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EXPLORING FIRST YEAR INDUSTRIAL DESIGN STUDENTS' UNDERSTANDING OF SUB-TOPICS IN DESIGN THINKING

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ABSTRACT
This study reports on what tool and methods design major students use to discover, define and solve design problems. The site of this study is Design Thinking and Methods, a compulsory course for first-year Chinese design majors. The teaching goal of this course is to cultivate students' design thinking practice and innovation ability. Firstly, this paper reviews the definitions of design problems and design thinking through literature. Secondly, it outlines students' understanding of design thinking and design problem solving. Then these concepts are analysed to explore similarities and differences among 220 students. Finally, students design project are classified in relation to students' attention in different stages of design activities. The study found that most students can find design problems, but often they are unable to identify the nature of the design problems, which then leads to inappropriate design solution.

Keywords: Creativity, ill-structure problem, design thinking, design method

1 INTRODUCTION

1.1 Research background
Although, it is argued that creativity is an important element to achieve a successful design solution, Youmans [1] suggests that designers' mindset may prevent them from realizing their innovative potential. This is in line with Wu's [2] argument that the design major freshmen might be confused and have cognitive difficulties when facing complex design projects. As the phenomenon of students' cognitive difficulties is not unique, it does require teachers to continuously reflect on how students complete design activities in the learning process. According to Ye [3], most teachers in China ignore developing abilities such as curiosity and dealing with a confusion which are important elements of the design thinking mindset. This study aims to better understand what elements of design thinking design students use to find, define and solve design problems.

1.2 Research objectives and methods
In order to understand students' understanding of design knowledge and their ability to solve practical design projects, the empirical research explored first year design students use of design tools and methods during a design studio project in the course of Design Thinking and Methods taught by one of the authors. The course is set in the second semester of the freshman year. This is the first design course that combines theoretical teaching with task-driven design.
This study is informed by data collected over the three years from September 2021 to November 2023. The curriculum and teaching content stated the same over this three-year period. A total of 220 students were surveyed. During the course the students were allocated to 12 design student teams comprising of 5 to 6 members. Prior to this course, the students completed basic design courses, and thus were familiar with basic professional design skills.

2 UNDERSTANDING DESIGN THINKING

2.1 Design process model guided by design problem

Bravo and Bohemia [4] used the design process model as a teaching tool, defines the learning objectives and activities at each stage, contributes to the generation of design professional culture, and helps teachers and students to form common values and promote the solution of design problems. The Double-Diamond proposed by the UK Design Council [5] suggests these four design stages: i) Discover (diverge), ii) Define (converge), iii) Develop (diverge) and iv) Deliver (converge). Brown et al. [6] mentioned that divergent thinking and convergent thinking overlap in the three stages of Inspiration, Ideation and Implementation in the design process, which is reflected in the different design methods and tools used in the design process. These two design thinking models embody the integration and innovation of design thinking and design cognition. As mentioned by Wynn and Clarkson [7], the motivation for studying design process models is that they "represent" how design practice is conceived. Therefore, combined with the focus of the two thinking models, this paper puts forward a design mode dominated by design thinking, as shown in Figure 1, which takes design problems as the core in the course and carries out design practice with real project design. Focus on exploring students' concerns at different stages of design activities.

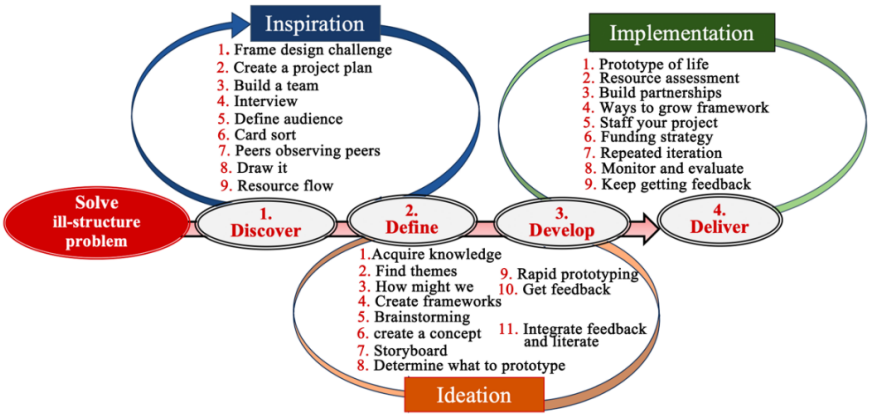

Figure 1. Design thinking model guided by design process

2.2 Students' understanding of design thinking

In the face of ill-structured problems, students need to use different design tools and methods, systematically evaluate and discuss proposed ideas, cross-experiment divergent thinking and convergent thinking, and repeat iterations to come up with creative ideas, so as to solve the design dilemma. To provide formative and summative feedback to students, it is essential that lectures understand how students understand design thinking and its application.

Over the three years, a total of 220 students responded to the question "What is design thinking?". However, 16 students' responses were excluded as they described information which was unrelated to the problem. Therefore, 204 valid text responses related to the problem were evaluation. The responses were pre-processed by LDA (Latent Dirichlet Allocation), a topic model of text semantic analysis, and sorted by frequency, as shown in Figure 2.

According to the collected data, the students mentioned a total of 18 terms. The data indicate that students associated solving problem, creativity, and defining problem and meeting the human needs with the Design Thinking. In the class, students were encouraged to exercise divergent thinking and convergent thinking through the use of different design tools, such as mind mapping, brainstorming, etc., so as to use methodology and innovative methods to promote creative thinking to solve complex problems. In this process, students demonstrated that they were able to establish empathy with users, conduct user-centred interviews with users, sketch users' journeys, understand users' needs, and pay attention to users' feelings. This would suggest that students should have developed some understanding of design thinking, but students paid a little attention to the final testing phase of the design process, as illustrated by Figure 1 （stage 4 Deliver). The stage is important to verify that the design is feasible and reasonable.

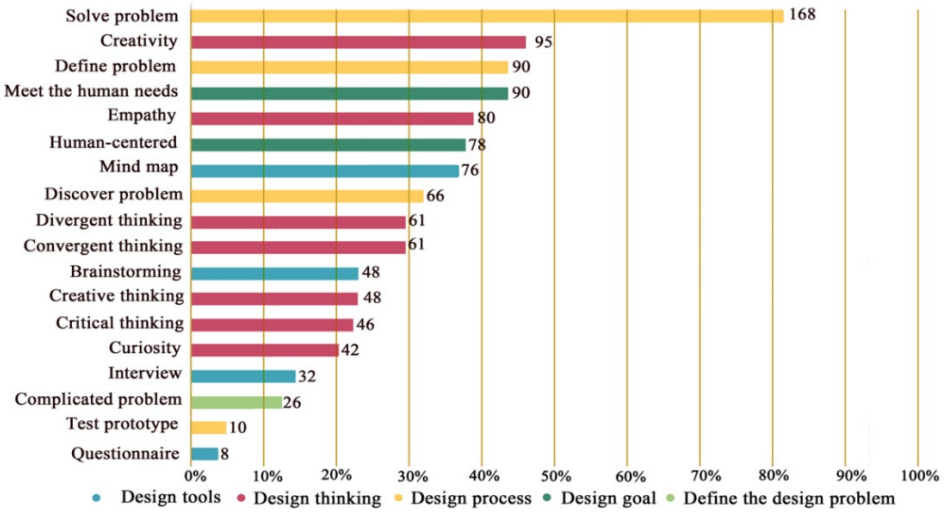

Figure 2. Keyword frequency distribution table

3 CURRICULUM DESIGN PRACTICE

Bohemia et al. [8] mentioned that learning assessment can provide a useful conceptual framework for more general teaching practice and students' learning experience. When students assume the dual design roles of client and designer, they can complete self-evaluation and improve their learning ability. Therefore, in the practical stage of the course, over the three years, 36 design teams were required to complete the final design project of the course on the theme of "Looking for Design Problems existing on Campus'.

During the practical phase of the design project, students assume the dual roles of clients and designers. The practical design component of the course lasted for 3-weeks and it incorporated these four dimensions of: problem finding, problem definition, problem solving and investigation methods. Figure 1 shows inspiration throughout the process of identifying and defining problems. Crilly [9] pointed out that designers often get stuck in design fixation in the process of finding and defining problems. In order to understand how students discover and define problems, it is necessary to clarify how students choose and use design tools, which is also the reason to investigate what tools helps students with deploying use divergent thinking, as shown in Figure 3.

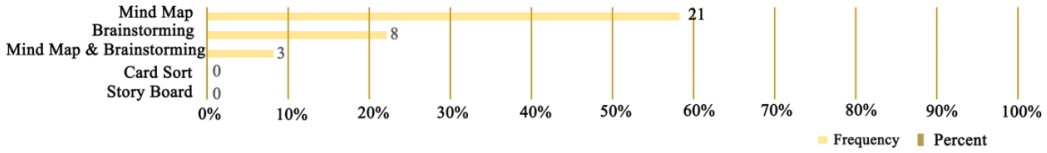

Figure 3. Design tools used by students

The data collected over the three years indicate that 21 design teams used mind mapping, 8 design teams used brainstorming, 3 design teams used both mind mapping and brainstorming tools, and the remaining 6 design teams did not use any of the specified design tools (e.g., card sorting, story boards, etc.). In addition, when investigating the willingness of students to participate in team cooperation in design practice, data from interviews with students showed that most students prefer to think from an individual perspective rather than explore the issues together with the team members, which is not conducive to promote the collaboration between design team members. As different students have different abilities and enthusiasm to participate in design practice, the division of labour in teams varies greatly. It was difficult for the students to delve into whether the design problems the team found needed to be addressed.

Data collected from the 36 design teams indicate that they have manage to identify design problems which could be allowed to 7 topics (see Figure 4), among which the most concerned problems for the students were the old campus public service facilities, unreasonable layout and hidden safety risks of campus roads, all these problems represent an imbalance in the interactive relationship between "people" and "products", indicating that students paid more attention to the perception of people in the space. Although these identified problems cannot represent the attitudes of all teams studying, living and

working on campus, students have not fully verified whether the problems of seven different themes are real and need to be solved, but nevertheless it demonstrates that students have the ability to find problems. During the course a few students tried to shift their focus from “products” to “people”. For example, some roads on campus cannot meet the needs of disabled people. Thus, they tried to create a sustainable social relationship on campus in a new way while meeting the needs of some teams on campus.

Figure 4. Design problem topics

Sarkar and Chakrabarti [10] mentioned that in the field of design, it is crucial to generate creative ideas and perspectives based on a common understanding. Therefore, the design process requires scientific research methods. Figure 5 summarizes the survey methods used by different design teams in the process of defining problems and proposing design schemes. Although the students belong to one of the target user groups, it was surprising that majority of the students, design teams (n=33) chose internal discussion, and only 2 design teams used questionnaire, and only 1 group used interview as to gather users’ data to inform their design solutions. This indicate that most students do not have a clear understanding of how to carry out user research, and it suggests that students have difficulties in choosing suitable research methods. The 3 design teams which either used interview or questionnaires to complete the field investigation, however, did not give comprehensive consideration to the determination of research objects, question setting, data collection and other contents, which indicates that students need systematic learning of the research methods.

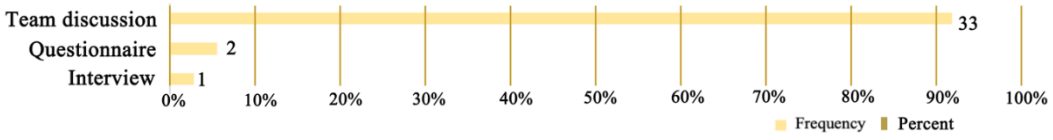

Figure 5. Research methods used by students

During the next design project stage, 16 design teams drew design sketches and proposed detailed solutions to the problems raised. However, due to the differences in communication and investigation methods of the design teams in the early stage, the completeness of the works presented by different design teams varied greatly. For example, 3 design teams focused on the needs of people with disabilities on campus and proposed optimization suggestions for related issues, but they did not conduct research on the target groups. Instead, they chose to discuss within the team and try to meet the needs of disabled groups through association. This approach contradicts the concept of " Meet the human needs " and "building empathy with users", which is the core of design thinking repeatedly mentioned by students (Figure 2). Poggenpohl and Sato [11] believed that reflective activities urge designers not only to improve the making of things, but also to improve the impact of things on the larger context (the audience, environment, materials or social culture), as it forces designers to think not just about how an object looks, but how it is experienced. As we move from design as merely a material activity to design as an experiential activity, it is crucial to focus on the design object itself. In this study, the 16 design teams submitted sketches which unfortunately have not indicated that students engaged sufficiently in reflective practice. Although students used different design tools and research methods to define the design problem, they still chose to change the shape, location, material, height or colour of the original item to optimize the product, or to create a new product in an attempt to alleviate the existing design problem, as shown in Figure 6. One of the design teams identified a problem of students using drawing tools which made their hands dirty, and thus the students were unable to open doors with clean hands. In consultation with the design team, they designed a doorknob that uses an arm to open the door with the help of the handle. However, the students did not consider whether the product design is reasonable

in the given environment setting, and whether they could have solved such problems in ways, such as continuous reflection: Why can't we use our hands to open the door? What kind of method can help us use our hands to open the door? Do all the students in the classroom have this problem? Whether students need a new tool to open the door, etc., students have not demonstrated a deep understanding of the target users' needs, and they were unable to reflect on the problems found in a deeper level, so that they were unable to realize the idea in more creative ways.

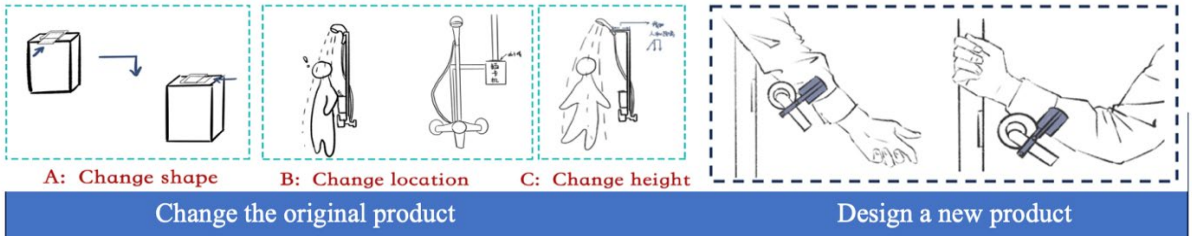

Figure 6. Door accessories

Designers have to start thinking about the usability of design by reconstructing the experience to get more alternative design approaches. Just like designing an environmentally friendly coffee cup, in the market, a large area of plastic and paper made of cup body and cup holder, when discussing how to optimize the product, designers often shift the focus of the design problem to the plastic itself has harmful, non-degradable defects, so as to choose other materials with environmental protection properties to replace the plastic, and rarely pay attention to whether the material itself has environmental significance. From another perspective, most plastic is made of petroleum, although it can't be degraded, but it can be compressed and recycled into other products that can be used in life (such as hangers, umbrellas, clothes, etc.), Paper is made of natural materials such as wood and bamboo. However, due to the composition of paper and other material used to make the cup waterproof, beverage paper cups cannot be recycled for reuse, The high cost of use will inevitably lead to large-scale waste of natural resources. In this way, "plastic cups" seem to be more environmentally friendly than "paper cups". Students often lack such critical reflection to explore these sort of design problems.

4 DISCUSSIONS

In summary, the performance of the 36 design teams in different stages of the design project is shown in Table 1.

Table 1. Performance of 36 design teams at different stages of design activities

Stages	Performance
Discover problem	Design tools were used in 33 of the 36 groups
Define problem	36 groups came up with 7 different design themes
Solve problem	16 out of 36 groups presented design sketches and schemes
Research methods	All 36 design teams used research methods, but students had cognitive difficulties in choosing the right research method

Saunders et al. [12] mentioned that selecting appropriate research methods is important for understanding and expanding knowledge in the research field, and research methods can reflect researchers' views on the relationship between knowledge development process and acquired knowledge. Although all the 36 design teams used different research methods to solve design problems (Table 1), from the information shown in Figures 4 and 5, it can be seen that students demonstrated a poor awareness of research methods. For example, only a limited number of design teams tried to use different research methods to understand the needs of users. However, even teams which attempted to engage with design research struggle to identify the target users and then to collect the information meant that the data results were not ideal, which indirectly led to the failure of the design process to identify the suitable solutions.

Secondly, when solving design problems, students needed to accurately locate the audience of design problems. While establishing empathy with target users, they also need to actively promote the stakeholders of design projects to participate in the research, so as to deeply understand the common needs of different stakeholders. Team members need to evaluate and plan different stages of the design, reflect on and criticize the internal logic of things through divergent and convergent thinking, and realize creative ideas through continuous experiments and verification. Yang [13] pointed out that Chinese

students are generally less creative in solving specific problems. This study also confirmed the similar phenomenon, which may be related to students' lack of comprehensive application of knowledge and deep reflection on complex problems. Only relying on their own design experience or discussions among teams cannot completely solve the problems in design, which requires students to have a forward-looking vision and social responsibility and change the focus of design from producer-centred to user-centred, and the production mode to service mode.

Finally, when considering the design scheme to solve the problem, it is still necessary to reflect on the nature of the design problem, explore the potential opportunities of the problem, and evaluate whether the preset solution can produce positive social, environmental and economic effects, so as to better improve the experience of target users and the positive feedback of the society through innovative and critical thinking.

5 CONCLUSIONS

This study focus was on the ability performance of industrial design majors in the freshman year and could not represent the design ability of students in all course stages. The research results indicate that although the novice design teams struggle to complete design project, all the students have the ability to find problems. The data also indicate that the students struggle to make a good use of design knowledge when defining and solving problems. The collected data is limited to verifying the design of product optimization. This study points out different forms of confusion in the design process of novice design teams formed by students. Therefore, this study also suggests that more scholars should further explore whether design thinking and methods courses can help cultivate students' creative thinking, and at the same time provide new course reform directions and reference suggestions for design educators.

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