible. This allows residents who*

业。你上游的、你下游的制造商他可能够给你做到什么样？让我知道做一个设计，它不是单个的，它是整体的，它是有这种社会性的。你毕竟是存在于社会中的一个部分，你做设计的过程中你也得考虑到这一点。去找到他这种向外发散的不同的关系。多考虑他们的不同的方向。(Lily)

[83] 儿童杂志不仅要考虑儿童的想法，还要考虑家长的需求，因为家长希望孩子通过杂志学到有用的东西。因此，在设计儿童杂志时，必须尽可能做到寓教于乐。除了包含能够吸引孩子兴趣的有趣故事外，还需要加入各种知识性内容，以达到一个平衡。比如，绘本故事要通过故事传递一些道理，而科普栏目则需要以浅显易懂的方式传递知识。这样才能赢得家长的认可，促使他们为孩子购买杂志。（Debby）

are not living in the building to use these facilities conveniently." (Caroline)[84]

In conclusion, students from both Clusters 1 and 3 demonstrated a consistent understanding and application of human-centred thinking and empathy. The understanding of stakeholders, however, remained less prevalent, with only a few students addressing this aspect in their design processes. This suggests that while the holistic consideration of design thinking is well-integrated, there remains an opportunity to enhance the understanding of stakeholders in design thinking education.

[84] 我们在设计时考虑了如何让人们的活动更方便，并且如何在布局上避免影响到休息。例如，我们的建筑靠近马路，噪音较大，因此对于学生宿舍来说，休息会受到很大影响。所以我们特意将住宿房间安排在远离马路的一侧，以尽量减少噪音的干扰。在人员出行方面，我们尽量将通道设计得更为便利。此外，我们还考虑到了周围住户的需求。比如，我们将健身房和桌游室等娱乐设施设置在了一楼，方便周围的居民随时使用。这样即使是非住户的人经过，也可以方便地使用这些设施。（Caroline）

Finding 13: In both Clusters 1 and 3, students received prototype training from their teachers. Almost all the students could explain that prototypes are for expressing design ideas, and most could create prototypes that expressed their ideas. While many Cluster 1 students mentioned the concept of validating prototypes, only a few did so. In Cluster 3, many verified their prototypes.

Widespread Use of Prototyping for Tangible Communication

All students in Cluster 1 received prototype training from their teachers, which resulted in a clear understanding of the role of prototypes in expressing design ideas. Many students in Cluster 1 could articulate the purpose of prototypes and create them to convey their concepts effectively. Helen's student Cook noted that prototypes provide an intuitive understanding of the design, while allowing one to assess its feasibility. After identifying any issues, improvements can be made in the later stages.

> *"The initial sketches and modeling are done in the early stages of design, giving you a more intuitive sense of the design and whether it is generally reasonable. If the design is unreasonable, this can be identified through sketches and modeling. However, if you don't do any sketching and rely solely on theoretical design, as the teacher mentioned, designing just on the computer isn't quite sufficient—it's too theoretical and may not be practical. Only by sketching can you identify which parts of the design are unreasonable and which parts can be improved. When you move on to creating prototypes in the later stages, you can further experience and refine your work, thus enhancing its rationality." (Cook)*[85]

[85] 前期的草图和建模都是在设计初期进行的，这能让你对设计有一个比较直观的感受，从而判断其大致是否合理。如果设计不合理，通过草图和建模就能看出来。但如果完全不画草图，只是纯理论化地进行设计，就像老师说的那样，只在电脑前做设计还达不到实际应用的程度，太理论化了，可能并不落地。只有画出草图后，你才能发现设计中哪些地方不合理，哪些地方可以改进。在后期制作原型时，你能对作品进行进一步的感受和完善，从而提高设计的合理性。(Cook)

Erell's student Jessie mentioned that because the teacher encouraged the use of various methods to express design concepts, they tried multiple approaches in the course. In addition to hand-drawing, Jessie also experimented with animation.

> *"The teacher encourages us to try various methods. In class, he frequently tells us to boldly experiment with different things. Who knows, one day a new method might replace traditional drawing. So, in addition to continuing with my usual hand-drawing, I've also started experimenting with other forms of expression, such as animation." (Jessie)*

Students in Cluster 3 also recognized the significance of using prototypes to communicate their design ideas. Many students effectively used sketches and models to make their ideas tangible. In Izzy's articulation, prototyping facilitated student communication, which then allowed them to refine their ideas and receive constructive feedback.

> *"In class, we also conducted some expert evaluations, which I think were quite important. We assessed each other's prototypes and shared our views. We created card versions of our prototypes and brought them to class for peer review. After receiving feedback from classmates, we made revisions when refining the prototypes. I believe this was a very effective approach." (Izzy)*[86]

Difficulties in Tangible Communication

Some students thought they experienced difficulties with tangible communication through prototypes. They faced challenges in making their prototypes easily understandable, particularly those with limited artistic skills. One student expressed frustration, saying:

[86] 在课堂上，我们还进行了专家评估。我认为这也很重要。我们同学之间互相评估对方的原型，并提出各自的看法。我们将自己的原型做成卡片，带到课堂上进行展示，同学们提供了意见后，我们在后续的原型优化中进行了相应的修改。我觉得这种方式也很有效。(Izzy)

"I think, first of all, it might be that I'm not quite suited for the path of design. I'm pondering this issue. Additionally, if you want to pursue design, especially creating a physical product, I believe you need to have a certain level of skills in areas like drawing and basic mechanics. I find myself lacking in these areas." (Ginger)[87]

Few Verified Prototypes in Cluster 1

While many students in Cluster 1 mentioned the importance of verifying prototypes, only a few actively implemented the test process. Some students, when required to do so by their teachers, validated their prototypes and produced subsequent iterations. These students benefited from structured guidance that allowed them to improve their designs based on feedback.

For example, Charlotte invited experts and stakeholders into the course to provide regular feedback on student prototypes. Her student, Katy, noted that after completing her prototype, it would undergo multiple rounds of testing, during which feedback is collected and used to make revisions.

"Based on the research findings, we identify issues and pain points and proceed with prototype design. After completing the prototype design, we conduct testing, gather user feedback and teacher suggestions, and finally move on to implementation and development. The entire process is an iterative cycle." (Katy)[88]

Few students in Cluster 1 refined prototypes and expressed they learned by doing. Sark said he learnt more about the process of doing prototypes and had a more holistic approach to design.

87 我觉得首先有可能自己确实是不是不太适合设计这个道路啊，我在想这个问题就是另外就是你想要搞设计的话，如果说是真的做一个实物的设计，我在想自己还是需要有一定的像画画啊，包括一些力学的一些基础的知识的，我这个还挺欠缺的。 (Ginger)

88 基于调研结果，我们识别问题和痛点，并进行原型设计。原型设计完成后，我们会进行测试，收集用户反馈和老师建议，最终进入实施和开发阶段。整个过程是一个反复循环的迭代过程。(Katy)

"As mentioned earlier, because this course requires creating a physical product, we have an additional step compared to other courses. During the process of making the physical product, we need to consider practical issues that might not have been deeply considered before, even those that might contradict our initial ideas. In this process, the preliminary ideas become more practical as everyone is involved in the arrangement, editing, and final production of the product, and then personally experiencing it. Therefore, design is not just about enriching user experience; for us as design students, the process also enriches our sensory and tactile experiences. The hands-on experience of creating a product, from initial design to final use, provides a different perspective compared to working on a computer or referencing other products. Evaluating the product through multiple stages, from creation to final use, results in a more comprehensive design consideration." (Sark)[89]

Because of time constraints, some students in Cluster 1 did not have the time to make in-depth changes to the prototype even if they wanted to do so. One student Yuki from Cluster 1 expressed that the limited time influenced her refining prototypes.

"So actually, the final app we created had a lot of issues, especially with the logic. We didn't have time to fine-tune everything. I wish this could become a long-term course instead of a short-term one. I think we only had about thirteen or fourteen classes in total, which is very few. Moreover, four of those were discussion sessions, so the actual time spent working together was very limited. I know from my friends who studied design that they spent

[89] 正如前面提到的，由于这门课要求最终制作出实物，相比于其他课程，我们多了一个环节。在制作实物的过程中，需要考虑一些之前可能不会深入思考的实际情况，甚至是与自己想法完全相反的情况。在这个过程中，前期的构思变得更加实用，因为大家基本上是自己去编排、主编，最终制作成品并亲自体验。因此，设计不仅仅是丰富用户的体验，对于我们这些设计学生来说，整个设计过程也丰富了我们的感知和触觉体验。设计从电脑上的草图到实际产品的制作，这种实际操作的感觉与在电脑上或参考其他商品时的感觉是不同的。通过多个环节分析和评估产品的好坏，从最初的制作到最后的使用体验，使得整体的设计考虑变得更加全面。 (Sark)

a lot of time hands-on, building their own models, which I think is a very important part of the process." (Yuki)[90]

Many Verified Prototypes in Cluster 3

In contrast, many Cluster 3 students verified their prototypes through feedback. One Cluster 3 student, Sylvia, applied several rounds of iteration in the design process and expressed the importance of feedback for prototype.

"It is essential to iterate and refine your drafts and prototypes multiple times. Through discussions with friends, other designers, and feedback from experts in class, we can continuously improve and perfect our prototypes." (Sylvia)[91]

Cluster 3 students exhibited a strong tendency to verify and iterate their prototypes. Many students in this cluster, after creating their initial prototypes, voluntarily engaged in verification processes, which led to multiple iterations. This approach was facilitated by the fact that their curriculum was dominated by time spent producing design projects, which allowed them time to improve and refine their designs continually. Another Cluster 3 student, Henry, talked about his experience of prototyping and constantly testing at different fidelities during the course.

"A low-fidelity prototype is often an initial attempt at design. At the beginning, you mainly focus on functionality because low-fidelity prototypes are quicker and easier to make. After the teacher completed the low-fidelity prototype, we also conducted expert evaluations and discussed opinions with a few classmates. We found that the issues with this prototype were relatively simple and the extent of modifications was minimal. By identifying unnecessary features in the low-fidelity prototype, we were able to easily

[90] 所以其实这个 app 最后做出来是有很多问题的，很多逻辑都没有时间去细调。我希望这个课程能够变成一个长期的课程，而不是短期的。我感觉我们总共才上了十三四次课，而且中间还有四次是讨论课，所以真正坐在一起做东西的时间非常少。但是我知道以前我好朋友学设计的时候，他们花了很多时间自己动手搭建模型。我觉得那个过程其实很重要。(Yuki)

[91] 肯定需要对自己的草稿和原型进行多次迭代和改进。通过与朋友、其他设计师的交流以及课上的专家评估，我们能够不断优化和完善原型。（Sylvia）

remove them when creating the high-fidelity prototype. If we had started with a high-fidelity prototype, it would have been more time-consuming and exhausting." (Henry)[92]

Lack of Time for Testing and Refining Prototypes

While both clusters demonstrated a solid grasp of using prototypes to express design ideas, Cluster 3 students showed a higher propensity for prototype verification and iteration. This distinction highlights the impact of course structure and pedagogical emphasis on students' engagement with iterative design processes. The limited time for design practice affected prototype verification among Cluster 1's students. A student from cluster 1 said regrettably:

"We don't fully understand that group yet. We didn't have enough time to thoroughly investigate the feedback from hardcore horror movie enthusiasts. Additionally, due to time constraints, we didn't fully find out if there are such people around us. The people we interviewed were just our classmates and friends, and when I tried to find such people online, most of them didn't respond, and those who did weren't particularly accurate." (Tina)[93]

[92] 这种低保真原型可能是对初步设计的一个尝试。刚开始时，你主要是考虑功能方面，因为低保真原型耗时较短且较容易制作。在老师完成低保真原型后，我们还进行了专家评估，并与几个同学交流了一下意见。结果发现，这个原型的问题比较简单，修改的程度也比较低。通过低保真原型，我们发现了一些不必要的功能，并在做高保真原型时轻松地将其删除。如果一开始就做高保真原型，时间成本较高，也比较累。(Henry)

[93] 对那个群体还不是非常了解。我们没有时间去充分调查重度恐怖电影爱好者的反馈。再加上时间原因，也没有充分了解到身边是否有这样的人。我们采访的只是周边的同学和朋友，我在网上找那些人时，大部分人都不回消息，有些回了消息的也不是特别准确。(Tina)

Finding 14: Despite having few courses with training on iterative processes, most students in Cluster 1 could explain the importance of iteration, but few used the iterative process in practice. In contrast, many students in Cluster 3 verified and iterated their designs in practice. After completing one round of solutions, students in both clusters rarely redefined problems.

Much Articulation but Little Application in Cluster 1

Despite the limited inclusion of pedagogies focussed on iterative processes in Cluster 1 subjects, many students could articulate the importance of iteration for optimizing design solutions, perhaps because their teachers frequently emphasized this concept in previous classes, or because they often heard teachers mention it in this course.

> *"These continuous iterations constantly refine the work. Throughout the process, we keep communicating, which not only perfects the work but also enhances my design thinking." (Lisa)*[94]

> *“When designing, you shouldn’t be afraid of making mistakes. Design solutions need continuous updating and iteration to generate new innovations. You should not settle for the first version; instead, start with the initial version, keep identifying issues, and make improvements to develop a better and more refined solution.” (Cherry)*[95]

In the absence of iteration instruction, students in Cluster 1 rarely engaged in iteration. Only a few proactive students did so, and these students took the initiative to test and refine their prototypes despite the lack of structured pedagogical support. Under

94 这些不断迭代的过程，都是让作品不断的完善。过程中我们不断的去。进行交流。它在作品完善的同时，让我的设计思维也更加的完善了。 (Lisa)

95 在做设计的时候，不应该害怕犯错。设计方案需要不断更新和迭代，产生新的创新点。不能停留在第一版方案上，而是要从第一版开始，不断发现问题并进行改进，才能制作出更好、更完善的方案。(Cherry)

Fritz's teaching mode of incorporating competitions into teaching, his student Gary actively optimized his solution.

> *"First, we might iterate by addressing the shortcomings of the solution. For example, we consider if there's a better implementation method, like screen prompts, which can be seen as a form of iteration. Second, we look at functional iterations. For instance, if I want to add a parent communication feature, we think about how to incorporate this function or add a feature for storing pen refills or pencils. Then we iterate on it again. The main reason for iteration is that we feel the solution is not perfect, convenient, or aligned with the original intent of the product, so we make modifications and improvements." (Gary)*[96]

A few students engaged in iteration within the course schedule and reported validating their solutions through iteration. Charlotte arranged for her students to undergo three mandatory iterations during the course. Her students interacted with stakeholders and experts during these iterations to receive feedback. Although the time between iterations was tight and project progress varied among students, everyone was required to iterate at least twice. Katy reminded of the iteration process.

> *"We advance and iterate based on user feedback and data, creating a closed loop, as design thinking is a circular process. This course follows a timeline, outlining each step. In the first week, we develop initial concepts and gather information to refine ideas. User interviews often reveal areas needing adjustment, and we also seek feedback from teachers and experts. The process is a continuous cycle, focusing on completing first and then perfecting, rather than achieving perfection from the start." (Katy)*[97]

[96] 首先，我们可能会通过发现方案的不足来进行迭代。例如，考虑是否有更好的实现方法，比如屏幕上的一些提示，这其实也算是一种迭代。其次是功能方面的迭代。比如，我想增加一个家长沟通的功能，那么我们会考虑如何添加这个功能，或者是增加一个装笔芯或铅笔的功能，然后再对其进行一次迭代。主要是这样思考。我们进行迭代的原因是觉得方案不够完善或不够方便，不够贴合产品的初衷，所以会进行修改和改进。(Gary)

[97] 我们就会根据这些用户的反馈，或者是一些其他的一些数据反馈，就是继续推进啊，迭代啊！它像一个圈的一个闭环。设计思维是一个循环的一个圆。这门课肯定是按照时间流程来安排每一步的任务。第一周我们可能会有一

However, Katy expressed feeling pressured by this tight learning mode, which involved frequent meetings and discussions within a single week.

> *"But actually, I don't really enjoy this constant iteration process. It's very painful for me." (Katy)*[98]

Apart from Charlotte's class, Mary arranged for her students to iterate on the design solutions from the previous course and showcase them. Most students completed the iteration. Her student Daisy also mentioned that she received feedback from users during the exhibition and reflected on her design from their perspective.

> *"When we later planned the preliminary stages of the exhibition, such as the research process or iteration improvements, we created mind maps to present our ideas. Through this method, we considered various aspects from the audience's perspective, not just from our own viewpoint. We focused more on the experiencers, taking into account different types of audiences and primarily thinking from the perspective of their experience and the feedback they could provide us." (Daisy)*[99]

Lack of Time for Iteration in Cluster 1

Most students in Cluster 1 lacked time to apply iterative processes in the course, as these require sufficient time for students to create and test prototypes. In Cluster 1 courses, students often felt that the time allocated for design projects was inadequate, with teachers typically scheduling project work in the latter half of the course or even in the last one or two weeks. Despite the high level of engagement exhibited by most Cluster 1 respondents, many students abandoned iteration due to time constraints.

个初步的概念，然后我们首先要收集信息，产生初步的想法。在调研过程中，我们会修正设计中的一些想法和细节。接下来，我们进行用户访谈，可能会发现需要调整的一些重点。用户访谈之后，我们还会与老师和专家沟通，获取建议。整个过程实际上是一个不断循环的过程。它不是一个完美的过程，它是先完成再完美。(Katy)

98 但其实我并不是很享受这种不停迭代的过程。我很痛苦。(Katy)

99 我们后来在进行展览前期策划时，比如调研流程或迭代改进方法的时候，都做了思维导图来呈现。通过这种方式，我们能够多方面地考虑问题，从受众的角度出发，而不仅仅是从自己的角度思考。我们更多地关注体验者，兼顾不同类型的受众，主要从他们的体验感和反馈来思考设计。(Daisy)

"Because the course duration is very short, we can't create something too surprising. We might pursue things that can produce results quickly." (Boris)[100]

In another class, Sunny expressed a similar sentiment. After adding two design competitions to the course, she felt there was not much time to work on prototyping.

"There were not two reviews. He only looked at our assignment once, and even then, he didn't give much feedback. He just emphasized that the research needed to be more in-depth before proceeding. Yes, it was just one or two sentences, and then it was over, and he moved on to the next group. It was a project for the city government, a standalone competition. Later, the assignment we worked on was for another, more ordinary competition. There were two competitions. But did he really have time? " (Sunny)[101]

Some students expressed that the tight deadlines compelled them to submit their assignments on time, often at the expense of further iteration. Michael mentioned that time for submitting the project to competitions during the course was tight; coupled with other major assignments, he had to rush to hand in his assignment to the teacher.

"Because we had many major assignments at that time, and the deadlines for both assignments were very close, our work was not perfect. We worked day and night, as both assignments required layout and rendering. We were incredibly busy and overwhelmed; that day we worked until 2:30 AM. Currently, our concepts are completed, and our product is also done, but it is still just a design concept, not an actual physical product. Our work has already been submitted to a competition." (Michael)[102]

[100] 因为这个课程时间很短，所以没有办法做得太过于惊喜。我们可能会追求比较快一点的东西，就是能很快出效果的东西。(Boris)

[101] 没有两次。我们的作业只看了一次，第一次他也没有给什么意见，只是强调那些调研要再做深入一点，然后再推进。对，差不多就一两句话，然后就结束了，他就看下一个组了。他是市政府的一个项目，是一个单独的比赛，后面我们做的作业是另一个比较普通的比赛。他是两个比赛来的。但是他真的有时间吗？(Sunny)

[102] 因为我们当时有很多大作业，两个作业的截止日期都很近，所以我们做得还不完善。我们通宵达旦地工作，两个作业都需要制作版面、进行渲染。当时真是忙得焦头烂额，我们那天干到了深夜 2:30。目前我们的概念已经完

More Iteration Applications in Cluster 3

Few students in Cluster 1 actively used the iterative process. In contrast, many students in Cluster 3 not only verified but also iterated their designs in practice. As we said in last finding, students in Cluster 3 began their project within the first two weeks of the course, which provided ample time for completion and validation. Henry mentioned that he began designing and iterating very early in the course; he even spent the first few weeks of the course iterating and refining his design ideas.

> *"During the eight-week course, we spent the first few weeks continuously iterating and refining our design ideas." (Henry)*[103]

In another subject, Andrea mentioned that her group skipped the sketching phase at the beginning and used prototype software with a furniture model database to build the house they were designing. They completed the model early in the course and then made subsequent modifications.

> *"We didn't have much time for sketching because it was too slow. Instead, we used existing software to set up prototypes early on, and then made modifications based on those prototypes. We completed the prototypes first and then adjusted them according to the references to address any shortcomings." (Andrea)*[104]

In a different course, Amelie began prototyping early on and went through many versions of material testing and design iterations.

> *"In the first draft, I thought it would fit, but after cutting it according to that shape, I found it didn't work well. So, I made changes in the second draft, but there were still issues with size. In the third draft, I asked a classmate to draw it using AI, but their depiction wasn't very good, so we made a fourth*

成，我们的产品也已经做完了，当然这只是一些设计概念，还没有做到实体产品。我们这边的作品已经投到一个比赛去了。(Michael)

[103] 我一共八周的课，前面几周全都是一直在做设计迭代，然后不断的去修正我们设计的想法。(Henry)

[104] 画草图的话我们没太多时间，太慢了，我们特别早就用现有的软件摆出设计原型打参考，再根据来修改。我们先摆完了之后再看参考的修改不足的。 (Andrea)

version. Only in the final version did we achieve a result that we felt was quite good." (Amelie)[105]

Tendency to Seek Teacher Approval in Prototype Refinement

To achieve higher grades, some students, despite validating their solutions, tended to refine their prototypes based on the options favoured by the teacher. They seemed to believe that the teacher's approval is crucial, and this tendency to align with the teacher's opinions influenced the direction of their prototype iterations. For example, Ricky mentioned that although the teacher reviewed many solutions during the iteration process, he still tended to favour the option preferred by the teacher. The opinions of others were less important compared to the teacher's preference.

"For instance, he thought that despite trying many solutions, the final outcome wasn't very satisfactory. He suggested creating a model first to assess the overall effect before proceeding with the actual work, as this could save time. I followed this advice, made the model, and then had others review it. I chose the final solution based on this feedback. I also showed the chosen solution to the teacher, because if the teacher didn't like it, it wouldn't be beneficial for me, even if others liked it. The teacher's approval is important as it ensures I receive better feedback and guidance."（*Ricky*）[106]

After completing one round of solutions with the teacher's approval, many students rarely undertook the next round. Like Una, she mentioned that she doesn't dare to continue with the design if the teacher doesn't approve it. However, even after receiving approval, she still didn't create the next prototype.

[105] 因为第一稿的时候，我以为那样能穿插，结果按照那个形状剪下来以后发现不太行。然后第二稿又去改了，改了以后发现还有点问题，大小也不合适。第三稿我交给同学用 AI 画，结果那个同学描绘得也不是特别好，所以我们又改了第四个版本。最后才出来了一个觉得还不错的效果。(Amelie)

[106] 比如说，老师觉得虽然尝试了很多方案，但最终产出的效果不太满意。他建议我先建模看看整体效果，再进行实际操作，这样可以节省时间。我按照这个建议做了，先建了模型，然后让其他人看看，最后选择了这个方案。当然，我也把选定的方案给老师看了，因为如果老师不喜欢这个方案，即使其他人喜欢，对我也没有什么好处。老师的认可很重要，因为这样我才能得到更好的反馈和指导。(Ricky)

"I probably won't be able to complete the plan in one go. I start by presenting my theme and ideas. If the teacher thinks they are okay, then we proceed. After I finish drawing the floor plan, and the teacher thinks it's reasonable, I dare to continue. I can't do what some others do, finishing the entire plan in one go; I think such people are incredible. I lack the confidence to complete the entire plan in one go. It's very time-consuming and exhausting for me. If you finish the whole plan and it's not approved, you'll have to scrap it and start over. But if you do it step by step, at least you can spot issues in time during revisions, and the teacher can also correct you promptly. This way, it's a bit easier." (Una)[107]

Few Students Redefined Problems in Iteratively in Clusters 1 and 3

In both clusters, few students redefined problems. After initially defining the design problem, most students did not consider altering the problem definition or design direction. Instead, they focussed on iterating solutions to address the design problem initially established.

Amelie stated that she first aligned the proposal with the teacher before proceeding with experiments. During the experiment, she focussed on the feedback obtained, but did not mention reflecting on or revisiting the proposal aligned with the teacher.

"Basically, the situation is that after successfully aligning the proposal with the teacher in the early stage, the subsequent experiments are conducted independently. During the experimentation process, feedback on the results may be provided to the teacher, and adjustments will be made if any issues are identified." (Amelie)[108]

[107] 我可能不会一次性就把方案做好。我先把我的主题和想法说出来，如果老师觉得可以，那我们才会继续往下做。当我把平面图画完以后，老师也觉得合理，我才敢继续进行。我可能做不到他们那样一次性完成整个方案，我觉得这样的人非常厉害。我没有自信一次性完成整个方案，这对我来说既费时又费力。如果整个方案做好了不通过，就得推翻重来。但如果一步一步来，至少在修改时可以及时发现问题，老师也能及时帮你纠正，这样会轻松一点。(Una)

[108] 大致情况是，首先是在前期与老师对接完成方案后，后续自行进行实验。在实验过程中，可能会将实验结果反馈给老师，如果发现有不适合的地方，还会进行调整。 (Amelie)

In another course, Claire followed a similar approach. She first identified several design directions through research and then selected one. After choosing this direction, she gradually refined it into the final solution. She did not plan to go back for further research or reflection on whether the direction was correct.

> *"Based on my initial research, I output several directions, then select one from those directions. I draw different sketches and gradually refine it until it finally create a final design. This is my approach." (Claire)*[109]

[109] 根据自己前期的调研去输出。几个方向，然后再从那几个方向里去筛选出一个。然后画不同的草图，然后慢慢去改。最后再做成一个最终方案的。一种这样的思路。（Claire）

Finding 15: Among students in Clusters 1 and 3, many received creative thinking training. Few recognized the limitation of their own perspective or began to consider others' viewpoints. Some students came to value the accumulation of design experience rather than breaking through thinking limitations. Many prioritized the teacher's comments over their personal ideas.

Few Recognized the Limitation of Their Own Perspective

In these design thinking courses, many students could articulate concepts related to novelty and value, but few mentioned the need to break through their own cognitive limitations. One student talked about the importance of design thinking to consider integration with other people's perspectives.

> *"I feel that design thinking doesn't solely represent an individual's design thinking. For example, in design companies or in this class where we are pretending to be a magazine company, it's not just one person doing the designing. Instead, it's more about collaboration. I believe that aside from design thinking, there's also a component of collaborative thinking or cooperative design thinking. It involves integrating others' ideas with your own, considering the thoughts of those you are working with, and not just stubbornly sticking to your own ideas." (Harry)*[110]

Although students in Clusters 1 and 3 could articulate the importance of innovation and creativity in design and could find new ideas under their teachers' guidance, few exhibited a creative thinking style in the design process, such as pursuing outside-

[110] 感觉设计思维并不代表一个人的设计思维，在因为我们现在目前，比如说在设计公司或者是，像我们这节课是假装一个杂志社，在这些工作当中，并不只是我们一个人在设计。然后反而更多的是多人合作。除了设计思维，我觉得里面还含有那种合作的思维或者是合作设计的思维。可能除了自己的想法之外要和别人的想法要更多的融合，然后要更多的考虑一起合作的这些人的想法，不能自己一意孤行。(Harry)

the-box thinking, resilience, a questioning spirit or a willingness to take risks that the teachers aimed to nurture.

Some Valued the Accumulation of Design Experience

Some students emphasized the importance of encountering new ideas and perspectives by accumulating design experience. Kelvin noted that building a mental repository of design inspirations and experiences would lead to greater innovation.

> *"If you feel like you lack inspiration and can't come up with something innovative, it's often not about a sudden idea that appears out of nowhere. Instead, it's the result of accumulated experience and knowledge. Inspiration often strikes when you've built up enough background and insights over time, allowing you to suddenly integrate and utilize various elements in new ways. Design thinking, therefore, requires cultivation and involves summarizing and integrating extensive experience. Through this accumulation, you develop your unique design mindset." (Kelvin)*[111]

Although he believed that accumulating design experience could lead to innovative ideas, he did not realize the need to break through conventional design thinking.

Prioritizing Teacher's Comments Over Personal Ideas

Despite this, when asked how they evaluated the comments on their designs, most students prioritized their teachers' opinions. They trusted that their teachers' perspectives were superior to and more innovative than their own. Even with training methods aimed at developing a creative thinking style, students continued to conform to their teachers' comments.

> *"Combining my own opinions with those of others to create something doesn't mean that my ideas are always right. Of course, I still need to*

[111] 当你觉得自己没有灵感，无法想出创新的东西时，可能并不是因为突然有了某个灵感，而是因为你已经积累了足够的经验和知识。真正的灵感往往是在你不断积累和整合各种经验之后，突然涌现出来。设计思维的培养也是如此，它需要通过总结和整合大量的经验来形成。你通过这些经验逐渐构建出属于自己的设计思维。(Kelvin)

consider many people's opinions, and mostly, I need to listen to the teacher's advice." (Effie)[112]

"Following the process step by step as instructed, I think this method is indeed useful. For our future practice, these teachings will certainly be beneficial. For example, I save all the materials the teacher provides, quietly keeping them for future reference." (Stephen)[113]

Some students designed work that conformed to what they perceived to be "innovative" in the minds of their teachers to try to gain high marks. This adherence to teachers' expectations often limited their willingness to take creative risks and develop an independent questioning spirit. Many students showed a desire to be recognized by their teachers.

"I started thinking in that direction because it was getting too late to not make the product. However, without the teacher's approval of my ideas, I was beginning to lose confidence in myself." (Michael)[114]

"The teacher will look at things from his own perspective, which is definitely deeper than that of those around us. We tend to see only surface-level issues. The teacher, being professionally trained, has more extensive and forward-thinking ideas. He has studied more, seen more, and experienced more due to his age. Therefore, his feedback will always aim to develop the product further in the long run." (Gina)[115]

[112] 结合我自己的意见，然后去做一个东西，但是也不是说我的就一定是对的，当然还是要结合很多人的意见，大部分还是先要听老师的意见。(Effie)

[113] 按这个流程一步一步跟你讲去怎么做，我觉得这确确实实会有用的。对于我们后面的实践，在做东西的时候，这些东西确实会有用。像老师他发的那些东西我都会保存，默默的保存起来。(Stephen)

[114] 会从这样的方向去想。因为当时候已经是再不做产品就晚了，但是自己的思想再不被老师肯定，自己都要失去信心了。(Michael)

[115] 老师会以他的角度。他的角度肯定会。会跟我们就身边人，他跟你讲。想法上会有可能会更。更深层一点，我们看到的可能都是一些表面上的一些东西……老师他也是学专业的，然后他的想法。肯定要比我们更长远。他就是学习的东西，还有他毕竟比我们年纪大的也比较多嘛，他看到的，还有他学习到的，肯定要比我们多的更多，所以他给我们的意见肯定是把产品往更长远的里头发展。(Gina)

"Yes, but the teacher's exact words were that there was no need to think further about it because he felt it wasn't worth pursuing. Since he said that, I didn't continue to delve deeper into it." (Ginger)[116]

Most students in this study sought their teachers' approval and high grades, which reflects a common scenario in universities in mainland China. This pursuit often shaped their approach to design and innovation, as they prioritized meeting their teachers' expectations over exploring different ideas. Mohana mentioned that the teacher thought their idea was too risky and did not like a mature product. As a result, after discussing with the group, they decided to abandon the risky idea.

"We discussed this idea with the teacher, and he felt that our concept didn't seem like a complete product. He preferred us to create a complete item. For example, he suggested that we should make a series, each with its own features. He thought this idea was a bit risky, and it might be challenging to produce because we would need actual items to display and achieve this functionality. So, for us, this was somewhat cumbersome. In the end, after discussing it, we decided to cancel this plan." (Mohana)[117]

[116] 对，但是但是老师的原话就是你不需要再去想他觉得没有做下去的必要了，他他都已经这样说我，也就没有再继续往后再深挖了。(Ginger)

[117] 我们拿这个想法和老师沟通了一下，老师觉得我们的想法不像一个完整的产品。他更希望我们能做一个完整的东西。比如说，他提出另一个意见，就是我们需要做一个系列，每个系列都有自己的特点。他觉得这个想法有点冒险，而且制作起来可能会有一定的困难，因为我们需要一些实物来展示和实现这个功能。所以，对我们来说，这有点繁琐。最后，我们讨论后决定取消这个方案。(Mohana)

6.4 Answers to Research Question 4

RQ4: How does students' understanding of design thinking affect their problem-solving?

Finding 16: Among students in Clusters 1 and 3 who applied design thinking, a small number expressed that their understanding affected their problem-solving approaches. Each key design thinking concept had impacts, but these impacts differed among students.

Some Students Reported Impacts

In interviews, a small number of students from Clusters 1 and 3 expressed that their understanding of design thinking led to effects in their problem-solving approach. These impacts stemmed from their reflections on their previous approaches and perspectives after learning and applying design thinking. These impacts were positive and helped students better apply design thinking to solve problems in the future. They not only enhanced students' problem-solving abilities but also fostered a more proactive and reflective approach in design practice.

Each Key Design Thinking Concept Had an Effect

Students understood the various key concepts of design thinking and mentioned in the interviews that each concept had an impact on them. Not only were students considerably influenced by the commonly applied principles of human-centred design and prototyping, but some also benefited from the iterative process. A few students mentioned that their training in creative thinking styles had made them feel the impact of design thinking.

Different Impacts on Students

These impacts varied among students. Some students improved their approach to considering design problems, such as changing their perspective on issues and placing a greater emphasis on human factors in design. Others experienced shifts in their mindset and attitudes towards tackling challenges and developing solutions. For instance, they became more open to different perspectives. Some students also reported increased ownership and confidence. We elaborate on these findings in subsequent sections. And figure 4 shows these impacts from different aspects of students' internalized design thinking.

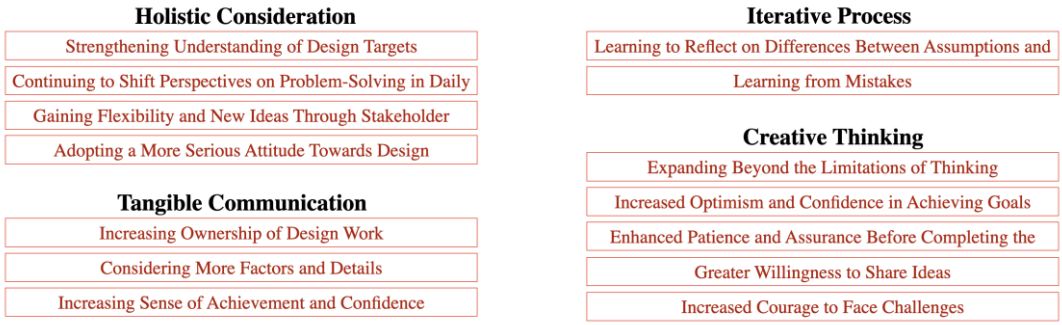

FIG 4. Impacts from Students Internalised Design Thinking

Finding 17: By practising a focus on human needs, many students realized the importance of emphasizing people and communication in future design processes. Some students felt they learned to shift perspectives in their daily lives. Learning about stakeholders expanded some students' design ideas. A few students reported increased interest in design and a more serious attitude towards their work.

Strengthening Understanding of Design Targets

Most students engaged in design research practices during their courses, which strengthened their understanding of design targets. Some students realized the need to focus more on people in their designs. For example, Becky also recognized the importance of enhancing communication with users throughout the design process.

> *"The biggest inspiration for me is that it probably made me think a little bit more holistically because to make a magazine you have to think about a variety of factors such as the audience target group. All these things have to be thought about. It makes me feel that when I do something or design something, I have to think about all aspects of it and think about its subsequent impact." (Becky)*[118]

Continuing to Shift Perspectives on Problem-Solving in Daily Life

Some students mentioned that they would continue to shift their perspectives on problem-solving in their daily lives. Dolly mentioned that she now has clearer goals because she shifted her mindset to think about why she was doing a particular design. She noted that this approach could also be applied to other aspects of life. For

[118] 然后再到上个星期的那个动态媒介设计的展览的结束，然后我们再根据那个展览上面收集的调查问卷进行一个后续的迭代设计。我感受到在设计一定要去多多跟别人交流。然后因为因为这个动态媒介设计这个展览我们也是小组合作的就是我觉得设计是一个交流的过程，不说跟。需求者不只是跟市场上面其他的人。我觉得设计是一个交流的过程。要提我们不仅要跟。不仅要跟设计的对象交流，也要跟。伙伴们一起交流同学！同学老师也是同为设计师的我们彼此之间交流，才可以呈现出一个饱满的作品，这样作品就不是一个片面的。不是一个形而上学的东西。(Becky)

example, when studying vocabulary, instead of just memorizing words, she now understands the structure of the entire test, which allows her to better plan her study goals. Woody stated that after studying empathy, he also found a new perspective for observing life.

> *"To think about why I want to do this design, like I go to background research, what am I going to do, and then what do I want to get out of it in the end, what's my intended outcome for this piece. And then applying that to other things that might apply to English words, like at this stage I'm going to. For a simple example let's say I want to brush up on my vocabulary, I don't know why I want to brush up on my vocabulary, just brush it up and then. Applying it to its I'm now cognitively then I might go and understand the whole basis of the paper what? Then there's a more purposeful, consequential piece to it. It's the piece of planning another stage of purpose." (Dolly)*[119]

> *"I believe this course has also cultivated my ability to identify problems, allowing me to observe life from a different perspective and better notice details that are often overlooked. It has taught me to see things from a designer's viewpoint." (Woody)*[120]

Gaining Flexibility and New Ideas Through Stakeholder Perspectives

One student felt that learning about stakeholders provided him with multiple viewpoints, leading to the generation of new ideas. His thinking became more flexible, and he was less rigid in his viewpoints.

> *"I think the class had a significant impact on me. For instance, when we worked on stakeholder mapping, the method encouraged me to think more*

[119] 我要去思考为什么要做这个设计。比如说，当我进行背景调研时，我需要明确自己在做什么，最终想要达到什么结果，我的目的是什么。这个思维也可以应用到其他方面，比如英语学习。举个例子，如果我只是一味地背单词，却不知道为什么要背单词，那么这种学习是没有目标的。相反，我应该理解整个试卷的结构，有一个明确的学习目的和结果导向，这样可以更好地规划每个阶段的目标。(Dolly)

[120] 我觉得这门课还培养了我发现问题的能力，让我换个角度去观察生活，更好地发现生活中平时看不到的细节，用设计师的角度去看待问题。(Woody)

expansively. It helped me avoid confining my ideas to a narrow focus and instead led to more creative and diverse concepts." (Harry)[121]

Adopting a More Serious Attitude Towards Design

Sunny's attitude towards design became more serious, with a transition from "designing for the sake of design" to "designing well". This occurred while also adopting a humbler attitude to design.

"It's true that on this, this this is what does have a feel for it, is when you have really in-depth research and don't go in and just ask the real users. When you do something, it's going to be different or the actual idea that you form is going to be different because if you don't talk to the real users, the real inhabitants, it's going to be different. It's hard to avoid being subjective when you're taking something for granted." (Sunny)[122]

[121] 我觉得上课对我影响比较大的。可能就是我们当时做利益相关者的那个范围，做圈的时候，当时方法可能让我在思考一些设计，或者是做一些新的东西的时候，它能让我更发散思维，不是说把你的想法局限于只是跟它密切相关的这一小块儿它能通过发散的方式带来更多新的想法吧！(Harry)

[122] 确实就这一点，这一这就是确实是有感受到，就是你有真正深入的去调研和没有去就问到真正的用户的时候。去做东西，它是会就或者是你形成的实际想法它确实是会不一样的，因为像如果没有去跟真正的用户，真正的居民去交流的话，确实会。比较想当然的去做一些设计，确实很难避免自己主观上的一些东西。(Sunny)

Finding 18: After completing their prototypes, many students experienced an increased sense of ownership. Some reported that they began to consider design details they had not noticed in daily life. Completing the prototypes brought them a sense of accomplishment and boosted their confidence.

Increasing Ownership of Design Work

Many students underwent prototyping training, which affected some of them. Some students reported that the process of creating prototypes enhanced their sense of ownership over their design work. For instance, one student initially viewed the task as a simple assignment, but his mindset changed when the teacher emphasized the need to present a prototype to the public.

> *"At the beginning, my attitude towards creating the piece was to treat it as just another regular assignment that I needed to complete. However, when the teacher mentioned that it would be showcased to the public and that we needed to produce a tangible product, my mindset changed. Since it was going to be presented to everyone, I felt I should strive to make it the best it could be. Even though my current skills might not be very strong, I still wanted to do my best. This marked a shift in my attitude towards the assignment." (Melody)*[123]

Another student Yuki also expressed the same point; after completion of the design, she saw the assignment as her own work. Woody mentioned that during the training process for the competition project, he realized his previous thinking was immature; his attitude towards design has shifted from "doing it for the sake of doing it" to "doing it well".

[123] 对作品制作的心态，一开始可能只是把它当成一个普通的大作业，想要完成它而已。但当老师说要展出、面向大众，并制作出一个实体作品时，我的心态就发生了变化。既然要面向所有人展出，那么就尽力做到最好。尽管我现在的能力可能不是特别强，但还是会尽量去做。这是对待作业心态的一种改变。(Melody)

"My shift in design thinking might be that my attitude towards design has changed. Initially, I treated the design project as an assignment, but after completing the design, I viewed it as one of my creations." (Yuki)[124]

"I think the most important thing is learning how to think maturely. For example, when I compare the project I did for a competition with my current project, my previous thinking was very immature and I couldn't come up with a complete and robust project. Now, my overall concept and understanding of design are different. Before, I was doing it just for the sake of doing it, but now I focus more on doing it well." (Woody)[125]

Considering More Factors and Details

The prototyping training also provided students with additional perspectives on design details in their daily lives. One student mentioned that he developed more comprehensive thinking and observation skills. Previously, he would only appreciate certain designs in his life, but now he also considers factors such as whether the materials are energy efficient.

"I now think more comprehensively about various aspects. For example, I used to like aimlessly observing and speculating without necessarily coming up with concrete ideas. Previously, I might have thought that setting the air conditioning on the subway to have strong airflow in the center and weaker airflow on the sides was a good idea. Now, when I sit on the subway, I think more about why it's set up this way, considering energy efficiency and human factors. I also consider materials more thoroughly; for instance, when I see a plastic bottle, I think about whether it's made of PET or PE. I've started

[124] 我的设计思维的转变可能就是，我对设计的态度发生了变化。之前，我会把设计当作一个作业来完成，但在设计完成后，我会觉得它是我的一件作品。(Yuki)

[125] 我觉得最重要的是如何成熟地思考问题。就像我刚刚举的例子，我打比赛做的项目和现在这个项目相比，之前的思考非常不成熟，无法构思出一个完整而饱满的项目。现在我对设计的整体想法和认知都不同了。之前是为了做而做，现在更多的是要做好它。(Woody)

thinking about everything in a more detailed and comprehensive way." (Kelvin)[126]

Increasing Sense of Achievement and Confidence

The prototyping training also instilled a sense of achievement and confidence. Students expressed that after completing the prototype and seeing the final product, they felt a genuine sense of accomplishment and independence, which increased their confidence in designing products in the future.

"Creating some small items that can make life better is actually a very interesting process and can also bring a sense of achievement. If these small items can be realized, the sense of accomplishment will be even stronger. This made me understand that being a designer is not far-fetched. As long as you observe carefully and truly want to make some changes and meet needs, anyone can become a designer. None of the students in our group had specialized in design before. It was the first time for all of us to be exposed to design in this course. During the course, we independently completed the design and final presentation of a product. This also gave us more confidence in designing products in the future." (Veronica)[127]

[126] 想的更全面了，各种方面，比如说我之前也是比较喜欢到处瞎看，瞎观察那种,就是不一定想出什么来，但是就喜欢瞎想。我可能之前就我坐地铁可能想地铁空调设置成中间是强风，两边是弱冷的方式好！好！真不错！然后现在可能坐在上面又会想更多说，这样省电了，然后它为什么是中间集中，而不是一个接一个，然后就省电这种东西全都会想一遍，然后它材料的使用也都会想就是生活中我可能现在看那个塑料瓶子，我都会想它是什么材质的，它是 PE T 的还是 PE 的？全方面的，什么都会想了，更全面。(Kelvin)

[127] 制作一些可以让生活更美好的小物品其实是一个非常有趣的过程，而且也能带来成就感。如果这些小物品能够实现的话，成就感会更强烈。这让我明白，设计师其实并不遥远，只要你留心观察，真正想要做出一些改变和满足需求，人人都可以成为设计师。我们小组的同学没有一个之前是专门学设计的，大家都是在这门课中第一次接触到设计，并且在课程过程中独立完成了一个产品的设计和最终的呈现。这也让我们对未来再设计产品充满了更多的信心。(Veronica)

Finding 19: Although only a few students practised the iterative process, some students learned to reflect on differences between ideas and reality. One student mentioned learning from mistakes.

Learning to Reflect on Differences Between Assumptions and Reality

During the iterative process, some students realized that they could not assume their designs were inherently correct and that they needed to understand that the actual problems might differ from their initial expectations.

> *"For instance, when we were working on dynamic programming, initially, we wrote the program based on our own understanding. We thought the operations were obvious and well-understood. However, when we actually gave the program to different users, we discovered that many people had different interpretations. This reflects a broader truth: in daily life, individual understanding of the same thing can vary greatly. What seems straightforward to one person may not be to another." (Peter)*[128]

One student began to reflect on their work from an observer's perspective and recognized that design should not merely align with their own preferences but should appeal to the users.

> *"I think a valuable insight from this course is the ability to view my own work from an observer's perspective. As a user or experiencer, I need to consider how the work would stand up to their scrutiny. This method was new to me before the course, but after experiencing various perspectives from different users, I realized that while everyone has unique requirements, there are*

[128] 比如说我们在做动态编程的时候。我们一开始在写这个程序的时候是按照我们自己的理解。我们觉得这个程序这样操作显而易见，我好像一拿到这程序，我就觉得它这么操作很好理解。当我们真正把它拿给不同的用户去使用的时候，会发现有很多人他们并不是这样想的。我觉得就是跟我们在平常生活中也是一样。每个人对同一个东西的理解是有非常大的个体差异的。并不是我的理解是理所应当的。可能别人觉得他那样理解是理所应当。大家的理解的差异还是很大的。(Peter)

consistent aesthetic standards for a complete design. Before taking this course, I might have focused on whether I personally liked my work. However, after the course, I understand that it's more important for the design to be liked by the experiencer or user, rather than just myself." (Chelsea)[129]

Another student mentioned that while designing, they considered user reactions during testing now more practically and reflected on potential issues with their designs.

"When creating something, I now pay more attention to its practical implementation and how it will be received by the public. I consider the potential issues that might arise during its actual use and try to anticipate these problems during the design phase." (Elaine)[130]

Learning from Mistakes

One student noted that they learned to draw lessons from mistakes and now apply this approach to learning and accumulating experience in daily life as well.

"In daily life, aspects of the iterative process in design thinking are evident. For instance, in middle or high school, I would list test mistakes to avoid repeating them. This mirrors design thinking's iterative cycle: creating a model, gathering feedback, optimizing it, generating a new version, and repeating the process. When faced with difficulties, I strive to avoid previous mistakes and discover new solutions." (Daniel)[131]

[129]这门课给我最大的启发是以旁观者的角度来看待自己的作品。我学会了从使用者或体验者的角度去考虑设计是否合适。以前，我只关注自己的感受和喜好，而完成课程后，我开始意识到每个体验者的需求可能不同，但他们对设计作品的审美标准却是相似的。在上这门课之前，我主要是按照自己的喜好来设计，但现在，我更注重让体验者或使用者喜欢我的作品，而不是单纯地让自己喜欢。(Chelsea)

[130] 我做东西可能就会更考虑他实际的落地的那种看法。更在乎它之后使用的时候，它会在人群中会有什么样的反应，之后它可能在落地的时候呈现出来的问题会有哪些？就是在我设计的时候，就是把它提前会先想好。(Elaine)

[131] 我觉得如果在日常生活中的话，就是说可能是设计思维中的一些这个迭代部分有所体现，就比如我比如说在以前上初中高中，我做题，然后之后考试的话我。如果有哪道题做错了，我会把它进行一个积累，然后去说弄一个错题，然后争取下次不再犯这个题不再做错，然后就说就比较像设计思维中的迭代部分就是前期这个模型，然后发放

Finding 20: Although only a few students applied creative thinking styles, some experienced a shift in mindset. Some mentioned expanding beyond their thinking limitations, while others increased their optimism and confidence in achieving goals. A few also enhanced their patience and assurance in completing designs, developed a greater willingness to share ideas and gained the courage to face challenges.

Very few students were able to apply creative thinking styles under current pedagogical approaches; these students were a small minority of the 93 participants in this study. They overcame difficulties in their courses and made numerous attempts to break through their own thinking limitations, which resulted in their mindsets being shifted by creative thinking.

Expanding Beyond the Limitations of Thinking

Some students believed they had overcome their personal limitations during the design process. They acknowledged the need to communicate with others to enhance their designs and gain new perspectives. For example, Sylvia mentioned that she became more willing to share her ideas and communicate with others because these discussions led to valuable insights. Another student Una mentioned that her perspective broadened, and she was able to break through her own thinking limitations by incorporating ideas from others.

> *"It seems that after participating in many such courses and presentations, I've become more confident in sharing my ideas and solutions. I am more*

给用户进行一些反馈，然后将第一代模型进行优化，然后生成第二代模型，然后再让用户进行使用。用户进行反馈，再不断的进行迭代，不断的进行优化，然后还有比如日常生活中如果我要做某件事情，或者说要干某件事情，如果我做这个事情，我可能遇到一些困难什么的，可能说我下第二次我做这个事情，我就不再犯同样的问题不遇到同问题，我可能会有新的解决方法。(Daniel)

willing to discuss my thoughts and innovations because these discussions often lead to valuable insights." (Sylvia)[132]

"One of the biggest takeaways is that my perspective has become much broader. When you focus solely on your own field, you tend to consider only the needs specific to your area of expertise. However, by interacting with students from other disciplines, such as those studying digital media or visual communication, you gain a broader view. During competitions, we often collaborate with students from various fields. This interaction helps you realize what might be missing from your design due to a lack of external viewpoints or professional limitations. Through their feedback, you can address these gaps and add new dimensions to your design." (Una)[133]

Increased Optimism and Confidence in Achieving Goals

Some students felt that they had become more optimistic about the design process. They showed increased recognition and confidence in their ability to achieve design goals. Gary expressed that he became more confident about his ideas and solutions. Kelvin mentioned that he felt a sense of accomplishment after he finished this work, although he did not know the result of competition.

"I tend to be more optimistic now. For example, I think about how a solution can be iterated and expanded upon, considering whether there is room for innovation or if different approaches can be applied, even if the concept already exists. This kind of thinking is more optimistic. I consider things more thoroughly now and am less likely to make mistakes due to oversight. I

[132] 好像可能是经过很多次这样的课程，很多次这样的汇报去讲自己的想法，自己的方案。会对自己更有自信吧！觉得很更愿意去和大家分享自己的一些想法一些点。自己在这个方面的当时的一些构思和创新的一些点，愿意去分享，去讨论，因为一讨论起来，就会收获很多有用的信息。(Sylvia)

[133] 我觉得最大的收获之一是视野变得更加开阔。因为在专注于自己的专业时，我们往往只考虑到自己领域的需求。但通过与其他专业的同学交流，比如我宿舍里有数字媒体专业的同学，或者认识一些视觉传达方面的朋友，我们可以从不同的角度来看待问题。在比赛中，我们也会与来自其他专业的同学一起合作。这样一来，我们会发现自己在设计中可能缺乏某些外部视角，或者存在一些专业上的不足，通过他们的建议，我们可以弥补这些不足，为自己的设计加光加彩。(Una)

think more deeply and feel more confident about ideas and solutions." (Gary)[134]

"I have more confidence now compared to before. Whether working alone or in a team, I've been able to produce something that received recognition from the teacher. Even though the outcome of competitions is uncertain, the fact that we created a complete project gives me a sense of accomplishment and boosts my confidence." (Kelvin)[135]

Enhanced Patience and Assurance Before Completing the Design

Andy reported becoming more patient, thorough and assured. He felt that, when dealing with design collaboration in the future, he would be able to cooperate with others with more tolerance for potential delays and uncertainties

"I believe I will approach design with more confidence and patience in the future. Previously, I lacked confidence because I was concerned about not being able to visualize concepts effectively. However, I've found that with complementary team backgrounds, almost nothing is unachievable. I am now more confident and patient, understanding that progress might require adjustments, but overall, the results can still be satisfying. This experience will make me more tolerant of potential delays and uncertainties in future collaborations." (Andy)[136]

[134] 会比较乐观吧，就是会比如说想这个方案可以怎么迭代，怎么再发散，有没有什么，它虽然以前有了，但是现在是不是可以做一个创新是不可以有不同的载体去做了，然后就这样去想。就比较乐观。考虑的会更多，不会像以前那样子容易因为考虑不周而犯下错误，就是现在会考虑的更多，会想的更多，也会比如说有些点子上、解决方案上，也会更加的有把握。(Gary)

[135] 会比之前更有一些信心，现在真正的去。不管说是自己还是和同学组队一起，然后就还是做出了一个东西来，然后东西，然后可能也算是得到老师一定的认可，然后他也就是做的很完整。然后我们去什么参加一些比赛，虽然不知道什么结果，至少这个东西是。一个完整的东西都做出来了，就比较有成就感，所以信心会稍微多一点。(Kelvin)

[136] 我觉得我之后做设计可能会更加自信，也会更有耐心。之前没有信心的原因是担心很多视觉化的东西做不出来。但是，我发现如果大家背景互补，其实没有什么东西是做不出来的。首先，我会更有自信。其次，我会更加有耐心。虽然我们最后的进度有一些调整，但最终的结果还是不错的，做出来的东西也比较充实。这让我觉得，下次再和别人合作时，我会更加耐心，允许更多的容错空间，对整体进度也会有更大的宽容度。如果因为某些不确定因素需要放缓进度，我也会有更大的耐心去面对。(Andy)

Greater Willingness to Share Ideas

One student even became more willing to share due to improved self-recognition. Ivory mentioned he had tended to question himself and often felt he was not as good as others. After the course, he felt he could also complete the design process. He also noticed his focus on design differed from that of others.

> *"I have a tendency to question myself and often feel that I am not as good as others. However, it is important to follow a complete design process to reassure myself and to be proud of my work. The project should not be something done just to meet requirements but should reflect a thorough and thoughtful design process. Even if my design is simpler in some ways compared to others, the focus on materials, texture, color, and overall theme makes it unique. The differences in focus and innovation set our work apart from others." (Ivory)*[137]

Increased Courage to Face Challenges

One student noted that they had gained the courage to face challenges. They felt more willing to take unconventional paths and considered making mistakes during the design process as a normal part of personal development.

> *"We believe that without a trial-and-error process, we don't develop our thinking skills. In fact, without this process, there are some detours that we might miss out on. Although there's an old saying that listening to experienced people can help avoid some mistakes, there are certain detours*

[137] 我这个人比较喜欢质疑自己，总觉得自己做的东西不如别人好。但是，我也意识到需要有一个完整的思路和过程来让自己心安理得，认可自己。因为你做这个东西不是为了应付，而是通过自己的推理，完成一个完整的设计过程。并不是说为了应付老师，让他觉得你的作品看起来和别人不一样，或者比别人的简单。尽管有时造型上可能看起来简单，但我发现我们注重的点不一样。我选择的材料、质感、颜色以及主题都和别人的不同。可能其他人只关注结构，没有什么创新，而我们组的设计在这方面就有独特之处。(Ivory)

that, if you don't take them, you will never gain that understanding." (Vincent)[138]

6.5 Chapter Summary

This chapter presented the findings of this study and the answers to the four research questions. These findings revealed the diversity in the understanding of design thinking among teachers, their pedagogies, the varying levels of student understanding and the impact of learning about design thinking on students.

[138] 我们觉得没有一个试错的过程，我们就没有把自己的思维培养起来，其实没有这个过程的话，我觉得就是我觉得有些弯路，虽然说他们老话说，听老人言可以少走点弯路，但是有些弯路不走的话，你永远没有这个意思。

Chapter 7 Discussion

This chapter presents the discussion of the findings in Research Questions 1 to 4, analysis of the data collected and interpretation of the findings in relation to each question. The discussion provides insights into the implications of the results, while highlighting key themes and patterns that emerged from the research.

7.1 Impact of Development of Design Thinking Education in China on Different focus of Teaching

There are differences among the universities in China that lead to variations in how design thinking is taught in these programmes. Differences in the ranking of design schools and the foundations on which they were established may influence how design thinking is taught in the different schools. The backgrounds of students in the different design schools also vary, which may in turn affect their acceptance of instruction in design thinking.

7.1.1 Universities' Different Focus on Nurturing Design Thinking

In our research, we found that some universities place a greater emphasis on students producing designs that meet industry standards, while others focus less on the practical implementation of designs and more on encouraging students to explore new ideas. This process of experimentation helps students reflect on the reasons behind their design choices. These differences may be due to variations in university rankings, access to different policies and societal resources, and varying university performance evaluations and student employment pressures, which lead to different educational goals. In design subjects, these factors influence divergent approaches to the instruction for design thinking.

Important University Ranking Systems in China

There are many forms of university rankings in China, with no universally accepted standard method. However, the Ministry of Education provides key policy support to some universities. These important support policies include the 211 Project[139], the 985 Project[140] and the Double First-Class initiative[141]. Only a few Chinese universities have a high rank in internationally recognized rankings such as the QS

[139] "211 工程" 学校名单 http://www.moe.gov.cn/srcsite/A22/s7065/200512/t20051223_82762.html

[140] "985 工程" 高等学校名单 http://www.moe.gov.cn/srcsite/A22/s7065/200612/t20061206_128833.html

[141] "双一流" 高校 http://www.moe.gov.cn/s78/A22/A22_ztzl/ztzl_tjsylpt/sylpt_jsgx/201712/t20171206_320667.html

ranking, but within mainland China, discussions often focus on the rankings influenced by these well-known policies.

The 211 Project, launched in 1995, involved 112 universities. It aimed to build around 100 key universities and a group of key disciplines, which made it the largest and highest-level construction project in higher education since the founding of the People's Republic of China.

The 985 Project, launched in 1998, supported 39 universities in aligning with the national innovation system for key construction. These 39 universities were already part of the 211 Project. The 985 Project was a significant national initiative to create world-class universities. It provided substantial support to universities such as Peking University, Tsinghua University, Shanghai Jiao Tong University, Fudan University and Zhejiang University, among others, which were recognized for their strong academic standing and high social prestige. For a long time, universities in the 985 Project were regarded as representing the top tier of higher education in China.

To promote China's transformation from a major player in education to an educational powerhouse, the State Council issued the "Overall Plan for Promoting the Construction of World-Class Universities and First-Class Disciplines[142]" in October 2015. This plan integrated the 211 Project and 985 Project into the Double First-Class initiative. In December 2017, the Ministry of Education announced the list of universities participating in the Double First-Class initiative, which included 42 first-class universities (36 in Class A and 6 in Class B) and 95 universities selected to develop first-class disciplines. These 42 first-class universities included the 39 universities from the 985 Project, and all universities from the 211 Project were part of the Double First-Class construction. The Double First-Class universities have been widely recognized and discussed in recent years, although the terms 211 Project and 985 Project are still frequently mentioned in various contexts.

Design schools and art academies in China also have their own rankings. While these rankings are not officially recognized by the government, they are widely discussed

[142] 国发〔2015〕64 号《国务院关于印发统筹推进世界一流大学和一流学科建设总体方案的通知》
http://www.moe.gov.cn/jyb_xxgk/moe_1777/moe_1778/201511/t20151105_217823.html

and applied in social and online contexts. For design schools, a common ranking comes from ShanghaiRanking[143], a well-known academic evaluation service in China Some design schools at non-Double First-Class universities are also highly ranked in this ranking, such as Jiangnan University and Guangdong University of Technology. This indicates that although these universities do not receive major national policy support, their design schools provide a respectable level of education and enjoy a good reputation in society. There are also eight independent art institutions in China with a long history. These institutions, such as the Central Academy of Fine Arts and Luxun Academy of Fine Arts, have a high reputation not only in China but also internationally.

These rankings represent the different levels of resources available to universities, such as government funding, which affects the facilities and learning environment provided at design schools. Rankings also influence the societal reputation of universities and design schools, which in turn affects the learning environment and employment prospects of graduates.

In our study, the design schools of the 23 universities offering design subjects were classified based on these popular rankings. They mainly fell into two categories. The first category includes high-ranking universities in mainland China, including Double First-Class universities, well-known design schools and prestigious art academies. The second category includes universities in mainland China that are not highly ranked, such as non-Double First-Class universities that also do not rank in the design school or art academy rankings.

Influence of University Ranking on Education in Design Thinking

The ranking of universities in China leads to differences in student training goals, which means the ranking of a university can significantly affect the distinction between intellectual and practical approaches in education. In Double First-Class universities, well-known design schools and prestigious art academies, educators tend to emphasize intellectual development over practical skills. In contrast, at non-

143 中国软科设计学排名 https://www.shanghairanking.cn/rankings/bcsr/2023/1305

Double First-Class universities without other significant rankings, educators focus more on practical skills.

In high-ranking universities, there is a greater emphasis on intellectual development, with a focus on cultivating students' mindset. These universities, with their significant endowments and strong industry connections, can afford to nurture a design thinking mindset that encourages students to engage in complex problem-solving and taking creative risks. Graduates of these institutions also face relatively less employment pressure and are often groomed as industry leaders. These universities often adopt a design thinking pedagogy that nurtures creativity and innovation: the goal is to equip students with the cognitive flexibility to tackle complex design challenges. Such institutions leverage their resources, reputation and the high expectations for both students and faculty to experiment with innovative pedagogies, thus preparing graduates to become leaders and innovators in their fields.

In our research, we observed that in high-ranking universities, regardless of whether students are required to iterate on their design projects in class, they often spend extra time after class reflecting on and improving their designs. When selecting design topics, students tend to choose challenges they have not tackled before, rather than sticking to safe, completed projects. These students generally exhibit higher self-efficacy and are more willing to take on challenges. This is related to the supportive learning environment provided by the university, where abundant policy support and lower employment pressure create a conducive environment for cultivating design thinking.

Conversely, universities that are not highly ranked may prioritize practical skills that enhance immediate employability. In these settings, educators often focus on specific technical skills and vocational competencies rather than fostering a design thinking mindset. This pragmatic approach reflects the reality that many students need a solid foundation of skills to secure jobs in the field immediately after graduation. The curriculum in these institutions is tailored to meet the immediate needs of the job market, thus emphasizing skills that are directly applicable to entry-level positions. These colleges are often evaluated based on the employment rates of their graduates, so they tend to prioritize employability over innovative capacities.

In non-Double First-Class universities, much of the instruction time is dedicated to training students to produce complete projects. For example, students are trained in sketching and 3D modelling to ensure that their work closely resembles industrial products. Students often appreciate this approach, as mastering hand-drawing or other modelling design tools can significantly enhance their employability. In China's job market, academic credentials play a crucial role, with many students entering university with the primary goal of securing a job rather than developing their thinking skills. This emphasis is reflected in teaching practices, as educators in these universities often prioritize training that results in tangible products. This focus on practical skills and immediate job readiness aligns with the broader employment context, where these skills are highly valued.

Such teaching practices can affect how students learn about design thinking. Students may lose focus on creative thinking and become more concerned with producing finished products. In this learning process, students may no longer see themselves as design thinkers but rather as technicians. They may lose the courage to take the opportunity to tackle difficult challenges, instead spending more time on learning practical skills. Overemphasis on practical skills may lead to a lack of experience in creative thinking, iteration and problem redefinition, which in turn may lead to a gradual erosion in their confidence to solve problems.

7.1.2 Development of Design School and Human-Centredness

In the findings, we observed that many teachers emphasized the importance of human-centred design in most of the subjects, which is a particular phenomenon in design schools in China. In Western countries, while human-centred design is also discussed, design thinking education often emphasizes different perspectives. Some educators highlight collaboration, while viewing design thinking as a process and mindset for co-creating solutions in various educational contexts (Panke, 2019). For instance, in Melbourne, design thinking courses aim to introduce students to broader issues in management and business (Melles et al., 2012), thus placing design students in a business environment for group practice. Other Western studies have mentioned that design thinking helps 21st-century students develop cognitive abilities such as reflecting through prototyping, empathizing with others and acquiring practical skills

(Noweski et al., 2012). Additionally, some educators emphasize that design thinking fosters critical thinking, promotes interdisciplinary partnerships and enhances students' creativity, which helps make them facilitators in the design process and leaders in developing solutions (Callahan, 2019). The Hasso Plattner DT Research Programme emphasizes the importance of learning through practice by guiding students towards a more action- and implementation-oriented mindset, thus transforming them into creative problem solvers and socially skilled team collaborators (Meinel & Krohn, 2022).

Design thinking education in China, however, still concentrates on teaching human-centred design, which may be related to the development of design schools in the country. In China, many university design schools originated from art and engineering faculties. Many teachers have a non-design background, such as engineering, computer science and art. Some teachers in this study came from design schools rooted in engineering and computer science, while others came from art-based design schools. These diverse academic and professional backgrounds have influenced the way design thinking is taught. Both groups of teachers emphasize human-centred design as a key focus in their courses.

The shift in the nature of the schools has led teachers to recognize the need to change their teaching focus, so they have transitioned away from previous subjects like engineering and fine arts to design education. Human-centred design is a distinctive feature of the design discipline that sets it apart from other fields. Many design schools in China are young. When other schools became design schools, emphasizing human-centredness was an important distinction from their previous academic background. Many teachers thus highlight human-centredness as a unique aspect of design thinking in contrast to their prior disciplines, where this consideration was not necessary. However, in Western design education, the emphasis is on how to innovate and collaborate across fields to solve problems after considering human factors. Compared to Western counterparts, design thinking education in China is still in an early stage of development.

7.1.3 Students' Knowledge Foundation and Reception of Design Thinking Pedagogy

In China, students in design schools come from different selection pathways, which leads to varying levels of foundational knowledge upon admission. At the undergraduate level, there are two main pathways for students entering design schools in China. The first pathway involves an initial selection based on artistic ability, followed by the National College Entrance Examination (Gaokao). Many students at high-ranking schools have this background, which makes them proficient in visualizing ideas due to their prior experience in art training. The second pathway involves only taking the Gaokao, without an art selection process. These students typically lack strong drawing skills and may be slower to grasp this aspect compared to those who underwent the art selection.

Graduate-level students are admitted through different selection methods. They either advance through recommendations or pass the graduate entrance examination. The initial selection for graduate admission typically tests the following subjects: English, politics, design sketching, design history and design theory. After the selection, they are interviewed by the school. During the interview, students need to present a portfolio of design works and discuss their understanding of design. Graduate students usually have an undergraduate knowledge base, although not necessarily in design. They may have a background in other fields, and some students have work experience prior to graduate admission. These students can quickly create prototypes and conduct user research and analysis to industry standards.

In this study, most undergraduate students had participated in art exams, while some entered university design schools solely through the Gaokao. The graduate students had diverse undergraduate degrees in fields such as art, design, journalism, accounting, engineering, advertising and Japanese, among others.

The impact of students' knowledge foundation on how they learned design thinking did not align with the teachers' assumptions. Many teachers believed that students with an art background would excel in creating prototypes and perform better in creative thinking. Some also thought that students from the humanities would be more empathetic and thus would not need special attention in user research. They

assumed that students with a science background would have stronger critical thinking skills. However, contrary to these beliefs, this study revealed no significant differences in student performance based on academic background. Although students with an art background could draw sketches more quickly, other students also mastered prototyping tools to express their design ideas effectively. There were no noticeable differences in creative thinking across students, and even those with an art background did not necessarily perform better in brainstorming sessions. Students from a humanities background showed similar performance in user research to their peers, and science students did not exhibit stronger critical thinking.

In China, the undergraduate design schools are generally four-year programmes, and postgraduate studies are three-year programmes. Most of the students in this study were undergraduates, with a few graduate students. The undergraduates were from Year 1 to Year 4. The graduate students were from Year 2. Additionally, two students had 3–5 years of work experience.

Some teachers may assume that third- and fourth-year undergraduates and graduate students should already understand the design process and have mastered the correct design methods. Particularly for students with prior work experience, teachers often expected them to perform better and adapt more quickly to the teaching methods in design courses. For many first- and second-year undergraduates, these courses were their first exposure to the concept of design thinking, and teachers often felt they needed more patience in guiding them through the pedagogy.

However, regardless of their year or prior experience, all students in this research followed the design process as instructed by their teachers, without significant differences in their reception of the teaching methods. This suggests that teachers could experiment with various design thinking pedagogies without worrying too much about their students' diverse knowledge foundations and prior experiences.

7.2 Impact of Integrating Design Competition on Design Thinking Education

In many universities in mainland China, it has become increasingly common for teachers to involve students in design competitions as part of their coursework. These competitions are often integrated into project-based courses, with the curriculum aligned to competition deadlines. For universities, the success of students in these competitions demonstrates the quality of their design programmes. Universities also use the result of important competitions to evaluate teachers' teaching performance.

7.2.1 Benefits of Competitions for Students

Many teachers believe that incorporating design competitions into the curriculum enriches the learning experience and better prepares students for employment. Participating in competitions enhances students' portfolios, which makes them more competitive in the job market. More important, however, is that integrating design competitions into the curriculum can drive student engagement and provide practical benefits. It can increase their motivation and provide valuable practical experience, thus enhancing their engagement and learning outcomes.

Design competitions often involve collaboration with industry partners, which provides students with valuable networking opportunities and exposure to current industry standards and trends. That is one reason that some students in the interviews mentioned that competitions expanded their mind. This approach can also enhance students' sense of ownership and provide real-world experience by exposing them to client interactions and practical design challenges. Competitions provide students with real-world challenges that encourage them to apply their theoretical knowledge in practical scenarios. This hands-on experience fosters creativity, problem-solving skills and innovative thinking, which are essential for future design professionals.

7.2.2 Challenges for Teaching with Integration of Design Competition

Integrating competition-focussed projects into the curriculum presents challenges. One major drawback is that the tight deadlines for competitions can disrupt the course schedule and compel students to prioritize meeting these deadlines over engaging deeply with the iterative process of design thinking. Students may thus focus more on refining their project to meet competition standards rather than developing it through iteration. In the interviews, some students questioned why their coursework was aligned with competition objectives and perceived it as a conflict where the course served the competition rather than their personal learning experience.

The emphasis on producing competition-ready outputs may also overshadow the educational goal of cultivating design thinking. This can lead to a narrow focus on producing polished, award-winning designs rather than fostering a comprehensive understanding of design thinking principles. Students may believe they are developing their problem-solving skills through iterative processes, but they may make the design rendering and presentation more sophisticated to get a good score in the competition.

Teachers should manage the process carefully. The focus on competition outcomes can diminish the emphasis on iterative design processes and creative thinking if not carefully managed, which could ultimately affect the quality of design thinking education. The challenge lies in balancing competition demands with the need to cultivate a mindset of holistic design thinking, thus ensuring that the educational process remains focussed on developing creativity and critical problem-solving skills rather than merely achieving competition success.

7.2.3 University Teachers' Survival Strategies in Mainland China

Because universities in Mainland China emphasize visible learning outcomes, teachers are expected to demonstrate tangible results from their courses. Teachers often see student projects as an opportunity to boost student motivation and gain recognition from the university. Teachers have different survival strategies based on their contract basis with the university. In this study, the participating teachers fell

into two groups: those with established university positions and those employed on a contract basis. These two employment models create different pressures and expectations. For teachers with permanent positions, job security is higher, and they generally face fewer research-related KPIs, which results in relatively less pressure. Such teachers rarely asked students to take part in design competitions. Contract-based teachers, however, experience greater pressure, as they must produce research outcomes in addition to teaching. With limited time and resources, they often need to showcase their teaching achievements quickly. One direct and efficient way to do this is by collecting and presenting student work. Many such teachers thus believed that integrating competitions into the course could motivate students to produce excellent work, and they frequently retained students' work as evidence of their teaching accomplishments.

Incorporating competitions into the curriculum is an effective strategy to generate notable student outcomes. It is widely used by many design schools in China, but it may also lead to ineffective teaching of design thinking. Many industrial competitions provide an extra channel in which only university students can participate. Teachers tend to evaluate creative thinking styles within a market-oriented context. This approach sometimes negatively influences students' understanding of creative thinking. In this study, many students mentioned that design should innovate to meet competition and market demands, with few discussing the importance of pushing beyond their own knowledge limitations to nurture creative thinking.

7.3 Impact of Inappropriate Curriculum and Pedagogies on Design Thinking Education

In the many project-based subjects examined in this study, students consistently showed signs of insufficient time for hands-on practice. This issue was particularly evident in courses where the schedule left no room for a second round of prototyping and iteration. However, learning design thinking through practical experience – that is, learning by doing – requires adequate time. The lack of time for practice also leads teachers to provide direct feedback on students' work instead of engaging in reflective questioning and follow-up discussions, as time constraints make this difficult. As a result, students miss opportunities for critical reflection on their designs, which in turn hinders the development of a design thinking mindset.

7.3.1 Lack of Appropriate Arrangement for Practice in Curriculum

The structure of the curriculum significantly affects students' engagement in iterative processes and prototyping within design thinking courses. Students often face high levels of stress and diminished engagement when multiple project deadlines coincide at the end of the term. This overlap can overwhelm students, which can lead to burnout and a reduction in their overall enthusiasm and effectiveness.

Design thinking requires extensive hands-on practice and iterative refinement in which students continually enhance their projects based on feedback and reflection. However, when students are simultaneously managing multiple large assignments, their ability to engage deeply in these iterative processes is compromised. The pressure to meet overlapping deadlines often leads to rushed work and lower quality, as students struggle to devote adequate time and attention to each project. This lack of time can result in shortcuts during the iterative process, with students failing to explore or refine their ideas fully, thereby diminishing the learning-by-doing aspect of design thinking.

The intense workload at the end of the term can affect students' attitude towards their projects as well and reduce the projects to mere tasks to complete rather than opportunities for experiential learning. When projects are seen primarily as

preparation for competitions or urgent deadlines, the educational value of engaging deeply with the iterative process may be lost. Students could end up focussing more on finishing their projects quickly rather than on refining their work through thoughtful iteration, which is crucial for applying a design thinking mindset.

A well-structured curriculum that introduces projects early in the course can enhance students' understanding and internalization of design thinking. Early engagement with projects would allow students to apply design thinking principles more deeply and consistently. This approach provides more opportunities for hands-on design work and iterative refinement, thus leading to a better grasp of the subject. Students would benefit from additional time to think critically about and iterate on their designs, which would also support more effective application and internalization of design thinking concepts. Schools of design should pay more attention to the proportion of practice time in their programmes when developing curriculum policies. In project-based programmes, an increase in practice time can give students a better learning experience when developing curriculum plans.

To improve student engagement and learning outcomes, it is essential to implement a more balanced curriculum. Setting several deadlines for verifying prototypes in a course process could provide more learning opportunities that would allow students to focus more on each prototype and engage thoroughly in the iterative process. Incorporating interim milestones and progress check-ins could also support better time management and sustained engagement. By structuring the curriculum to distribute students' workload and deadlines more effectively, educators can create a more supportive learning environment. This approach would not only enhance students' ability to learn through practice but would also foster a deeper understanding and application of design thinking principles.

7.3.2 Helping Students with Direct Comments but Doing More Harm than Good

Due to time constraints, teachers often resort to direct instruction to guide students to meet the course requirements quickly. Teachers have clear criteria for evaluating assignments in many subjects, and some diligent instructors review students' work frequently. However, they often do not adopt methods that allow students to reflect

on their designs. Many students feel that receiving direct feedback is helpful, as it clearly indicates what the teacher wants. However, this approach can limit students' learning opportunities, which can lead them to focus more on meeting the teacher's standards rather than developing their own independent thinking. Students may not realize that they lack time for reflection and design improvement: Once the teacher provides direct feedback, students quickly implement it and are satisfied with the results. This issue highlights the need to include moments for questioning and encouraging students to explore on their own when planning design thinking pedagogy. Teachers should refrain from giving direct feedback early on, while allowing students time and space to think critically.

In addition to time constraints, another factor that reduces learning opportunities is the excessive sharing of personal experiences by some instructors, which often takes up too much class time. One student expressed dissatisfaction with lectures dominated by the teacher's personal opinions, noting that it diminished her motivation to learn. She described the lectures as "half-cooked rice", where the teacher's talk was filled with personal anecdotes, which made it difficult to extract practical methods from the content.

Although teachers sharing their experiences in class is common, as it can quickly provide students with insights from real-world design projects, it is also important to ensure that students have enough time to learn through practice. With sufficient practice, students can better understand the experiences and understanding of design thinking that teachers aim to convey.

7.4 Impact of Teacher–Student Hierarchical Relationships on Learning Creative Thinking

It is a cultural phenomenon in China that many students are taught from an early age to respect and obey their elders and teachers. Chinese parents and teachers are used to interfering with their children's judgement, which evolves into a subconscious hierarchical relationship in the classroom. This hierarchical relationship can have an impact on the effectiveness of students' creative thinking as they learn about design thinking.

7.4.1 Students' Conformism from Asian Culture Brought Difficulties to Break Perceptual Blocks

Students in mainland China are generally taught from a young age to respect and follow the guidance of authority figures such as teachers and parents. This upbringing fosters a culture of conformity, characterized by a hierarchical respect for authority and a strong inclination to follow superiors' opinions. This cultural norm can limit students' opportunities to think divergently and challenge conventional ideas.

Conformism among students in mainland China significantly affects their creative thinking and understanding of design thinking. Rooted in a cultural tradition that emphasizes respect for authority and adherence to established norms, this tendency often leads students to prioritize compliance with teachers' expectations over independent exploration and innovation. As a result, students may struggle to develop the creative thinking styles essential to engage effectively in design thinking processes.

In design thinking courses, this inclination towards conformity can inhibit students' ability to engage deeply with creative processes, particularly the iterative and exploratory aspects critical to design thinking. When students prioritize meeting perceived expectations over pursuing their own creative ideas, their approach to design thinking becomes more risk-averse and conventional. Rather than experimenting with bold or unconventional solutions, students may focus on producing designs that align with what they believe will satisfy their teachers' criteria.

This cautious approach can restrict their creative thinking and prevent them from fully exploring and refining their ideas through iterative processes.

To mitigate the impact of conformism and foster a more creative thinking style, educators should encourage students to embrace experimentation, take risks and view mistakes as opportunities for growth. When considering pedagogy, teachers should value independent thought, support iterative exploration, and encourage students to challenge conventional ideas. In this way teachers can help students overcome the constraints of conformism. This approach would not only enhance their understanding of design thinking but also cultivate a more innovative and effective creative thinking style.

7.4.2 Dominant Role of Teachers limited opportunities for Independent Thinking

Some students expressed dissatisfaction when their designs were overly influenced by their perception of teachers' desires rather than their own creative instincts. This dissatisfaction could further diminish their motivation and engagement in the design process, thus making it even more challenging to develop a creative thinking style. In many courses, teachers' opinions play a dominant role, as they often provided direct feedback and rarely employed questioning techniques that would encourage students to think critically and engage in in-depth discussions. Due to students' upbringing in a cultural context that emphasizes obedience to teachers and parents, they are less likely to develop independent thinking and the courage to challenge authority in a classroom dominated by the teacher.

Although many teachers sought to cultivate qualities associated with creative thinking through various exercises, when the teacher's dominant role meets the strong conformity deeply ingrained in students' minds, it is difficult for students to break away from their established mindset. In the interaction between teacher dominance and student conformity, students align their design work with the teacher's opinions to achieve better grades or gain more guidance. This strong teacher dominance may lead students to focus more on meeting expectations rather than developing their own independent thinking and creativity. For example, in this study, some students experienced significant frustration if they did not receive approval from their teachers.

Despite teachers' intentions to create a supportive environment for creative thinking, their dominant role in the classroom may not lead them towards this goal. Teachers need to reduce the sense of hierarchy in the learning process. They should empower students to take ownership of their learning and become the main actors in the classroom. To nurture creative thinking effectively, educators must prioritize students' independent thinking and personal learning experiences over the constant emphasis on meeting established standards. To better nurture creative thinking, educators should balance the teacher's role with a focus on student-centred learning, while encouraging students to critically engage and allow mistakes and crazy ideas.

7.5 Chapter Summary

This chapter discussed the findings related to the research questions explored in the previous chapter. Four key areas were examined: the impact of differences between universities on design thinking education, the influence of integrating design competitions, the influence of curriculum on design thinking education and the effect of student conformism in Mainland China on the development of creative thinking.

Chapter 8 Conclusion

This chapter is structured to provide a comprehensive overview of the research findings and their implications. Section 8.1 presents the conclusions drawn from the study, highlighting the key outcomes and insights gained. Section 8.2 addresses the limitations of this study, discussing the constraints and challenges faced during the research process. Section 8.3 offers recommendations for future research, suggesting potential areas for further investigation and improvements. Finally, Section 8.4 provides a summary of the chapter, encapsulating the main points and emphasizing the significance of the findings.

8.1 Conclusions

In conclusion, this research contributed knowledge to pedagogical research of design thinking education in design schools in China. Design thinking should not taught as a class, it should be embedded in design practice. Design thinking is not just talking, it's about doing.

This research bridged the knowledge gap of insufficient empirical research in design thinking education in China. Through empirical research in 23 design courses, the study addresses four key research questions and reveals insights into the state of design thinking teaching, as well as how both teachers' and students' understandings of design thinking evolve. The findings reveal the situation of design thinking pedagogies in design schools in China, elucidate teachers' and students' understandings of design thinking, and demonstrate how these understandings influence students' learning and development. The analysis offers valuable insights into how design thinking is taught, perceived, and applied in mainland China, and its impact on students.

The findings indicate that teachers generally demonstrate a solid understanding of design thinking concepts, such as human-centred focus, creative thinking, and the use of cognitive tools. However, the extent to which these concepts are translated into effective pedagogy varies. Majority of teachers in project-based courses (Cluster 1) incorporate design thinking principles into their teaching, while others rely more on traditional lecture-based approaches. Despite this, there is a noticeable lack of emphasis on iterative processes and creative thinking style.

Students' understanding of design thinking is influenced by the pedagogical methods implemented in their courses. In Cluster 1, most students show a good understanding of design thinking, particularly in areas like human-centred focus and tangible communication. However, there are variations in the depth of understanding and application of concepts like iteration and creative thinking styles. In Cluster 1, while some students apply design thinking principles effectively, some demonstrate only articulation. Cluster 3 reveals that even without explicit design thinking instruction, students in project-based courses still develop an understanding of the concepts.

In addition, this study explores several key factors influencing design thinking education in China. The impact of universities' different focus reveals how varying institutional contexts shape the depth and focus of design thinking pedagogy. Integration of competition-focused elements into the curriculum highlights both opportunities and challenges in design thinking pedagogy. Curriculum arrangements significantly affect students' learning experiences, with overlapping project deadlines and workload often hindering their ability to engage deeply in iterative processes and prototyping. Furthermore, the cultural tendency towards conformity among Chinese students impacts their creative thinking styles, as adherence to teachers' expectations may stifle independent exploration and risk-taking spirit. Addressing these factors is crucial for enhancing design thinking education and supporting students in developing more robust and creative problem-solving skills.

8.2 Limitations of the Study

This doctoral research, conducted over three years, faced several limitations concerning research resources, personnel, and time.

Although many other schools in mainland China offer design thinking courses, we could not gather data from those classes due to the lack of willingness from the teachers. Future studies would benefit from more researchers to enrich the study. During the initial phase of identifying willing schools to participate in the study, one researcher contacted approximately 50 eligible institutions across China. After six months, only 13 schools agreed to participate.

Additionally, not all students in the classrooms were willing to participate in the research. The study's participants were selectively chosen from those who were more enthusiastic. Among these participants, most were high-performing students who were more receptive to the teacher's instructional methods. Therefore, the results of this study do not represent the learning experiences of other students.

Due to limited personnel for data collection and analysis, all data in this study were gathered by a single researcher. Nearly every participant took part in two one-hour

semi-structured interviews, resulting in over 200 transcripts and numerous documents provided by the participants. The limited funding made the process of organizing, anonymizing, transcribing, and analyzing this data exceedingly time-consuming and labor-intensive, pushing the researcher to their limits. Involving more researchers for broader data collection would greatly supplement the findings of this study.

Furthermore, during the data collection phase, the large-scale COVID-19 pandemic in mainland China hindered the researcher from conducting in-person classroom observations. Out of the 13 project-based design courses, 11 were affected by the pandemic. The few non-participatory observations included in this study were conducted through Tencent Meeting with local teachers.

The COVID-19 pandemic also impacted the implementation of teaching methods in these courses. Some project-based courses could not conduct field research, and the transportation of materials for student prototypes was disrupted. If these teaching methods had been implemented more effectively, the results of this study might have been more comprehensive.

8.3 Recommondations and Future Research

This study has summarized the following experiences and recommendations, while also suggesting directions for future research.

It is crucial to pay attention to data beyond interviews in project-based design courses, as this data can reflect students' understanding of design thinking throughout the design project process. Based on the experiences from this study, having participants regularly summarize the course and write reflective notes during the process is an effective method. Additionally, periodic conversations with participants to inquire about their experiences in the course, such as once a week or every two weeks, can be beneficial. Care should be taken to set the frequency of these conversations so that they do not interfere with the students' primary learning tasks. It is also important to

focus on the process documents generated during the design, rather than only the final design outcomes.

However, in the process of using such experience sampling methods, attention must be paid to the participants' learning experience to avoid disrupting their design projects or offering design advice beyond the course. In this study, many participants asked the data collector for opinions during the project. The researcher was very careful not to provide design advice or comment on their design works during these times.

One potential research direction is to use the theory and research design of this study to investigate design thinking education in other design courses in mainland China. By the end of this study, there were still lack of empirical research on design thinking education in mainland China's design schools, indicating the need for continued empirical research in this field.

Another possible direction for future research is to investigate design thinking education in non-design programes in mainland China. In the initial research phase of this study, it was also found that universities in mainland China have introduced design thinking education in non-design schools, mainly in business, humanities, and engineering disciplines. Research on design thinking training in non-design disciplines is still relatively rare in mainland Chinese universities and requires much empirical research to fill this knowledge gap. Comparative studies can also be conducted by combining these disciplines with research on design thinking education in design schools in China.

A further potential research direction is to study the impact of the rise of AI-generated content (AIGC) on design thinking education. During the research phase of this study, AIGC was gradually becoming popular in design education, and some participants indicated that they had tried using AIGC tools in their design processes. There is still a significant research gap in integrating AIGC tools into design education in mainland China, necessitating related educational research.

8.4 Chapter Summary

This chapter introduces the conclusion of this research, including limitations and possible future research directions. Limitations include potential biases and issues with generalizability, and the chapter concludes with recommendations for future research, such as examining effective pedagogical strategies and balancing competition with iterative learning.

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Appendice 1 List of Research Samples

1. Information of samples in Cluster 1

	University	Student Major	Student Level
1	Shanghai Jiao Tong University	Cultural industrial management and product design	Master year 2
2	Shanghai University of Engineering Science	Multiple design background (product design, interior design, digital media, visual communication)	Master year 2
3	Fujian Normal Uninversity	Fashion design	Bachelor year 1
4	Tsinghua University	Service design	Master year 2
5	Guangzhou University	Product design	Bachelor year 3
6	Zhejiang University of Technology	Product design	Bachelor year 2
7	Jiangsu Ocean University	Product design	Bachelor year 2

8	Southwest Jiaotong University	Industrial design	Bachelor year 3
9	Luxun Academy of Fine Arts	Graphic Design	Bachalor year 3
10	Wuhan University of Technology	Visual Communication Design	Bachalor year 4

2. Information of samples in Cluster 2

	University	Major	Website
1	Zhejiang University	Industrial design	https://www.icourse163.org/course/ZJU-1003462001?tid=1467058477
2	Beijing University of Posts and Telecommunications	Product design	https://www.icourse163.org/course/BUPT-1003561003?from=searchPage&outVendor=zw_mooc_pcssjg_
3	Xi'an Polytechnic University	Fashion design	https://www.xuetangx.com/course/XPU13051000526/14602300?channel=i.area.manual_search

4	Tsinghua University	Visual communication design	https://www.xuetangx.com/course/THU13051000381/14768168?channel=i.area.manual_search
5	Nanjing University of the Arts	Product design	https://www.icourse163.org/course/NJARTY-1449615168?from=searchPage&outVendor=zw_mooc_pcssjg_
6	Capital Normal University	Art and Design	https://www.xuetangx.com/course/cnuP135720240321021190072?channel=i.area.manual_search
7	Geely University of China	Design	https://www.xuetangx.com/course/guc1305bt1429/19324583?channel=i.area.manual_search
8	China University of Mining and Technology	IndustrialDesign	https://www.icourse163.org/course/CUMT-1207337801?from=searchPage&outVendor=zw_mooc_pcssjg_
9	Yanshan University	Design	https://www.icourse163.org/course/YSU-1463077165?from=searchPage&outVendor=zw_mooc_pcssjg_
10	Xiangtan University	Graphic Design	https://coursehome.zhihuishu.com/courseHome/1000003139#onlineCourse

3. Information of samples in Cluster 3

	University	Student Major	Student Level	Teacher's Background
1	Beijing Institute of Fashion Technology	Fashion design	Bachelor year 3	Fashion design, Interaction design
2	University of Science and Technology Beijing	Industrial design	Bachelor year 2	Interaction design
3	Guangdong University of Technology	Interior design	Bachelor year 2	Interior design

Appendice 2 Demongraphic Information of Students

The tables below present the demographic information of students in clusters 1 and 3, including their gender, year of study, major, and work experience. In the “Gender” column, F denotes female, and M denotes male. For “Year of Study”, B represents bachelor’s, and "M" represents master’s, with the number following indicating the student's grade level in 2023.

Students in Cluster 1

Design Subject	Student	Gender	Year of Study	Bachalor Degree	Master Degree (if applicable)	Working Experience (if applicable)
A	Student A1	F	M2	Director for Television Programmes	Product Design	
	Student A2	F	M2	Digital Media Art	Product Design	
	Student A3	F	M2	Journalism	Product Design	
	Student A4	F	M2	Accountancy	Product Design	
	Student A5	M	M2	Journalism	Product Design	5 years
	Student A6	F	M2	Advertisement	Product Design	
	Student A7	F	M2	Japanese	Product Design	
B	Student B1	F	M2	Digital Media Design	Digital Media Design	
	Student B2	F	M2	Product Design	Product Design	
	Student B3	F	M2	Environmental Design	Environmental Design	
	Student B4	F	M2	Environmental Design	Environmental Design	
	Student B5	F	M2	Interior Design	Exhibition and Space Design	1 year

	Student B6	F	M2	Engineering	Product Design	
	Student B7	M	M2	Environmental Design	Exhibition and Space Design	
C	Student C1	F	M2	Information Art Design	Information Art Design	
	Student C2	F	M2	Architecture	Architecture	
	Student C3	F	M2	Environmental Design	Information Art Design	
	Student C4	F	M2	Environmental Design	Industrial Design	
D	Student D1	F	B3	Product Design		
	Student D2	F	B3	Product Design		
	Student D3	F	B3	Product Design		
	Student D4	F	B3	Product Design		
	Student D5	F	B3	Product Design		
	Student D6	F	B3	Product Design		
E	Student E1	F	B1	Fashion Design		
	Student E2	F	B1	Fashion Design		
	Student E3	F	B1	Fashion Design		
	Student E4	M	B1	Fashion Design		
	Student E5	M	B1	Fashion Design		
F	Student F1	F	B2	Industrial Design		
	Student F2	M	B2	Industrial Design		
	Student F3	M	B2	Industrial Design		

	Student F4	M	B2	Industrial Design		
	Student F5	M	B2	Industrial Design		
G	Student G1	M	B2	Product Design		
	Student G2	F	B2	Product Design		
	Student G3	M	B2	Product Design		
	Student G4	F	B2	Product Design		
	Student G5	F	B2	Product Design		
H	Student H1	M	B3	Industrial Design		
	Student H2		B3	Industrial Design		
	Student H3	F	B3	Industrial Design		
	Student H4	F	B3	Industrial Design		
	Student H5	F	B3	Industrial Design		
	Student H6	M	B3	Industrial Design		
	Student H7	F	B3	Industrial Design		
	Student H8	F	B3	Industrial Design		
	Student H9	F	B3	Industrial Design		
	Student H10	F	B3	Industrial Design		
	Student H11	M	B3	Industrial Design		
	Student H12	F	B3	Industrial Design		
	Student H13	F	B3	Industrial Design		

	Student H14	F	B3	Industrial Design		
	Student H15	F	B3	Industrial Design		
	Student H16	M	B3	Industrial Design		
I	Student I1	F	B2	Humanities and Design		
	Student I2	F	B2	Humanities and Design		
	Student I3	F	B2	Humanities and Design		
	Student I4	F	B2	Humanities and Design		
	Student I5	F	B2	Humanities and Design		
	Student I6	M	B2	Humanities and Design		
	Student I7	M	B2	Humanities and Design		
	Student I8	M	B2	Humanities and Design		
	Student I9	M	B2	Humanities and Design		
	Student I10	F	B2	Humanities and Design		
J	Student J1	F	B3	Visual Communication Design		
	Student J2	F	B3	Visual Communication Design		
	Student J3	F	B3	Visual Communication Design		
	Student J4	F	B3	Visual Communication Design		
	Student J5	M	B3	Visual Communication Design		

	Student J6	F	B3	Visual Communication Design		
	Student J7	F	B3	Visual Communication Design		
	Student J8	F	B3	Visual Communication Design		
	Student J9	F	B3	Visual Communication Design		
	Student J10	F	B3	Visual Communication Design		
	Student J11	M	B3	Visual Communication Design		
	Student J12	F	B3	Visual Communication Design		

Students in Cluster 3

Design Subject	Student	Gender	Year of Study	Bachalor Degree	Master Degree (if applicable)	Working Experience (if applicable)
K	Student K1	F	B3	Fashion Design		
	Student K2	F	B3	Fashion Design		
	Student K3	F	B3	Fashion Design		
	Student K4	M	B3	Fashion Design		
	Student K5	F	B3	Fashion Design		
L	Student L1	F	B2	Visual Communication Design		

	Student L2	F	B2	Digital Media Art		
	Student L3	F	B2	Environmental Design		
	Student L4	F	B2	Exhibition Design		
	Student L5	F	B2	Digital Media Art		
	Student L6	F	B2	Environmental Design		
M	Student M1	F	B2	Industrial Design		
	Student M2	M	B2	Industrial Design		
	Student M3	F	B2	Industrial Design		
	Student M4	F	B2	Industrial Design		
	Student M5	M	B2	Industrial Design		

Appendice 3 Interview Protocol with Teachers

Interview Protocol for Teachers in Cluster 1

Guideline	Start Questions	Follow-up Questions
Understanding of Design Thinking	What is your understanding of design thinking?	Can you explain more about the concept you just talked about? Why these concepts are important?
Pedagogy	What pedagogy do you use for design thinking in the course process?	Why do you use these pedagogy?
Curriculum	What is the course process?	Why you arrange the course process like this?
Course Target	Could you introduce the course?	Why do you want to reach these targets in this course?
Assignments	What are the assignments? (including the assignments in the course process and the final project)	Why do you choose these assignments?
Others	What else do you see in the course process?	

Interview Protocol for Teachers in Cluster 3

Guideline	Start Questions	Follow-up Questions
Curriculum	What is the course process?	Why you arrange the course process like this?
Course Target	Could you introduce the course?	Why do you want to reach these targets in this course?
Pedagogy	What pedagogy do you use to reach these targets in the course process?	Why do you use these pedagogy?
Assignments	What are the assignments? (including the assignments in the course process and the final project)	Why do you choose these assignments?
Understanding of Design Thinking	Have you heard of the concept "design thinking"?	Could you share about your understanding of design thinking?
Others	What else do you see in the course process?	

Appendice 4 Interview Protocol with Students

Mid-interview Protocol for Students in Clusters 1 and 3

Guideline	Start Questions	Possible Follow-up Questions
Students' perceived pedagogy	Can you briefly recall the course process?	How do you feel yourself has been trained in the current course process?
Application	Could you share the progress of your project? If you haven't started it yet and it's still in the idea stage, could you share the idea?	What is the purpose of your design? How do you consider human factors in the project? How do you solve the problem? Did you encounter any difficulties or problems in between? If so, how was the difficulty resolved? After the project finished, how do you see the design problem? How you innovate in the design process？ Share your breakthroughs in this design process. If you have a prototype, how do you iterate your prototype? Why you make prototype in the design process? How do you iterate your prototype?

Articulation	Could you share your understanding of design/ design thinking?	What do you learnt from this course that is important for designer to solve problems? Did you have this understanding before the subject? (Did the course give you any new understanding?)
Transformation	How do you see yourself shifting in this course? For example, in problem-solving approach, motivation, mindset and attitudes.	Why is this change occurring? At what point in the course do these shifts happen?
Others	Do you have any other learning experiences and feelings to share?	

Final Interview Protocol for Students in Clusters 1 and 3

Guideline	Start Questions	Possible Follow-up Questions
Students' perceived pedagogy	Can you briefly recall the course process?	How do you feel yourself has been trained in the course process?
Application	Could you share the progress of your project?	What is the purpose of your design? How do you consider human factors in the project? How do you solve the problem? Did you encounter any difficulties or problems in between? If so, how was the difficulty resolved? After the project finished, how do you see the design problem? How you innovate in the design process ? Share your breakthroughs in this design process. If you have a prototype, how do you iterate your prototype? Why you make prototype in the design process? How do you iterate your prototype?
Articulation	Could you share your understanding of	What do you learnt from this course that is important for designer to solve problems?

	design/ design thinking?	Did you have this understanding before the subject? (Did the course give you any new understanding?)
Transformation	How do you see yourself shifting after taking this course? For example, in problem-solving approach, motivation, mindset and attitudes.	Why is this change occurring? At what point in the course do these shifts happen?
Others	Do you have any other learning experiences and feelings to share?	