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Study on the Learning Effectiveness of Stanford Design Thinking in Integrated Design Education

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Abstract: Due to industrial demand and the influence of government policies, the number of design colleges and students specializing in design in Taiwan has been increasing year by year. As a result, the topics on design education have gained great attention. To adapt to the rapidly-changing society, training that is designed to strengthen the professionalism and integration ability of those design majors should also be adjusted. Unlike traditional teaching methods, Stanford Design Thinking is a people-oriented problem-solving method. Proceeding from human needs, it offers creative solutions to various topics. Placing emphasis on integrated team communication and the cooperation and exchange among interdisciplinary talents, it is a new teaching model in response to the changes to the design environment. In this study, Stanford Design Thinking was introduced to the integrated design curriculum education as a creativity teaching strategy, and the action research method was adopted to explore the learning effectiveness of the design thinking method. According to the findings, the design thinking method can improve teaching; it can promote student participation through interview training in class during the Empathize stage; it offers substantial assistance to students in actual interviews; it reveals information about the demands of target groups, deepens students' discussions on design-related topics, and creates a favorable atmosphere for teaching; it fosters a positive interaction between students and teachers and makes students more attentive in class. Inspired by this teaching method, students can independently seek product-testing objects to review their design concepts and develop a stronger motivation for self-learning.

Keywords: Stanford Design Thinking; creativity; creative thinking teaching; action research

1. Introduction

"Design education must be changed" (Norman, 2010) [1]. According to Norman, designers often put forward shocking propositions when they face complicated problems or are ignorant of the evidence for a proposed statement. They have good ideas and can make excellent products, concepts, or models, but their propositions are far from satisfactory. This fully reveals the problems in design education in Taiwan [2]. Yang (2001) [3] advocated that design education aims lead designers to solve design problems with existing knowledge and experience and enables them to design more efficiently. Nevertheless, there are differences in students' knowledge, experience, and problem-solving ability in the teaching process. How teachers make good use of teaching tools and teaching situations to lead students to study and move towards the same destination from different starting points is a topic worthy of consideration.

1.1. Research Background and Motives

In 2003, the Ministry of Education released the White Paper of Creativity Education [4], showing the emphasis the government places on creativity education in Taiwan. According to the document, the resources for Taiwan to promote educational creativity are inadequate as a whole, and there are still many aspects that need to be improved, including school administration and curricular textbooks. As it shows, one of the problems in teaching in Taiwan is that much attention is paid to short-term, rather than long-term, effects and the evaluation of results is more important than the students' learning effectiveness, which makes it difficult to trigger students' learning motivation. Another problem is that teachers and school leaders are authoritative and there is no equal interaction between students and teachers, and there are no methods of triggering students' internal motivation. Worse still, the workload of teachers in Taiwan is so heavy that they fail to pursue creative teaching or action research. Consequently, they must adopt traditional textbooks, which results in insufficiently creative textbooks. All these problems demonstrate that the environment for design education remains to be improved. In short, if design education [5] wants to follow the changing environment and meet new design demands, the educational community must create a better environment for design education and adjust the teaching guidelines.

1.2. Research Purpose

Design education in Taiwan is now being transformed, and training students to face the global competitive environment is a major topic for Taiwan's educational circle. Traditional design education is dominated by one-way instruction, where most students learn in a passive way. They are slow to challenge and criticize the current situation and show weak active thinking; as a result, their vision on design is restricted. The purposes of this study were as follows: (1) to explore if the design thinking method can improve teaching when it is applied to design courses in Taiwan; and (2) to explore what needs to be adjusted when the design thinking method is applied to design courses in Taiwan.

1.3. Research Scope and Limitations

There are many groups in Taiwan, and schools popularize design thinking through workshops and curricula; there are also a number of cases where it is applied to enterprises. In the field of design, there are many studies on design thinking [6–10], but the number of studies on the application of design thinking to teaching or textbooks and the factors influencing student learning and learning effectiveness are rather small. Therefore, this study took the design thinking method as the teaching material to explore its teaching model and the key points for successful teaching, and the research focus was placed on teaching guidelines and the teacher-student relationship. Given that the research subjects should have received thinking training and the professionalism of design, and that the diverse backgrounds of students are consistent with the purpose of interdisciplinary cooperation in design thinking, postgraduates were taken as the research subjects. According to the degree of difficulty to which the tests were conducted and the data were obtained, the students of the integrated design program at the Graduate School of Design of National Yunlin University of Science and Technology were chosen as the subjects of this study.

2. Literature Review

2.1. Relationship between Thinking and Creativity

According to Hsiao (2011) [11], the spirit of design thinking does not reside in design, but in thinking. Design with thinking is the beginning of a disaster in creativity. Scholars of different fields, such as education and psychology, have expressed their opinions on the correlation between thinking and creativity. Ouyang (2007) emphasized that "Creativity is closely related to thinking" [12]. The difference between the one-way input of knowledge and directional thinking is that some are born to be smart. However, a smart person is not necessarily one who is good at thinking. To learn

how to think deeply, one needs an appropriate environment and adequate training. According to Chen (2006) [13], creativity means that a person combines five major characteristics (agility, smoothness, flexibility, originality, and improvement) under a supporting environment and develops different views on things through thinking and gives special and new meaning to things; in this way, he/she and others become satisfied. Yu (2009) [14] suggested that creativity originates from thinking and that it is tantamount to thinking. According to Yu, such an ability can be developed through training and everyone can possess it through learning; design thinking can be developed via much practice. Thinking generates creativity, and creative thinking aims to solve problems. In his book titled Art of Creative Thinking (Lu and Weng (trans), 1982) [15], Olson mentioned four stages of creation and problem-solving, or the process of "practicing" creativity: define problems, tolerate all possible solutions with an open mind, determine the best solution, and put the solution into use. Hence, we should pay attention to the importance of the inseparable relationship between thinking and creativity [16]. In terms of the application of design education, we should focus on strengthening the thinking of students specializing in design and equipping them with the knowledge of different fields, so as to deepen and broaden their thinking and enhance their creativity [17].

2.2. Design Thinking

Launched by Stanford Design School (D.school) [18] and the IDEO Design Consulting Company, design thinking is a set of emerging creativity theories for solving commercial and social problems. It advocates taking humans as the core of thinking and design. In the teaching, the method gets to know users and define user demands through stages, so as to trigger students' creativity and inspiration and motivate them to quickly present creative ideas with a prototype. Then, the ideas are improved through testing. Deign thinking can realize the objective of getting to know user demands in a procedural way, and new design ideas can catch the attention of the design community.

The creative problem solving (CPS) [19] teaching model was proposed by Parnes (1967), who emphasized using systematic thinking to solve problems and advocated that decision-makers should consider adoptable methods from different perspectives in problem solving. This strategy (Chen, 2006) consists of five steps—knowing facts, detecting problems, noticing concepts, finding solutions, and seeking acceptance.

The whole set of design thinking is comprised of five steps [20]: (1) empathize; (2) define; (3) ideate; (4) prototype; and (5) test. The thinking objectives in each stage of design thinking are similar to that of CPS. In the thinking model, constant divergence and convergence in the process are adopted until the end for practical use. The processes of the two methods are shown in Figure 1. This study assumed that the design thinking method [21] could be effectively applied to education and hoped that it could be demonstrated in the experiment.

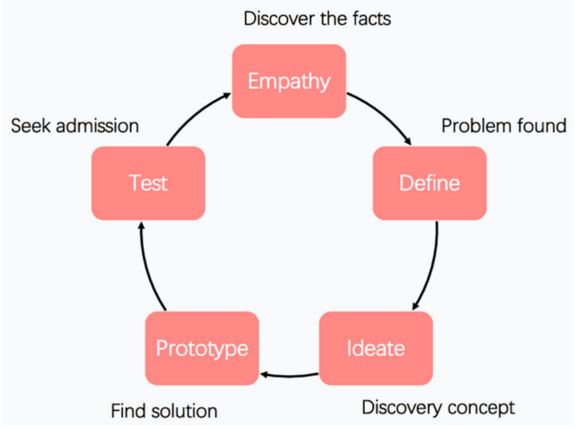

Figure 1. Relationship between creative problem solving and design thinking.

2.3. Traditional Teaching and Creative Thinking Teaching

Traditional teaching [22] is characterized by the spreading of the teachers' knowledge. In terms of the learning environment, focus is placed on class consistency; teachers play a dominant role in teaching, teaching approaches are standardized, and skill learning is taken as the main teaching objective (Tsai, 2001) [23]. The main purpose of creative thinking teaching is to trigger and enhance students' creativity. Teachers who aim to develop students' creativity can stimulate students' productivity (Parnes, 1967) [24]. The comparison between the two teaching methods is shown in Table 1.

Table 1. Comparison between traditional teaching and creative thinking teaching.

Item	Traditional Teaching	Creative Thinking Teaching
Teaching philosophy	Teachers are expected to lead students to become familiar with textbooks	Focus on the training of creativity
Teaching objective	Realize the objectives set in the textbooks	Equip students with the ability of creative thinking
Teaching mode	An unchanging model	Creative thinking
Teaching approach	Instruction plays a dominant role	Adopt creative thinking strategies; diverse and flexible
Role of teacher and student	One-way; dominance by teachers	Inspirer and helper; focus on teacher-student interaction
Teaching resources	Textbooks	Diverse
Teaching material and tool	Textbooks, blackboards and chopsticks	Diversified teaching materials
Teaching evaluation	Written exam-based evaluation and standard answers	Diversified evaluations and flexible answers

2.4. Action Research

Advocated by American scholars such as Kurt Lewin and Stephen M. Corey in the 1940s, action research is a research method which emphasizes the combination of practical "action" and "research" [25]. It is a highly appropriate method of exploring the application of the design thinking method in design education [26,27]. In the face of problems deriving from design education, teachers have the duty to improve the environment and quality of teaching. Through action research, teachers can review teaching situations, promote students' independence and motivation of learning, and improve teaching situations [28,29]. If action research is adopted to observe and record the interaction between teachers and students, the events in teaching will have the value of research analysis. Through constant reflection and teaching, the design thinking method is applied to actual teaching, the expected teaching effectiveness is set before the class, imbalanced teaching is observed and recorded in class, review and reflection is done after class, and countermeasures are proposed before the next class. In the end of the research, the thoughts on teaching and the research achievements are summarized, and the improved design thinking teaching model is released [30].

3. Research Method

3.1. Research Design

This study employed action research, in-depth interviews [31] and a Likert Attitudes Scale [32] to discuss teaching effectiveness and learning effectiveness. It consisted of three stages. Stage 1 was the preparation, where the research topics were defined, research materials were planned, relevant academic papers were collected, and relevant design thinking activities were organized. Stage 2 was the experimentation, where the effects of the design thinking method were observed and recorded and corresponding action strategies were adopted. Stage 3 was the research demonstration,

where the interviews with teachers and the student attitude scale were used for research analysis to demonstrate the results of the experiment and draw conclusions.

The design and implementation architecture of this study are shown in Figure 2.

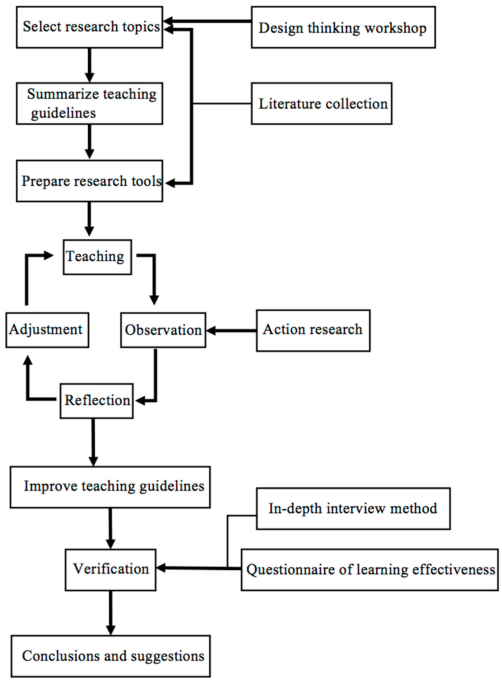

Figure 2. Research architecture.

3.2. Teaching Materials and Assessment

3.2.1. Teaching Materials

The teaching materials of this study were divided into three parts: teaching materials made public by the Design School of Stanford University (D.school) [33], materials from the Design Thinking Workshop [34] of the Different Thinking Club at National Taiwan University, and literature about design thinking [35], including Design Thinking Changes the World [36]. This is all about Design Thinking [37], and Stanford's Creative Courses of Changing Life [38]. Summarized according to the teaching group, the guidelines of the design thinking teaching of this study are shown in Table 2.

Table 2. Guidelines of design thinking teaching.

Stage	Contents of Teaching
Empathize	Participatory observe and deep interview users—getting to know user demands. Recording procedure—analyze interviews with sticky notes, observe the contents and find out user needs, gain insight.
Define	Create core sentences, such as "Somebody needs ____, because in her/his world, ____is important." Create roles—create groups similar to users to assist in the analysis of the lifestyle. Use core sentences again—define the deeper demands of the role and make them consistent with the requirements for the core sentences.
Ideate	Brainstorming—develop different creative ideas with core sentences to enhance creativity.
Prototype	Put creativity into action with a quick prototype and improve it to solve the users' problems.
Test	Users test the prototype and the model is improved according to the reality to make perfect products.

3.2.2. Teaching Curriculum Planning and Assessment

The planned time for the curriculum was 18 weeks. As two weeks were for statutory holidays and one week was for off-school visits, the total time for the class was 15 weeks. Each week there were three periods of class, and each period lasted for one hour. The teaching process was as follows: (1) check students' learning achievements of the previous week; (2) listen to comments and suggestions from teachers; (3) present the design thinking method-based instruction; and (4) monitor the students' class performance. The teaching evaluation was divided into two stages: a mid-term report and a final achievement exhibition. Three teachers evaluated the achievements and scored them as a group. As the design products had not been made by the middle of the term, the learning achievements were reported on at this stage in the form of an achievement report. At the end of the term, the finished products were evaluated.

3.3. Research Samples

3.3.1. Basic Data

The samples of this study were teachers and students, including three professors (coded as T, F, and J, respectively) from Taiwan Design Schools, one teacher (coded as W), and two teaching assistants (coded as H and L, respectively), as shown in Table 3.

Table 3. Research subjects: background information about the teachers.

Code	Name	Educational background	Specialty	Program
P_T	Professor T	PhD, Graduate School of Industrial Education, The University of Tennessee (U.S.)	Industrial design Green design Lifestyle and design Design education	Course instructor
P_F	Professor F	PhD, Graduate Institute of Electrical Engineering, National Sun Yat-sen University	Game design and research Cross-cultural research Film and animation analysis Media research Kansei engineering Machine learning	Course instructor
P_J	Professor J	PhD in Social Studies and Arts, University of Technology Sydney (Australia)	Design anesthetics research Design and art Education research Network art application and research	Course instructor
P_W	Professor W	PhD, Graduate Institute of Building and Planning, National Taiwan University	Design history Design culture research Design method	Interviewed teacher
A_H	Teaching Assistant H	Graduate Institute of Digital Content and Animation Design, Southern Taiwan University of Science and Technology	Animation design	Facilitate teaching
A_L	Teaching Assistant L	Graduate Institute of Design, National Yunlin University of Science and Technology	Green design Lifestyle and design	Prepare textbooks and the author of this paper

Due to the context-specific nature of action research [39], excessive research is unnecessary; the sample selection should simply be based on a specified target, for instance, a class of students. This study is based on students of integrated design education from the Design Institute of National Yunlin University of Science and Technology were taken as the research subjects. These students were from different universities and fields and met the requirement of design thinking to form an interdisciplinary teamwork model. Altogether, there were 14 students (coded as S1 to S14 respectively), as shown in Table 4.

Table 4. Research subjects: background information about the students.

Code	Group	Gender	Educational Background
S_01	Group 1	Male	Department of Creative Design, National Yunlin University of Science and Technology
S_02		Female	Department of Chinese Language and Literature, National Chi Nan University
S_03		Female	Department of Visual Communication Design, Asia University
S_04	Group 2	Female	Department of Cultural Heritage Conservation, National Yunlin University of Science and Technology
S_05		Male	Department of Electrical Engineering, National Formosa University of Science and Technology
S_06		Male	Department of Product Design, Tainan University of Technology
S_07		Female	Department of Visual Communication Design, National Yunlin University of Science and Technology
S_08	Group 3	Male	Department of Product Design, Tainan University of Technology
S_09		Female	Department of Business Administration, National Taipei University
S_10		Female	Department of Industrial Design, Datong University
S_11		Female	Department of Digital Media Design, National Yunlin University of Science and Technology
S_12	Group 4	Male	Department of Industrial Design, National Yunlin University of Science and Technology
S_13		Female	Department of Industrial Education, National Kaohsiung Normal University
S_14		Female	Department of Early Childhood Education, National University of Tainan

The courses were offered at the Design School of National Yunlin University of Science and Technology, and the class was given in the meeting and discussion area of the Design Creative Technology Research and Development Center. The space was open, and the students could freely brainstorm for creative ideas. Moreover, it helped the students present their design concepts.

3.3.2. Research Tools and Data Coding

This study implemented the action research method to explore the students' learning effectiveness. Therefore, it is necessary to record in detail the happenings during the course, such as the teaching situation, the formulation, implementation, events, and strategy adjustment of the teachers' teaching plans. Hence, relevant tools were developed for research use. Due to the diverse sources of data generated during the teaching, in order to effectively categorize the research data, the collected data were encoded in this study, and the codes are presented as follows. Action research was adopted to record and collect the Teacher Opinion Form (SN), the Teaching Record (TC), the Teaching Meeting Record (TM), the Teaching Reflection Log (IS), and the Student Interview Record (TVs). Focus was placed on data with research value which were generated in the interaction between the researchers and research subjects. Taking the Teacher Opinion Form SN171017_AH, for example, the form is a record of the suggestions from teachers on the briefs released by students. In the title, "SN" stands for the teachers' opinion, "171017" represents the record date (17 October 2017), and "_AH" refers to the person who filled in the form (Teaching Assistant H). The same logic was applied to other coding, as shown in Table 5.

Table 5. Coding of research data.

Item	Recorder	Record Date	Code	Coding
Teacher Opinion Form	P_T	Take 17 October 2017 for an example	SN	SN171017_PT
	P_F			SN171017_PF
	P_J			SN171017_PJ
	A_H			SN171017_AH
	A_L			SN171017_A L

Table 5. *Cont.*

Item	Recorder	Record Date	Code	Coding
Teaching Record	A_L	Take 3 October 2017 for an example	TC	TC171003
Teaching Meeting Record		Take 15 November 2017 for an example	TM	TM171105
Teaching Reflection Log		Take 10 January 2018 for an example	IS	IS180110
Student Interview Record	Several interviewees	Take 2 November 2017 for an example	TVs	TVs171102
	Code of interviewed student: S13	Take 10 January 2018 for an example	TVs	TVs180110_S13

4. Research Implementation Process and Results

The action research implementation steps illustrated the problems and solutions that were encountered during the implementation of the design thinking course. In-depth interviews were conducted on four teachers who were implementing the design thinking courses to explore the impact and results of the design thinking teaching method on the teaching effectiveness. By analyzing the results of the Likert attitude scale, the students' attitudes towards the design thinking teaching method were summarized, and the students' learning effectiveness from the traditional teaching method and the adjusted design thinking method were compared and analyzed.

4.1. Planning of Design Thinking Course and Results of Course Plan Implementation

The difficulties in the implementation of the course plan and the countermeasures were illustrated from three aspects: events, reflection and strategy, and results. The implementation was divided into three stages according to the sequence of the teaching problems: (1) the user demand exploration stage (Empathize); (2) the demand definition stage (Define); and (3) the creativity formation stage (Ideate, Prototype, and Test).

4.1.1. User Exploration Stage (Empathize)

(1) The survey on the lifestyle of elderly was taken for an example (the teaching records included TC_171003, TC_171017)

" ... the design theme for this semester, where the clarification for the interview and the observation tools for the seniors and pre-seniors behavior surveys were given, teaching assistant H explained during the lecture that took place on 3 October." The course was conducted through a slide presentation in combination with printed behavioral observations and interview records, which were handed out to the students during the course. The learning was, of course, directed in accordance with the phase-wise design thinking implementation process.

(2) Discovery, Reflection, and Strategy Formulation

The observations and interviews have revealed some problems throughout the course of the experiment. For instance, in relation to the observation of the in-class student presentation session on 17 October, teaching assistant H reported, "The students' observation targets were not specific enough. The supporting photos and videos were not solid enough to show the depth of the observation. The specificity of several information, such as the observation time and frequency, were also inadequate." (Teacher Opinion Form No. SN171017_AH)

In order to gain a deeper understanding of the students' problems during the interview and observation stages, randomly-selected student participants were interviewed during and after the class. According to student S_07, as recorded by teaching assistant L, students and teachers held different opinions on the purpose of the interviews. Based on this feedback, the writer of this paper

then reflected on the problems derived from the teaching, and divided them into two parts. The first part was the specificity of the interviewee selection; and the second part was whether the students are clear about the purpose of the observations and the interviews.

According to the interviews with Teaching Assistant L (S_07) and one student (S_12), the students had a preference for passive learning, and they were reluctant to raise questions or express opinions; worse still, they would seldom point out problems after these problems were detected, and they even failed to detect problems. How to help students raise questions in class, understand the purposes of interviews and grasp valuable interview opportunities is an issue worthy of consideration.

Based on the problems found above, the teaching team believed that the students who behaved passively during the class would need to be asked to complete at least an in-class exercise, otherwise it would be difficult for them to raise problems proactively. Additionally, students who lack the experience attending an interview observation might find it challenging to raise questions. Thus, the team decided to let the students conduct the exercises instead—a decision that conforms reasonably well with the pretext of giving the teachers more space to grasp the students' performances. Therefore, the teaching team decided to change the original idea of having the presentation-based discussion into practical exercises.

The goals of the adjustment made on the Empathize stage teaching strategy are as follows: ensure during the course that students can understand thoroughly the purpose of the interview, that they are guided to raise questions proactively, and that the selection of the interviewees can be standardized. By first referring to the interview exercise of the Design Thinking Workshop, the students would be asked to conduct a discussion beforehand on the topic-related contents of the interview, then interview the respondents in the upcoming activities, and assign a teammate as an interviewee to another group. Next, students would be instructed to practice interviewing each other, and to share their experiences at the end of the exercise.

(3) Results

After the grouping, the students were asked to share the experience of the exercises. The students who became the respondents could clearly indicate the noteworthy skills demonstrated by the good interviewers and the assistants, and conclude on the exemplary ways to ask questions, wait for the respondents to answer, enrich the interview topics, and ease the tension, etc. Students who were interviewing and assisting could then practice the cooperative interview skills, complement each other's deficiencies, experience first-hand the difficulty of controlling the atmosphere of interviews, and understand the importance of preparation. The students who were responsible for recording the interview were then able to understand the importance of presenting authentic information in the following the Recording stage. The records kept by this member of the team would affect the subsequent design direction of the entire team. The results of the adjustment of teaching strategies in this stage are shown in Figure 3.

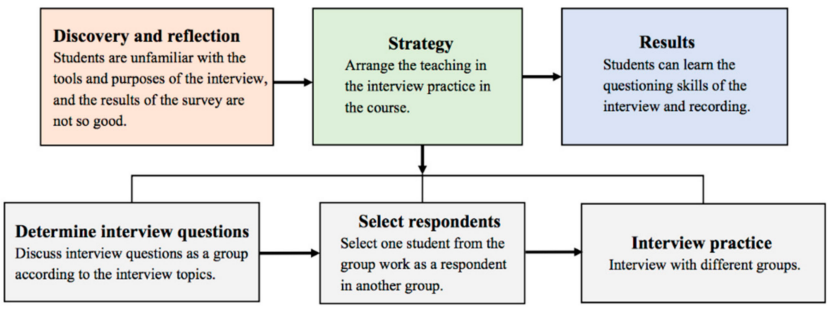

Figure 3. Teaching action in the User Exploration stage.

4.1.2. Demand Definition Stage (Define)

(1) The action demands of elderly were defined in this stage.

The students started by organizing and analyzing the results of the survey on the behavior of the seniors in the previous stage, and the results were compiled through presentations which went according to the order of the group. The content of the presentation was the result of the interview and observation summarized into the Recording program, which was presented by organizing a series of sticky notes on a poster. Teaching assistant H would explain the goals and steps of the Define stage, and then the exercise would proceed in groups. Professor J and assistant H would be responsible for the first week of teaching. In order to facilitate the recognition of the Recording from the previous stage, as well as the current Need and Insight, they were each assigned sticky notes of differing colors, all of which were provided by the teaching team: yellow for Recording, green for Need, and pink for Insight.

(2) Discovery, Reflection, and Strategy Formulation

It was discovered in this stage that if the interviews and observations in the Empathize stage were incorrectly done, the user Needs and Insights in this stage would be insignificant (student interview TVs171102). According to the results of the survey, student reluctance to raise questions could be a variable that influences the quality of teaching. Other problems included the mixture of Needs and Insights in the later stage of teaching and the confusion caused by performing the wrong Recording operation. However, this also indicated that the students failed to fully understand the meaning of Needs and Insights and could not make judgments by themselves. In this stage, teaching assistants would need to offer guidance near the students to strengthen the students' confidence and help them with the correct operation.

From the above research findings, the problems encountered in the teaching can be divided into four parts: the first two occurred during the early stages, wherein students were not good at asking questions, and the number of staff might become a variable that affected the quality of teaching; and the other two, which occurred at the later stages, were the confusion between Need and Insight, as well as the confusions that were caused by flaws in Recording operations. The teaching team believed that the adjustment of teaching was necessary, and that the teaching strategy was bound to be modified. It was concluded at the end of the teaching meeting that the adjusted teaching strategy could be divided into two parts, one was to adjust the teaching schedule, and the other was to increase the number of teaching teams. According to the design thinking textbooks released by D.school and relevant teaching literature, design thinking was adopted in the planned class for nine weeks. After the Define stage, Professor T believed that if the recording time of the original plan was maintained, the students would fail to absorb knowledge and would lack a deeper understanding. Therefore, the teaching schedule was revised, and a special plan involving a 15-week adoption of design thinking was made, excluding statutory holidays for two weeks and an off-school visit for one week. Moreover, the students were required to review the development of the previous week in the form of a brief.

(3) Results

Under the teachers' guidance, and with the reference of the operational results from the observing students, the points in need of improvement were pointed out, and the students reverted to the right direction. The adjusted schedule was changed to two weeks per stage. The time between the start of the class each week will be extended, to deliberately cause students to forget where they left off. To keep the students on track of the results of the investigation and induction, the students would be asked to review the progress with weekly presentations. The results of the adjustment of the teaching strategies in this stage are shown in Figure 4.

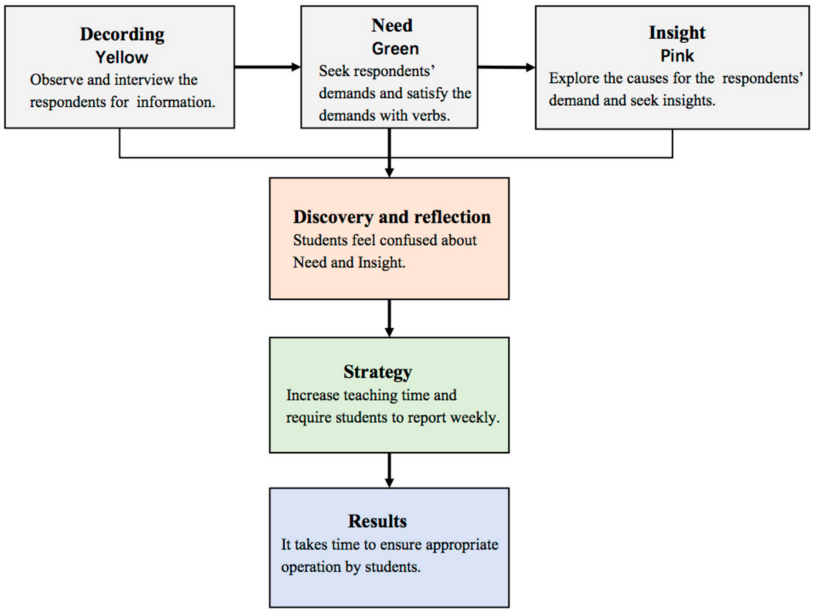

Figure 4. Teaching action in the Define stage.

4.1.3. Creativity Formation Stage (Ideate, Prototype, and Test)

(1) The needs of elderly, solutions and creativity plans were completed during this stage.

In this stage, the brainstorming of creative ideas was adopted to enable the students to meet the demands of the elderly as defined in the previous stage. The arrangement of the teaching activities would require students to present the design concept from the previous Ideate stage in sketches and draft models, discuss the design concepts with the support of the draft models with the teachers, test and modify them and, eventually in the final stage, make refined prototypes based on the draft models. The schedule for the draft model testing stage are as follows: in the first week, the design concepts were to be presented in the forms of ten draft models, from which three semi-refined models would be carefully selected after being screened out by the teachers. The final design plan will be selected a week after, after which the final refined model will be made.

(2) Discovery, Reflection, and Strategy Formulation

During the course, the students would be interviewed by the researcher. With respect to the idea from this stage, student S_01 expressed that in the previous design process, he drew sketches and built 3D models, which made it easier for him to visualize the structure and the product itself in comparison to the 2D models. He was very accustomed to building 3D models to convey his concepts, and this was his first time conducting a draft model test as a part of the design procedure. However, for groups short of members with modeling and professional competence, they have demonstrated some difficulties during the draft model test when it came down to expressing and communicating in the appropriate terms of the 2D and 3D models. Even if they could imagine parts of the product, it was still difficult for them to present their ideas and to convert their design into a real product. To this end, the teaching team believed that more attention and guidance should be given to these student group. In order to increase the student's sensitivity and productivity in design modeling, the teaching team has decided to increase the number of external test participants for the Test stage. Each week, students would be arranged to meet the participants, communicate with them as product users, and record the opinion from them to set the direction of the next adjustment. Through the implementation of the teaching strategy adjustment, in which the students were allowed to directly

communicate with the users, the students can be exposed to more kinds of voices, opinions, and angles to help students view their design works from broader perspectives.

(3) Results

After the model testing and discussion, students were expected to be able to grasp the design direction and correct their own design workflow. However, for those groups lacking the professional competence and training, they might still struggle when it came down to fully understanding the design key points during the stage of model production and creativity formation, and would, hence, be unable to keep up with the progress of the other students. The results of the adjustment of teaching strategies in this stage are shown in Figure 5.

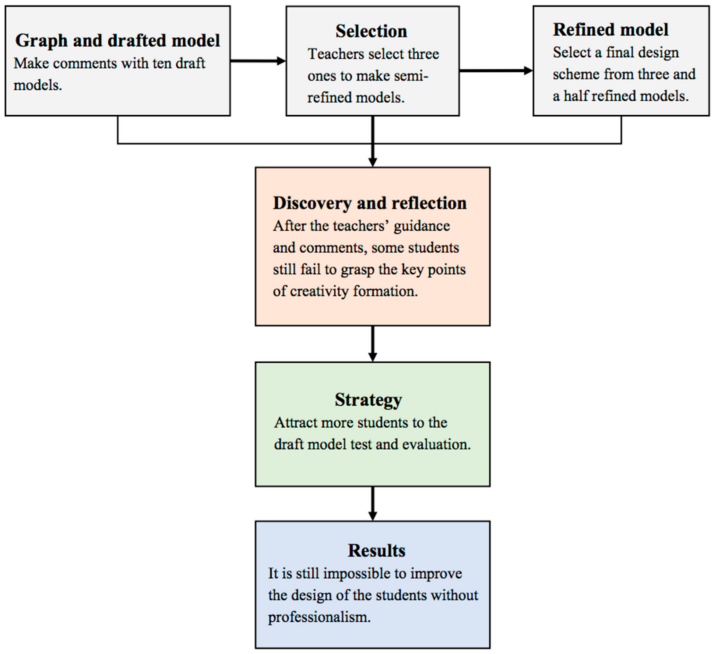

Figure 5. Teaching action of creativity formation.

4.2. Teaching Effectiveness of the Design Thinking Teaching Method

Using the in-depth interview method as a data collection tool, coupled with the interviewer's perception and insight of the improved design thinking teaching method, the teaching effectiveness of applying the Design Thinking concept in design education could be evaluated.

4.2.1. The Cultivation of the Ability to Collect Information

This section explored the results of the adjusted Empathize stage teaching from a teacher's point of view in order to understand the teachers' views on this stage. The interview content was based on the outline which was summed up from the issues generated throughout the course's implementation. In the Empathize stage, observations and interviews were used to conduct a series of user demand surveys. The application and adjustment of the teaching strategies were accepted by both the teachers and the students. The researchers found that the main sources from which the students based their thinking and obtain their reference materials prior to the interview and observation stages, were the Internet and books. However, the use of these materials as the basis for design has produced similar design concept proposals, and has created a gap between the designs' objectives and the users' needs.

Professor W believed, "observation and interviews are very important for students to process information and communicate with users, and how to train students to capture the information should be the focus of the adjusted Empathize stage. In the traditional teaching method, the abilities to

approach users and obtain information are less demanded and trained in the class, and this is where the deficiency of traditional teaching methods lie". Professor W also claimed, "If the ability of collecting and analyzing design data is too weak, the design skills will not be improved. Therefore, the question of how to further find from the information the entry point for the design is the crucial part, I usually hope that they can be given more opportunities to interview the real users". The greatest difference between the design thinking method and the traditional ones is that the former pays more attention to the users and, hence, tend to develop a deeper understanding on the user than the latter.

By compiling the interview results, and summarizing the teachers' views on the teaching effectiveness of the users' demands exploration stage, the teachers believed that the adjusted design thinking teaching method could help students learn how to handle the information, how to gather the data, and how to express the close relationship between the design concept and the amount of collected information, and acknowledge the importance of this teaching stage and its impact on the subsequent design outcome.

4.2.2. Importance of the Demand Definition Stage

The teaching effect of the adjusted Define stage will be discussed. During the implementation of the design thinking teaching method, the number of problems generated by teachers and students in the stage of defining the user's demands were much higher than those generated during the other stages. Therefore, it was hoped that the teachers' views on this stage can be understood through interviews and the teaching effectiveness from the adjusted Define stage explored. After summarizing the interview, it was found that many teachers believed that, "this stage is the core as well as the most important stage of the design thinking teaching method". Professor T emphasized, "If a student is unable to propose an insightful, substantive problem, and point out a solution, the design outcome will not be impressive. Even if the student has found a good creative point during the brainstorming, or has attained a satisfactory model testing evaluation, the score will still not be outstanding". This showed that Professor T has attached great importance to the Define stage. He also mentioned, "The required crucial skill during the exploration of the design issues is to be able to point out the problems from the provided information and materials, and be able to define the problem, as well as to capture its insights". Professor F believed that the teaching hours arranged in this stage was not enough for students to define the requirements, and he also emphasized the importance of Define, because it is crucial that the design direction be decided at this stage. He also suggested that students should conduct the same survey and study on both users and customers, taking into account consumer psychology, habits, as well as other related research, in order to help think through the Define stage. He claimed that the students' lack of research on the design direction in this stage was the real deficiency at this stage.

Based on the results of the interviews, it was found that all the teachers had agreed with the importance of this stage. In addition to the ability to collect information in the previous stage, it is also important to train students to self-derive their own design workflows for the current stage. Therefore, it is also very essential to start focusing on the training of this very skill from this stage, as well as learning how to confirm the requirements of the demand definition stage from the interviews.

4.2.3. The Abilities for the Creativity Formation Stage

The teaching results include three stages: Ideate, Prototype, and Test. The design idea of the Ideate stage was presented in the form of the draft model from the Prototype stage, and the model was tested in the Test stage. The attributes of the three stages are relatively close so, during the interview, it was often collectively referred to as the creativity formation stage. The following is an interview record with the teachers to explore the teaching effectiveness for this stage. Professor J believed, "The main reason for the imperfection of the finished products in the creativity formation stage was the students did not have enough time. Even the time for the reviewers to provide their comments for the review was not enough". On the contrary, according to Professor T, The Prototype stage

should be arranged at least three times." He thought that the review of the creativity discussions in the previous stage was not practical and must be reviewed during the draft model stage in order to produce a more solid design outcome. Professor F mentioned, "There is a significant relationship between the students' basic knowledge and the operation of creativity formation". He pointed out the shortcomings of design thinking in the creativity formation stage, which was that if students had insufficient professional competence, it was impossible to judge whether the creative design idea could be implemented. Professor F proposed an improvement approach for this, he said, "Before proceeding with the design, students should do relevant information research. As for the materials research, the students themselves should be very clear about what should be done, as well as what the nature was supposed to be. This should give some improvements to the design thinking teaching method in the creativity formation stage".

According to the interviews, teachers at this stage think that it was necessary to increase the time for discussions to review the design concepts with the draft models. They also believed that the professional competence of the students would affect the creative outcome at this stage, meaning that students who lack the required design training will have the difficulty in evaluating the development and the feasibility of the design idea at this stage.

4.2.4. Teaching Effectiveness of the Adjusted Design Thinking Teaching

By first studying the teachers' opinions, the exploration on the teaching effectiveness of the adjusted design thinking method, as well as the summary of the teaching effects from the three stages and the discussion the overall teaching effectiveness, were presented in this section.

Concerning the design thinking teaching method, Professor T believed, "It can provide a stage-wise guidance for the students into the design scenarios, avoid any unlawful behaviors in the design industry, and reduce the cognitive gap between the teachers and students". He also said, "this teaching method can help ease the start of the learning phase for non-design major students. It is also due to this jump in educational background that design education must be adjusted". Professor J said, "Design thinking is suitable for education. He emphasized that design education is not equal to a design outcome. Due to the difference in purposes, design education focuses on teaching, guiding, imparting, and investigating the ways of finding creative ideas to cultivate designers, which is different from the purpose of the practical design of mainly focusing on the design output. He believed that the teacher must develop a clear and step-by-step teaching method to guide students to learn". For students with a design background, if the design thinking method can achieve the same results in teaching effectiveness after the adjustment, Professor F believed, "This teaching method can guide design major students to learn more of the in-depth design discussions, but unfortunately for some students, it could still be observed that the lack of willingness was in fact the main issue".

To summarize, the teaching effectiveness of adjusted design thinking method lies in the stage-wise instructions and guidance allowing students to gradually be immersed into the design scenarios, lowering the design operation threshold for non-design major students, and reducing the cognitive differences between teachers and students in terms of design concepts. The interviews showed the importance attached by teachers onto the demand definition stage. The advantage of the adjusted design thinking method is that students from all fields of study can now enter the design scenarios step by step throughout the previous important stages, without the limitation of professional backgrounds and learning difficulties. Although the gap caused by professional competence will still appear in the creativity formation stage, this teaching method can still achieve the teaching purpose of people-oriented design innovation and guidance, so that students can learn about how to focus on people during the design process, and think about how to meet the users' needs through design.

4.3. Students' Learning Effectiveness of the Design Thinking Method

At the conclusion of the entire course, a questionnaire survey was conducted on the 14 participating students, aiming to reveal their opinions towards and the learning effects of the

adjusted design thinking method. The questionnaires were filled in anonymously and the Likert Attitudes Scale was used to understand each of the students' learning response. According to the order in which the teaching problems occur, there were three stages worthy of noting: the user demand exploration stage (Empathize), the demand definition stage (Define), and the creativity formation stage (Ideate, Prototype and Test).

4.3.1. Students' Learning Effectiveness in the User Exploration Stage (Empathize)

This stage of teaching guided students to use observation and interviewing tools to interview respondents. Students were expected to learn from this stage of teaching activities on how to obtain a theme that strongly carries a unique design development value based on the respondents' words and actions. The students' learning effectiveness can be measured by making reference to the following questionnaires:

From the statistical analysis of the questionnaire (Table 6), it can be observed that the students in the user exploration stage generally agreed that the learning assistance at this stage was able to help them understand the users and acquire inspiration for their future designs. The teaching guidelines adjusted at this stage allowed students to practice interviewing in the class, which most students believed to have given them a substantial boost to their actual interviews. This is the significant effect of this study on the adjustment of teaching strategies. However, at this stage, more than half of the students believed that the assistance of the teachers and teaching assistants was highly required to carry out the study smoothly, and that they had faced doubts during the implementation of this stage, which indicated the level of importance of the teachers' participations. Hence, at this stage, the teachers should pay special attention to the students' learning situations.

Table 6. Statistical analysis of students' learning effectiveness in the User Exploration stage.

Factors Influencing Students' Learning Effectiveness	Percentage	Ranking
The interview practice in the Empathize stage is helpful for my on-site interview at a later stage.	93%	1
I will make preparations before observations and interviews.	93%	1
In the Empathize stage, I can understand the respondents' linguistic and behavioral demands.	86%	3
I believe that the Empathize stage helps me develop design concepts.	86%	3
The download in the Empathize stage can help me locate the key problems confronting users.	71%	5
In the Empathize stage, I will feel uncertain about the appropriateness of implementation.	64%	6
In the Empathize stage, I need help from teachers and teaching assistants.	57%	7

4.3.2. Students' Learning Effectiveness in the Define Stage

The purpose of this stage was to guide students to define the collected information, to increase the understanding of the respondents, and to derive a design guideline from the demands of the respondents. However, this stage was also the stage in which students raised the most questions. The questionnaire of the learning effectiveness in this stage was then analyzed.

In this stage of the teaching method, the sticky notes were used when they discussed and defined the users' needs and insights. During the course, the students had been asked whether they could adapt to the teaching methods at this stage. S_07 said, "Just from yellow (the color of the Need sticky note), I think this course is rather fun . . . " This shows that students gave positive feedback to this teaching method. From the results of the questionnaire (Table 7), most students believe that the Define stage has helped them find the design concept and understand the target group. However, most of the students' problems during this stage could also be seen from the results of the questionnaire, since half

of the students admitted that they could not distinguish between Need and Insight, and that there were uncertain doubts during the exercise. After the analysis, it was found that the results of the questionnaire were consistent with the results of study process observation. The only part that had perhaps exceeded the expectations of the action research was whether the teachers or the assistants were needed. Although half of the students thought it was necessary, there were students who chose to abstain and voiced their disagreement. It also showed that there were only a small number of students who had proactively asked questions during the Define stage, however, after the teachers and assistants got involved, some students found that they had taken the wrong path and were forced to repeat their process.

Table 7. Statistical analysis of students' learning effectiveness in the Define stage.

Factors Influencing Students' Learning Effectiveness	Percentage	Ranking
I think the Define stage helps me develop design concepts.	79%	1
The Define stage helps me analyze the respondents' linguistic and behavioral demands.	79%	1
In the Define stage, role creation deepens my understanding of the target groups.	71%	3
In the Define stage, the core needs and insights I summarize match my interviewees.	71%	3
In the Define stage, I am uncertain about the implementation.	64%	5
In the Define stage, I don't know the difference between "needs" and "insights".	57%	6
In the Define stage, I need assistance from teachers and teaching assistants.	50%	7

4.3.3. Students' Learning Effectiveness in the Creativity Formation Stage (Ideate)

This stage was divided into three parts: creativity development, draft model test, and refined model making. Compared with the previous stages, the tasks in this stage could be independently finished by students. The following are the results of the questionnaires at each stage.

In the Ideate creativity development stage, the goal of the teaching is so that students can learn to boldly come up with creative ideas and develop concepts on the premise of respecting the ideas of other members. According to the analysis (Table 8), most students could try different ways of enhancing the atmosphere of the team discussion, increasing the efficiency of brainstorming, and guiding the team out of the deadlock in the discussion. At this stage, the design thinking method was supposed to create an atmosphere of open discussion and encourage the development of any creative ideas without worrying about making mistakes. However, the questionnaire showed that most students thought that they needed the teachers' assistance, and that they were uncertain in the execution of the plan, which showed that the adjusted design thinking teaching method was not successful in creating a teaching environment that makes students boldly express their ideas. This was the stage of the method that required reviewing.

Table 8. Statistical analysis of students' learning effectiveness in the Creativity Formation stage (Ideate).

Factors Influencing Students' Learning Effectiveness	Percentage	Ranking
In the Ideate stage, I will use different methods to help the team get rid of distress.	79%	1
In the Ideate stage, I can help foster a favorable atmosphere for concept development.	71%	2
In the Ideate stage, I need assistance from teachers and teaching assistants.	71%	2
In the Ideate stage, I will feel uncertain about the implementation.	71%	2
I believe that the Ideate stage helps me develop design concepts.	64%	5
In the Ideate stage, my ideas meet the requirements for the core sentences.	57%	6
In the Ideate stage, I can find out the design guidelines that will solve users' problems.	50%	7

In the Prototype draft model testing stage (Table 9), students generally agreed that the help given at this stage, i.e., making the draft model, had made them understand the users' demands and smoothen the brainstorming process. During the prototype production, students generally believed that using the draft models to convey the design concept and improve the design could help them smoothly finalize the product.

Table 9. Statistical analysis of students' learning effectiveness in the Creativity Formation stage (Prototype).

Factors Influencing Students' Learning Effectiveness	Percentage	Ranking
In the Prototype stage, prototypes can help me and others convey my design concepts.	93%	1
The Prototype stage is helpful for me to turn design concepts into reality.	86%	2
In the Prototype stage, prototypes can help me improve my designs.	79%	3
I think the Prototype stage can deepen my understanding of user demands.	71%	4
I believe that the Prototype stage helps me develop design concepts.	71%	4
In the Prototype stage, I need assistance from teachers and teaching assistants.	50%	6
In the Prototype stage, I will feel uncertain about the implementation.	43%	7

During the product testing stage (Table 10), students agreed that this stage had helped them to understand the users and the concept development, as well as to make the concept more complete. Students also displayed more confidence in the model testing activities, which indicated that the students could understand the teaching objectives of this stage. In addition, the noteworthy part of the students' learning outcomes was that they had met this stage's expectations, and independently looked for test subjects to examine the design concept, thereby achieving the purpose of having the students pay more attention to the user's demands [40].

Table 10. Statistical analysis of students' learning effectiveness in the Creativity Formation stage (Test).

Factors Influencing Students' Learning Effectiveness	Percentage	Ranking
I believe that the Test stage deepens my understanding of the users.	93%	1
I think the Test stage can make my design concepts more complete.	86%	2
In the Test stage, I will find test objects to review my design concepts.	79%	3
I think the Test stage helps me develop design concepts.	64%	4
In the Test stage, I need assistance from teachers and teaching assistants.	36%	5
In the Test stage, I will feel uncertain about the implementation.	29%	6

4.3.4. The Students' Learning Effectiveness of Adjusted Design Thinking Method

According to the research and analysis, students had demonstrated a positive attitude towards the learning effectiveness of the adjusted design thinking. They believed that design thinking can help users explore, assist in concept development, enter the design creation context, and enhance their design expressions. It can be confirmed that the teaching method used in this study has improved the students' learning productivity, enhanced their sensitivity towards problems, encouraged them to propose creative ideas, helped them gain a variety of insights under the teaching guidance, and come up with unique ideas from their peers. In terms of the learning input, almost all of the students said that they spent more time and effort thinking and studying than they did with the other previous teaching methods, which showed that the method has had a significant impact on student learning effectiveness. In the part of creative thinking, students also claimed that they have also benefited in terms of creative thinking and learning.

4.4. Analysis of the Comparison of Students' Learning Effectiveness between Traditional Teaching Methods and the Design Thinking Method

From the analysis of the questionnaire (Table 11), the adjusted design thinking method can enhance students' participation in the class, create a class atmosphere that attracts to students,

improve the students' willingness to learn, and increase the level of interaction between students and teachers. Additionally, students have also said that they spent more time and effort on thinking and studying than they did with other previous teaching methods, which showed that the method has had a significant impact on the students' learning effectiveness. In the part of creative thinking, students claimed that they have also benefited in terms of creative thinking and learning. Comparing the two teaching methods, students believed that the design thinking method required too much time, especially in the early information gathering and defining. A student mentioned that, with the traditional design method, an individual could complete the homework by himself in a short period of time, but with the design thinking method, he needed to ask everyone to participate and discuss which took him considerably longer to complete. This response also reflected the inadequacies of the adjusted design thinking in this curriculum. It is, therefore, recommended that, in the future, the time spent for designing and thinking should be shortened, so that the course duration for students to carry out the design idea would not have taken so long.

Table 11. Statistical analysis of students' learning effectiveness of teaching methods (traditional and design thinking).

Factors Influencing Students' Learning Effectiveness	Percentage	Ranking
I think the design thinking method is more effective than traditional teaching in promoting my class participation.	93%	1
The design thinking method is more effective than traditional teaching in strengthening my ability to detect problems.	93%	1
I prefer the class atmosphere created by design thinking to that created by traditional teaching.	93%	1
Compared with traditional teaching, a design thinking class brings me more opportunities to interact with classmates and teachers.	86%	4
Compared with traditional teaching, the design thinking method enables me to have efficient communication with people in different fields.	86%	4
Compared with traditional teaching, the design thinking method is more helpful for me to brainstorm creative ideas.	86%	4
Compared with traditional teaching, the design thinking method cost me more time on thinking.	79%	7
Compared with traditional teaching, the design thinking method cost me more time on assignments.	79%	7
Compared with traditional teaching, the design thinking method can strengthen my ability to solve problems.	71%	9
Compared with traditional teaching, the design thinking method can increase my concentration in class.	64%	10

In summary, the students spoke highly of the design thinking method's effectiveness on guiding them to discover problems, improving the ability of solving problems, and enhancing the communication skills with cross-disciplinary talents. They have also expressed that, in the future, they are willing to use design thinking as a strategy for design execution, which conforms with the expectations of this study.

5. Conclusions and Suggestions

5.1. Conclusions

After a semester of teaching participation, this study has evolved from research topic development, teaching schedule planning, course introductions, teaching guidelines revision, and finally to the course's conclusion. Having gone through many rounds of planning and adjustments, it was found that,

compared with the traditional teaching method, students have become more willing to spend more time on thinking and studying in accordance with the adjusted design thinking teaching method, which can reduce the occurrence of students falling asleep in the class. This study found that the design thinking method can enhance students' class participation, create a favorable class atmosphere, and foster effective interaction and efficient communication between students and teachers. Students are willing to spend more time on thinking and after-class assignments, which has significant effects on students' learning effectiveness. The interview practice in the course can help students interview and brainstorm design ideas more efficiently in actual interviews, and students can gain a deeper understanding of the target groups of design. During brainstorming, this teaching method can lead students to try different approaches, create an atmosphere for open discussions, encourage students to propose creative ideas, foster a favorable atmosphere for group discussion, make brainstorming more efficient, and eliminate stalemates. Inspired by this teaching method, students will be able to seek product test objects to review their design concepts and strengthen their motivation for self-learning. The results of the questionnaire on the influence of adjusted design thinking method on students' creativity showed that the students believe that the teaching method can improve their sensitivity towards problem identification, help them come up with a variety of ideas and unique innovative thoughts. According to what has been mentioned above, this study found that the design thinking method can intensify students' intention for learning, deepen their discussion on design topics, and help teachers improve their teaching.

5.2. Suggestions

In order to improve the design thinking teaching method and increase its contribution to design education, several research suggestions will be proposed based on the results of practical teaching, so as to act as a foundation for future researchers who share the interest in using the design thinking teaching method.

(1) Curriculum Adjustment

After the research, it was found that the design thinking method is a coherent process, where the students have to reach the creativity formation stage to understand the users' intention at the demand exploration and definition stages. This study suggests that, for further research, the process of design thinking with a narrow topic and shorter duration should be carried out first, before implementing the whole design thinking course, so as to help students quickly understand the connotation and the operation of design thinking.

(2) Training for the Teaching Team

The design thinking method has many details requiring more attention to be paid on during the teaching. For instance, it is necessary to create a learning environment that encourages thinking and openness but, at the same time, the teaching process must also guide the students to the correct design direction whenever necessary. Therefore, all members of the teaching team themselves must be very familiar with the objectives of each stage and teaching methods of the design thinking. In the teaching process, the teaching team should spend more effort to communicate with, and guide, the students, and must participate in the whole process and stages, to prevent the students from receiving contradictory guidance from many parties. Lastly, the teaching team should also have enough training and communication beforehand to first achieve a consensus among themselves.

(3) Establish Cross-Disciplinary Communication and Cooperation Channels

It has been proven that the design thinking approach for design education can effectively guide students to learn. However, in the stage of design concept and creativity formation, students may be faced with limitations in terms of thought development and initial major background. Therefore, it is recommended that the channels from which students can communicate with people from different

fields are expanded. If students are found to lack the business-related knowledge, the teaching team should adopt cross-disciplinary course selections to invite business-related departments to join the curriculum, so as to increase the diversity from the perspectives of design education, gain professional advice for subsequent business-related considerations, and attract talents from different fields to participate accordingly.

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