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Designing a Teaching Method for Enhancing Students' Creativity in Product Design Education—a Case Study of Chinese Higher Education

SUN XIAOLEI

Japan Advanced Institute of Science and Technology

Doctoral Dissertation

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Japan Advanced Institute of Science and Technology
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ABSTRACT

Creativity is an essential skill in this increasingly complex, uncertain, and changing world. It has become increasingly prominent in education in the last few decades. Several countries emphasize developing their students' creative potentials with their education policies. Design education is crucial in preparing innovators, creators, and thinkers of the 21st century. Product design promotes student engagement in creative problem-solving. The development of problem-solving skills among students majoring in product design requires opportunities to work on real-world problems and construct tangible knowledge in authentic professional contexts. Project-based learning (PBL) is a useful tool for accomplishing this goal. Traditional product design education in China excessively emphasizes fundamental theory and skill training. Lecture-based strategies are the usual teaching method. It is rare for classroom activities and curricula to be designed to emphasize teaching strategies that develop creativity. Research on the PBL teaching method for product design in China is at a preliminary stage and lacks systematic study. Most studies outline the pedagogical steps of PBL in a course but lack validation of its effectiveness and research on the PBL teaching paradigm in product design education. Hence, designing teaching methods based on PBL to enhance creativity in product design education has become significant.

The main research objective of this dissertation was to develop a teaching method using PBL for product design education to improve students' creativity. Three studies were designed and implemented to achieve this primary research objective.

First, we conducted a survey using a questionnaire to evaluate personal creativity levels and influencing factors among college students majoring in product design in Study 1 (Chapter 3). We examined their current product design capabilities, cognition of creative thinking methods, and perceptions and preferences for teaching methods and course forms. According to the data analysis, the students' creativity was generally poor. The teaching method usually caused low creativity levels among the students. The lack of understanding of creative thinking methods, disinterest in homework assignments, and the rigid teaching environment were also factors contributing to the students' lack of creativity. The findings from Study 1 provide a reference for designing a future efficient teaching method to enhance students' creativity by considering the influencing factors.

Second, in Study 2 (Chapter 4), we conducted semi-structured interviews with eight educators of different educational backgrounds. Through the interviews, we examined the respondents' application of creative thinking methods regarding teaching effectiveness, perceptions, and teaching suggestions involved in their teaching process. The interviewees provided their insights into the specific application of other creative methods. They chose from among the several creative thinking methods we provided to them, which did not include the TRIZ (Theory of inventive problem solving) method, as it was not recommended. We conducted a thematic data analysis to reveal the eight educators' perceptions of the students' low creativity. We summarized the following reasons for the students' low creativity on the basis of the interview analysis:

1. Their lack of life experience hampered the students in discovering their daily problems and developing innovative products.

2. The students failed to observe the objectives effectively and scientifically in their daily lives.

3. They had a poor capacity for independent thinking and excessively relied on teachers and electronic devices in the learning process.

4. The imperfect curriculum design resulted in the students' lack of training in creative thinking methods.

5. The students had poor time management and self-management skills.

6. The rigid teaching environment and unreasonable classroom layout negatively affected the students' creativity.

7. There was a lack of novelty and attractiveness toward the course assignment proposition.

8. The teaching method lacked innovation, and the teaching content was monotonous.

The teaching method designed in this dissertation was based on the results of the interviews. The respondents even suggested five ways to stimulate student creativity: sharing excellent design cases with students, recommending SWOT analysis, working and discussing in groups, random stimulation, and role-playing. In the next stage of the instructional design, we used the methods suggested by the respondents in the interviews as a platform for the students. The respondents' suggested methods for generating creative ideas at various product design stages were summarized. In future teaching experiments, these data will support students as a scaffold. The educators, who had excellent teaching experiences, were asked to suggest and advise on teaching methods to improve student creativity. The respondents proposed teaching methods to enhance student creativity in the following dimensions: assignment proposition, teaching methods, teaching activities, student learning behaviors, and teaching content. The analysis of each interview question informed the design of the teaching method proposed in this dissertation.

Third, in Study 3 (Chapter 5), we combined the findings from studies 1 and 2 with PBL to develop our instructional design, which we call "PIEPR." The teaching process was organized into the following phases: preparation, impartion, exploration and implementation, presentation and evaluation, and reflection and improvement. The teaching experiment conducted a pretest and posttest to determine students' creative thinking levels using the Torrance Test of Creative Thinking-Figural. We also investigated the teaching effect after the experiment to determine the effects of the teaching method on the students' creative thinking levels. We drew our conclusions from the analysis of the interview data, the pretest and posttest results of the experimental and control groups, and the observations of the course conduction. According to the above-mentioned processes, both the experimental and control groups exhibited improvements in all four criteria of creative thinking abilities. A comparative analysis of the creative thinking levels of the students in the experimental group between the pretest and posttest revealed that the students' flexibility, fluency, originality, and elaboration were significantly improved with the experimental activities in our PIEPR teaching method. However, these were also slightly increased in the control group, but the improvements were not statistically significant. Thus, this indicates that the improvements of the creative thinking skills in each evaluation criterion in the experimental group were more effective than those in the control group. This implies that the PIEPR teaching method, which is based on PBL, is implementable and valuable in cultivating creative thinking skills among product design students.

The main contribution of this study is the teaching method we designed, PIEPR, which is an innovative teaching method based on PBL that enhances the creativity of product design students. Specific creative teaching methods and teaching processes were proposed: preparation, impaction, exploration and implementation, presentation and evaluation, and reflection and improvement. This research provides a reference for future product design education by designing the PIEPR teaching method. We hope that the teaching method proposed herein could be popularized and utilized in future product design education courses. This study also provides educators with preferable teaching strategies to cultivate more innovative talents to drive product development in the new era.

Keywords: Creativity; Creative thinking methods; Project-based learning; Product design education; PIEPR.

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LIST OF ABBREVIATIONS

PBL	Project-based Learning
NAF	Novelty, attractiveness and functionality
TRIZ	"Theory of inventive problem solving "
SCAMPER	A combination of Substitute, Combine, Adapt, Put to other uses, Eliminate, Reduce and Rearrange.
5W2H	The inventor uses five English words starting with w (why, what, where, when, who) and two English words starting with H (how, how much) to ask questions, solve problems by finding clues and create inventions.
SWOT	Strengths, Weaknesses, Opportunities, Threats
TTCT	The Torrance Test of Creative Thinking
PIEPR	The teaching process we designed in this dissertation, including Preparation, Impartion, Exploration and Implementation, Presentation and Evaluation, Reflection and Improvement

CHAPTER 1 Introduction

In this chapter…

- Research Background
- Research objectives
- Research methods
- Structure of this dissertation

Chapter 1 Introduction

1.1 Research Background

1.1.1 The demand for creativity

We acknowledge that humanity has entered an era of innovation where individual and social creativity has become increasingly necessary (Trilling & Fadel, 2009). Scientific and technological progress and rapid social change are interrelated and affected by globalization. They even require creative thinking as an essential adaptive skill (Beghetto & Kaufman, 2013) and guarantee a developing sustainable future (Said-Metwaly et al., 2018). Over the last decade, the need for innovation and creative problem-solving skills has been recognized across various enterprise sectors. Thus, focusing on fostering and developing students' creativity has garnered numerous appeals (OECD, 2013). The development of creativity gathers interest in several areas. According to the Human Development Report (UNDP), creativity is one of the key human qualities of the 21st Century, included among the "4Cs" of critical thinking, collaboration, creativity, and communication (National Human Development Report,2018). The International Labor Organization identifies creativity as one of the most crucial skills needed today and emphasizes its importance in the academic and professional education processes (International Labour Organization (ILO), 2013). Throughout history, creativity has helped enhance our lives, from the first wheel to the latest microprocessor. It contributes significantly to science, innovation, and the arts (Feist & Gorman, 1998; Kaufman, 2002; MacKinnon, 1962). Creativity is also significant in solving daily problems (Cropley, 1990); Hirt et al., 2008), maintaining and enhancing our well-being (Hirt et al., 2008; Reiter-Palmon et al., 1998), and adapting to change(Cropley, 1990; Hirt et al., 2008). Creativity, the capacity to produce original and valuable ideas (Amabile, 1983; Mumford, 2003; Sternberg & Lubart, 1999), inspires us, and it is an essential life and work skill in today's complex, fast-changing world. Individuals must be able to utilize and generate knowledge creatively. Nations, organizations, and individuals must be capable of thinking differently and making connections between seemingly unrelated things to sustain competitiveness. The global surveys indicate that organizational leaders are satisfied with the content knowledge or technical skills of their employees (Robinson, 2014) but complain about their lack of creativity (Robinson, 2014).

The demand for creativity exceeds its availability throughout the system. The academic community, business leaders, and policymakers worldwide have stressed that creativity should be fostered among the population to meet the needs of the 21st century (Scholte, 2008).

1.1.2 The demand for creativity education

In the last few decades, creativity has become an intriguing topic in education (Craft, 2005; Smith & Smith, 2010; Huang et al., 2020). This is due to the accumulation of empirical evidence that indicates creativity contributes positively to relevant academic and social outcomes, like academic performance (Freund & Holling, 2008b; Hansenne & Legrand, 2012b; Aleksandra Gajda et al., 2017; Fanchini et al., 2019b) and a successful life (Sternberg, 2002). Creativity is crucial in an increasingly complex, uncertain, and changing world. It can be developed, and educational contexts can help develop creativity (Chan & Yuen, 2014). Several countries are emphasizing the development of their students' creative potential in their education policies (Beghetto, 2010; Hui & Lau, 2010; Lin, 2011). Several countries want to reform school education to achieve more creative outcomes (Sawyer, 2017). In international contexts, creativity is considered an important component of curriculum design and educational practice. Educators' creativity is essential for their own and students' success, especially in our increasingly complex and shifting knowledge ecosystems (Damian Farrow, Joseph Baker, et al., 2018). Creative thinking and teaching within education are crucial in today's extremely competitive world, especially for design education (Razzouk & Shute, 2012). Design education prepares for the innovations, creators, and thinkers of the 21st century (Wei et al., 2015). Creativity is considered an important competency among learners (Ellis & Lawrence, 2009; Lemons, 2011; Dollinger, 2011), particularly among students and practitioners of art and design (Kees Dorst & Cross, 2001; Y. Lin et al., 2012; Carabine, 2013; Clarke & Cripps, 2012). It has become a central aspect of assessment in art and design education (M. Cheung, 2012; Eshun & de Graft-Johnson, 2012). However, schools rarely teach and practice methods that transform existing knowledge into novel ideas and solutions to problems. Creativity is not an inborn trait, and one can be trained and developed to think creatively (Scott et al., 2004; Kienitz et al., 2014; Kleibeuker et al., 2016; Ritter & Mostert, 2017). Unfortunately, this usually does not happen in education. Although there have been revolutionary changes in the world, teaching practices remain relatively unchanged. There is still a strong focus on rote learning in education. It is rare for classroom activities and curricula to emphasize cognitive strategies that develop creative thinking.

China has emphasized the development and education of creative people, insisting that innovation primarily drives growth. China's Ministry of Education for the twenty-first century aims to cultivate high-level talents with innovative abilities. The "National Innovation-Driven Development Strategy Outline" issued by the Central Committee of the Communist Party of China and the State Council in 2016 stated that China will become an innovative country by 2020. China will lead the innovative countries by 2030 and become a world leader in scientific and technological innovation by 2050 (J. Jung, 2016). In 2019, the Central Committee of the Communist Party of China and the State Council jointly issued "China's Education Modernization 2035", which helps strengthen the cultivation of innovative talents, especially first-class innovative talents (Jiuquan, 2020). General Secretary Xi Jinping stated at a scientific symposium in September 2020 that it is important to train innovative talents, focus on education, train undergraduates in basic disciplines, and also cultivate students' innovative consciousness and abilities.

Creative thinking is emphasized in numerous reports as a crucial 21st-century skill (Beghetto, 2007; Harkema & Schout, 2008; Al-Balushi & Al-Aamri, 2014) and is a skill that schools should cultivate (Sternberg & Lubart, 1999; Beghetto, 2005). Schools should train not only the creative elite but also the entire future generation.

1.1.3 Product design education in China

2011 was the year of change. "Design" became the first-level discipline in six secondary disciplines, including Industrial Design (Ministry of Education of the People's Republic of China, 2011). Industrial Design programs focusing on art are renamed "Product Design" and the scientific ones are named "Industrial Design". Students of Industrial Design focus more on comprehensive problem solving, whereas the students of product design specialize in visual comprehension and creative expression (X. Huang et al., 2021). Statistics from China Higher Education Student Information and Career Center's (CHESICC) website show that by 2020, 785 Industrial Design or Product Design undergraduate programs had been offered at 561 colleges and universities. Industrial Design is similar to Product Design from a professional point of view (X. Huang et al., 2021). Industrial designers and product designers play almost the same roles in the industry. The design talents of these two majors are primarily engaged in product design. Public perception of Industrial Design is more technical, engineering-based, and academic. However, Product Design is considered straightforward and commercial. The difference between Product Design and Industrial Design programs in China is due to the different admission categories that art schools favor for their product design programs. Science and engineering colleges prefer Industrial Design. The Art Schools typically grant a Bachelor of Fine Arts (B.F.A) in Product Design, and universities grant a Bachelor of Engineering (B.E.) in Industrial Design. The arts-based student has a good foundation in drawing and modeling. They are experts in form, color, and visual language, with strong communication and storytelling skills. They have poor knowledge of mathematics, science, and technology and cannot innovate and integrates multidisciplinary knowledge(X. Huang et al., 2021).

Product design is a significant branch of design education and is essential for higher education. Its unique structure combines practical and theoretical knowledge, synthesizes vertical and lateral thinking, and creates a rich and flexible learning environment. Education in product design is based more on practice than theory. The critical feature of product design is creativity. Creative ideas are the foundation for innovative products (Starkey et al., 2016). Product design is also a comprehensive interdisciplinary subject with much practical application. It integrates knowledge from the arts, sciences, society, economics, and other fields related to the subject that requires plenty of generalist knowledge (ZHANG, Lixin; GAO, 2020). In product education, students are trained explicitly in creative processes. Nowadays, Chinese consumers demand high-quality product designs, interactive services, and intelligent systems. The development of products for the international market created a massive demand for talented designers. The product design curriculum in higher education must be reasonable and enriching to improve design students and explore their creative potential (K. W. Lau et al., 2009). Students must be encouraged to develop and explore their creative potential by design educators to be able to solve complex future problems. Colleges and universities have an important role in cultivating innovative talents. Colleges and universities must carefully consider their teaching methods to cultivate innovative talents that help develop products in the new era.

Numerous scholars tried bold practices and innovations in teaching methods for product design education. For instance, Kowaltowski and some scholars stated that a design-studio teaching example can introduce formal methods of creativity enhancement (D. Kowaltowski et al., 2007). Some scholars also combine design studios with Outcome-based education (OBE) to operate work-based studios. They even organize students to participate in real-design tasks in enterprises to increase students' motivation to learn professional knowledge and professional skills. This enhances their professional competence and creativity(ZHANG et al., 2020). Some scholars also believed that students participating in design competitions in the curriculum will enhance their practical and innovative abilities as product designers (JIANG, 2015). Mei stated that context-driven methods in product design education develop students' design innovation skills and enhance their creative confidence (Mei, 2016). Based on Teresa M. Amabile's creativity component theory, Zhang and Yu proposed the sectional creative training education method for prior heuristic tasks and postpositional algorithmic tasks. The Consensual Technique for Creativity (CAT) became a scoring standard for creative performance and was finally proposed as the sectional theoretical framework of effective creative training in product design (ZHANG Zi-ran ; YU Ying, 2020). Liao and some scholars also proposed an interdisciplinary teaching model for industrial design majors in a comprehensive university. The innovative concept of the "MCII" model, which is matching, collaborating, interpenetrating, and integrating relevant workshops, was demonstrated to benefit the teaching outcomes and also enhance students' creativity (Liao et al., 2020). Project-based learning can even improve students' learning motivation, provide them with better knowledge absorption, and boost their innovative abilities(Liu & Zhao, 2021). The above teaching methods cannot be extended to all product design courses. The applicability and effectiveness of these teaching methods must be further explored.

Thus, contemporary design educators feel challenged in training creative thinkers (Gustina & Sweet, 2014). Higher education institutions have recently attempted to teach students hard skills, including cognitive knowledge and professional skills (Vogler et al., 2018), and soft skills like problem-solving and teamwork (Casner-Lotto, 2006). These skill-related goals are difficult to achieve as traditional learning is significant where teachers are "the transmitter of knowledge" and students are "the receiver of information" (Alorda et al., 2011). Traditional product design education in China excessively emphasizes fundamental theory and skill training (Hongbo, 2016). Students struggle to engage in educational practices, leading to a superficial understanding of disciplinary knowledge. Educators' methods in design curricula seem inadequate to improve students' design creatively. Individual creative talents and the development of creative thinking have been severely ignored, resulting in a shortage of student innovation. Chinese higher education lacks in its research and practice focused on fostering creative thinking among students in product design. There is no comprehensive and systematic study on creativity education in product design. Thus, educators and researchers should focus on this research gap to encourage innovative education.

1.1.4 The Implementation of project-based learning in Product Design Education in China

Product design helps engage in creative problem solving(Terzioğlu & Wever, 2021). A product designer develops artifacts and services through their understanding of human behavior and physical attributes. They use brainstorming, ideation, sketching, model-making, and engineering skills to solve a problem. The development of problem-solving skills among students, majoring in product design, requires given opportunities to work on real-world problems where they can construct tangible knowledge in authentic professional contexts. Project-based learning (PBL) is an effective means which can accomplish this goal (N. Bin Yang, 2010). PBL is a form of inquiry-based education, wherein authentic problems and questions are integrated into real-world practices to inform education (Al-Balushi & Al-Aamri, 2014b), which leads to meaningful learning (Wurdinger et l. 2007). Yang described his methodology and evaluation criteria for applying project-based learning to product design courses. He proposed that future research could suggest targeted topics for students of different grades (N. Bin Yang, 2010). Liu and Zhao's study outlines the general process of implementing PBL in their courses(Liu & Zhao, 2021). Each teaching session does not have a detailed description. Other scholars have also illustrated the use of PBL. Researchers Chen and Yang (2019) examined the effect of PBL and direct instruction on students' academic achievement in primary, secondary, and tertiary education. However, only 20 percent (6 out of 30) of the studies reviewed had been conducted in higher education. Meanwhile, there is still a shortage of systematic studies and research on "PBL" paradigms of teaching design, particularly in China, a lack of research is also evident in the disciplinary area of product design. However, its effectiveness has not been studied in their research (CAI, 2013; JIA, 2016; JIN, 2019; YANG, 2020; HOU, 2020). Thus, we indicated that the most recent research on the PBL in product design education in China is only at its preliminary stage, and its practical approach needs further exploration and research. This study will address the above research gap to promote the effective application of PBL in education in product design.

1.2 Research objectives

Main Research Objective:

This study's main research objective (MRO) is to develop a teaching method for product design education to improve students' creativity.

Hence, there are four sub-objectives (SRO) of this research, which are as follows:

SRO1-To assess the creativity level and product design ability among product design students.

SRO2-To discover the factors that lead to low creativity among students.

SRO3-To explore educators' pedagogical suggestions for creative thinking methods and techniques of enhancing students' creativity.

SRO4-To design teaching methods that enhance students' creativity and test the effectiveness of these teaching methods.

Achieving these four sub-research objectives will fulfill the primary objective.

We will conduct research through a questionnaire to explore students' creativity level and the influencing factors to achieve the first and second sub-objective. The findings of the first study serve as a reference for designing an efficient future teaching method to enhance students' creativity by considering the influencing factors.

Semi-structured interviews of eight respondents will explore the third sub-objective of this research. It will include their application, teaching effectiveness, perceptions, and suggestions for creative thinking methods in the teaching process. An in-depth analysis of each interview question will inform the teaching method design in the following chapters.

The fourth sub-objective of this research will be achieved by conducting a teaching experiment with the innovative teaching method designed during this study. The experimental and control groups will be organized and evaluated on the effectiveness and practicability of the teaching method. The pre-and post-tests of the teaching experiment to determine students' creative thinking levels will use the Torrance Test of Creative Thinking-Figural (TTCT-Figural). The teaching effectiveness following the experiment will also be assessed on the effects of the teaching methods on students' creative thinking levels.

1.3 Research methods

(1) **Literature research method:** It is a method to develop a scientific understanding of the facts by collecting, reviewing, and organizing the literature published by scholars of previous research in related fields. This paper summarizes and outlines the relevant concepts and theoretical models involved in this research by reading literature and book reviews from the keywords like creativity, PBL, and teaching methods. This provides sufficient preliminary preparation for the subsequent research on this topic.

(2) **Quantitative research method:** It is conducted to produce statistical results on the totality of a specific research subject. It is a purely scientific, rational, and precise method. It is fact-based that are often reflected in precise numbers. In quantitative research, information is represented by numbers. Quantitative research is a theoretical analysis of models combined with certain mathematical methods, primarily using data, patterns, and graphs to analyze data. Study 1 in this thesis uses quantitative research to investigate the students' creativity level and the factors influencing it.

(3) **Qualitative research method:** This method uses logical reasoning and historical comparisons (Jonker & Pennink, 2010) and describes the properties of objects. The conclusions obtained through this research method are based on textual descriptions. A qualitative understanding is explored for potential reasons and motivations to preliminarily understand the research problem. Study 2 in this dissertation uses a qualitative research approach to explore educators' pedagogical suggestions for creative thinking methods and ways of enhancing students' creativity.

(4) **Mix-methods research method:** The research of Study 3 combines qualitative and quantitative research methods to comprehensively test the effectiveness of the teaching methods involved in this dissertation. It helps ensure the accuracy of the research results.

(5) **Behavioral observations:** Behavioral observations are used in Chapter 5 to investigate the effect of the experiment on students' learning statements during the teaching experiment.

1.4 Structure of this dissertation

The structure of this dissertation is outlined below. The dissertation is divided into six chapters. The first chapter of the thesis is the introduction. It outlines the background relevant to this study. Chapter 2 is a literature review and a discussion of relevant definitions. Chapters 3, 4, and 5 provide an overview of the primary findings of this dissertation and explain studies 1, 2, and 3, respectively. Chapter 6 summarizes the findings of studies 1, 2, and 3, followed by an overview of the contributions of this thesis. Finally, it includes the limitations of this study and recommendations for future research. The details are presented below, and the framework of this dissertation was shown in Figure 1.1.

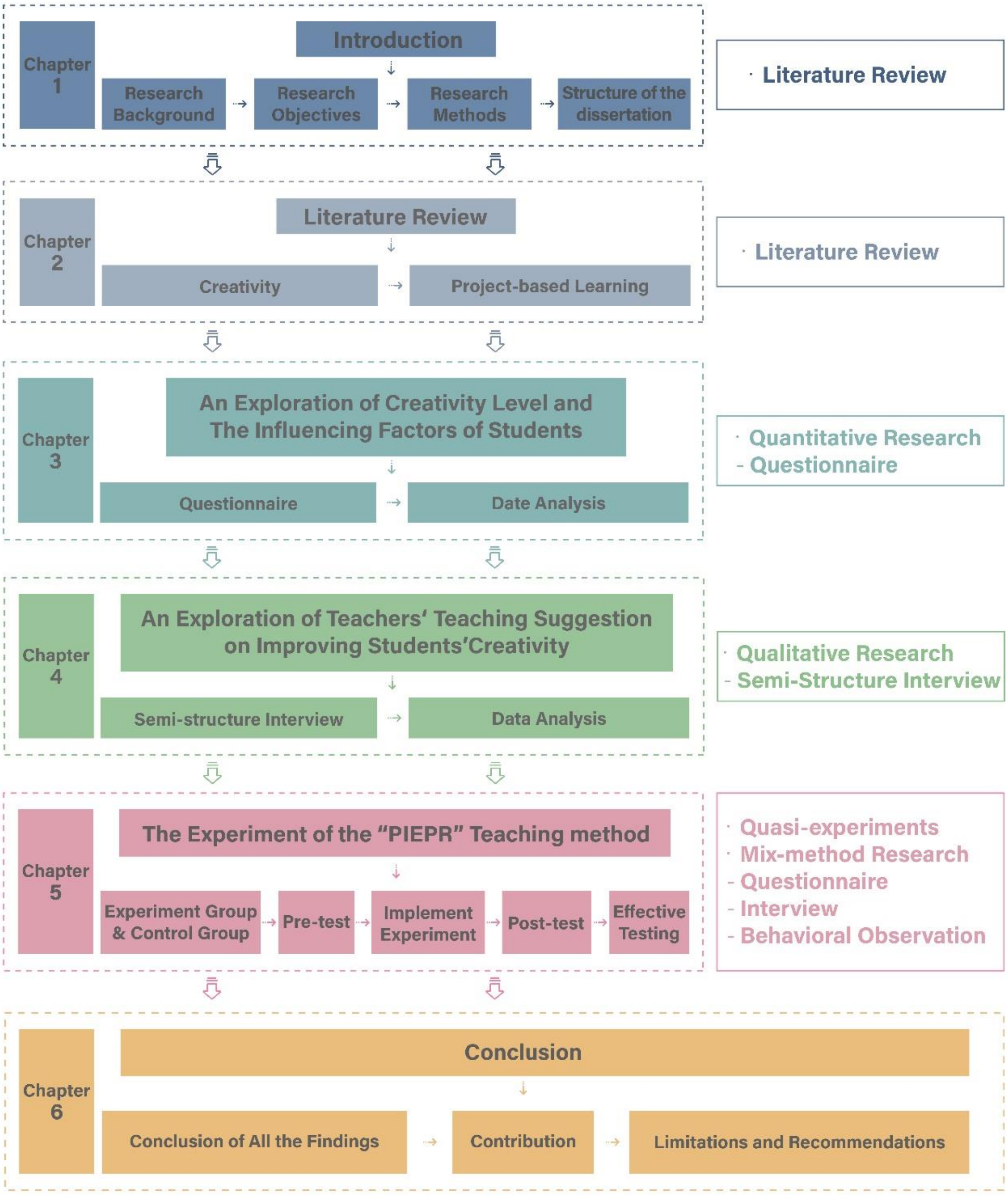

Figure 1. 1 The overall framework diagram of this dissertation

Chapter 1 presents an overview of this dissertation, including the research background, research objectives, research methods, and its structure.

Chapter 2 presents the theoretical background of this study based on the literature review. It includes a literature review and a definition of certain terms. This section contains the main theories studied in this dissertation, including theories related to creativity and project-based learning.

Chapter 3 presents the study 1 results involving a questionnaire survey. The questionnaire was administered to 177 students majoring in product design to explore their creativity level and the influencing factors. The study 1 findings serve as a reference for designing an efficient future teaching method to enhance students' creativity by considering the influencing factors.

Chapter 4 outlines the study 2 results which included a semi-structured interview with respondents. It helps explore their application of teaching effectiveness, perceptions, and suggestions for creative thinking methods in their teaching process. It also outlines the research objectives, participants, research methods, results and findings, a discussion of study 2, and the chapter summary. The research finding will be included in the teaching method design in the next chapters.

Chapter 5 summarizes the empirical study results of the "PIEPR" teaching method designed in this study. This chapter outlines the purpose of the teaching experiment, research objectives, methods, research procedure, results and findings, and conclusion. The chapter includes various validation methods to test the validity of the instructional design.

Chapter 6 summarizes the findings of studies 1, 2, and 3. It also illustrates an overview of the contribution of this thesis to knowledge science. Finally, it outlines the limitations of this study and suggestions for future research.

CHAPTER 2 Literature Review

In this chapter…

- Overview of Creativity
- Overview of Project-based Learning

Chapter 2 Literature Review

Chapter 2 presents the theoretical background of this study based on the literature review. It includes a literature review and a definition of certain terms. This section contains the main theories studied in this dissertation, including theories related to creativity and project-based learning.

2.1 Overview of Creativity

2.1.1 Definition of Creativity

Creativity was first scientifically studied in the mid-twentieth century. Creativity is the potential that human beings can inspire. The capacity to create something novel and appropriate is considered creativity (Lubart & Sternberg, 1998). The concept of creativity is often defined by terms such as "creative thinking," "ability," "problem-solving," “imagination,” or "innovation." Some definitions contain an element of problem-solving, where insight is required to find a solution (Simonton, 1999; Sternberg & Davidson, 1995). Some scholars often define creativity as a process of exploration, imagination, and creative thinking. Since theoretical perspectives on creativity are diverse, there is no universally accepted definition. In the psychological tradition, creativity is defined in terms of originality and usefulness (Barron, 1955; Runco & Jaeger, 2012). Uniqueness, novelty, and infrequency are characteristics of originality. It is not creative to come up with an idea that is not new, unusual, or unique. Utility, appropriateness, or fit are all aspects of usefulness. Therefore, it must be valuable to a group or culture. Some scholars have suggested that there are other components to creativity. For instance, the third criterion proposed by Kaufman and Sternberg is quality (Kaufman, J. C., & Sternberg, 2007), and Simonton proposed surprise as a third element (Simonton, 2012).

Creativity helps us solve difficulties in various disciplines(Goldberg et al., 1991). A more recent view is that everyone can be creative(Saliceti,2015; Weisberg, 2006). This research refers to creativity applied to the world of design, which is defined as "design creativity." Design creativity can be defined as the expression of novel ideas through product design (J. H. Jung & Chang, 2017; Nagai & Taura, 2015). According to Dumas, Schmidt, & Alexander, the concept of design creativity refers to a person's ability to produce novel designs (Gabriel et al., 2016). The designing process involves asking, imagining, planning, creating, and improving. Among the outcomes of design are final design products and design solutions (National Building Museum, 2016). Students learn to be creative in their design education lessons at the school level. Especially, design is strongly tied to creativity in that it is engaged in both the conception and implementation of new ideas and the solution of problems (K. Dorst, 2003). It is undeniable that creativity is an essential and necessary aspect of the design process (Rutland and Barlex 2008； Howard et al. 2008).

2.1.2 The Components of Creativity

The creative component directly affects the results of his creative performance(T. M. Amabile & Pillemer, 2012). Many scholars have summarized various creative components according to existing theoretical frameworks and research. It is also recognized that creativity is impacted by individual characteristics and contextual variables rather than existing in isolation (T. M. Amabile et al., 1996). The knowledge, motivation, emotions, and experience dominate the creative process, enabling them to create new, functional, and valuable products (Anusca Ferrari & Mackenzie, 2017). Individuals who want to be creative must have specific creative potential in possess certain professional knowledge (T. M. Amabile & Pillemer, 2012). With a specific creative potential in terms of personality traits(Jin, 2004), mastering specific creative thinking techniques in skills (T. M. Amabile & Pillemer, 2012), people get effective incentives in a proper environment to stimulate self-efficacy and intent on creativity (C. Wang et al., 2014). Therefore, design educators should create a relaxed learning environment for students, stimulate students' initiative and creative enthusiasm, guide students to choose appropriate creative thinking skills, and complete an effective creative process. The creativity mentioned above components were also considered in the teaching methods design of our study.

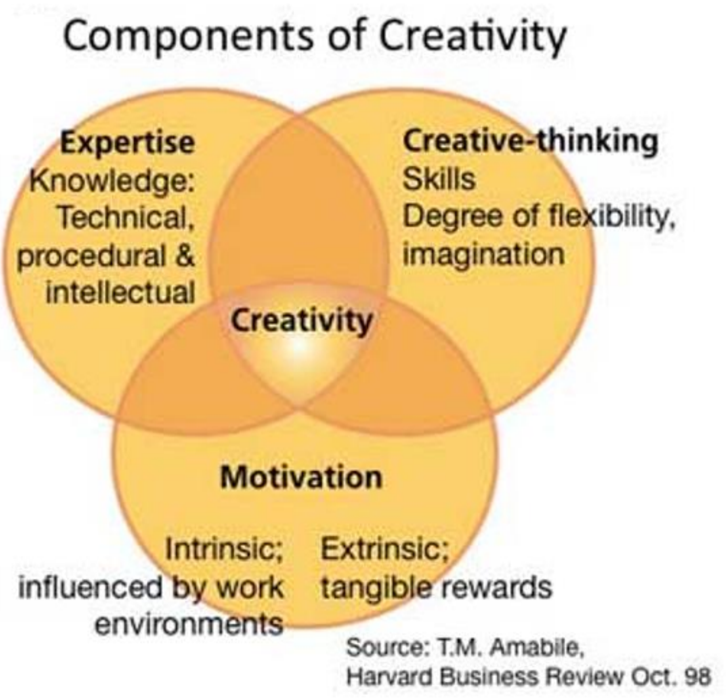

Figure 2. 1 Components of Creativity
Source: T.M Amabile, Harvard Business Review Oct.98

2.1.3 Creativity and Creative Thinking

A critical competency of the twenty-first century is creative thinking, and its effects are widespread. The importance of creativity has not only been recognized in the sciences and arts (Feist & Gorman, 1998; MacKinnon, 1962; Sternberg & Lubart, 1996) but it has also been demonstrated to play an important role in everyday problem solving (Cropley, 1990; Mumford et al., 1991; Runco, 1994; Torrance, 1971). Creative thinking also helps us remain flexible in addition to solving problems. Cognitive flexibility allows us to deal with the changes and opportunities associated with our fast-changing and complex world (Cropley, 1990; Gabriel et al., 2016).

Creativity and creative thinking are still undergoing considerable debate in regard to their precise definitions (Corazza & Agnoli, 2016). Researchers such as Barbot, Besançon, and Lubart maintained that creativity is the result of creative thinking (Barbot et al., 2016). Based on these considerations, Corazza and Agnoli (2016).proposed that the terms are closely related and can be interchanged. Thus, cultivating creative thinking among students is the same as encouraging creativity, which many researchers concentrate on in academia (Miller & Dumford, 2015; Hu et al., 2016; Berrueco, 2011). Innovation begins with creative thinking, which is one of the desirable characteristics of design students. Moreover, Creative thinking includes coming up with creative solutions to problems using techniques such as brainstorming and visualization (Ruggiero, 2003; McArdle, 2018). The definition of creative thinking is: (1) developing original and unique approaches to solving problems (Guilford, 1956; Harris, 2014; Saccardi, 2014) and innovative ideas are essential to finding solutions to problems (J. Y. F. Lau, 2011); (2) a process for generating new and useful ideas, solutions, and products that have not been invented yet (Sarkar & Chakrabarti, 2011); (3) considering characteristics such as cognition, personality, environment, and motivation, as well as positioning outcomes in the context of a wide knowledge base (Black et al., 2015); (4) It is an incidental occurrence without any clear early goals for creating elaborate plans and processes (He, 2017); (5) an intentional occurrence is the exact opposite from an incidental event; it has a specific goal, and is not just an accident (He, 2017); (6) The creation and development of new ideas, strategies, and approaches to accomplish tasks with the aim of achieving more productive results (M. F. Y. Cheung & Wong, 2011). According to Munandar, fluency, adaptability, originality, and elaboration are essential aspects of creative thinking (Munandar, 2021). Hence, creative thinking is a way of thinking that generates new ideas in various ways. An individual with creative thinking skills can develop a novel idea in multiple ways. As a way of synthesizing these diverse perspectives, creativity or creative thinking in this paper refers to be able to generate novel ideas and concepts, as well as the ability to think divergently and productively within an design setting.

It has previously been found through research that there have been various aspects of creative thinking research, from teaching creative thinking techniques in the classroom (Torrance, 1962) to developing cognitive tools for creative thinking (Wissink 2001; Candy and Edmonds 2000), designing learning environments that foster creativity (Piirto 2005; Hennessey 2004; Riddoch and Waugh 2003), and assessing creativity (Runco 1989; Torrance 1971). Despite diverse approaches to the creativity education, all agreed that students' creativity could be stimulated by convergent and divergent thinking (Karnes et al. 1961; Davis and Rimm 1989). Further, the research also proved that allowing students to brainstorm uses of everyday items in unusual ways, as well as providing them with a glimpse of problems that may stimulate their creative ideas, can be helpful in the process of restructuring problems, which in turn, will aid in the development of ideas (Jacobs and Dominowski 1981; Martinsen 1995). People's curiosity will drive them to explore and discover problems throughout the creative process. People observe and summarize to understand how others create new and creative things(Craft et al., 2007).

Furthermore, creativity cannot be taught, but approaches and procedures for creative thought can. Creative thinking also plays a vital role in the product design process. People have discovered that developing students' creative thinking skills, particularly in product design education, can perform better product innovation. Therefore, this research aims to improve students' creative thinking skills by teaching appropriate creative thinking methods for students in instructional design.

2.1.4 Education for Creativity Enhancement

Promoting creativity in educational contexts has been a key research topic (Fasko 2001; Feldhusen and Goh 1995; Robert 1991; Hennessey and Amabile 1987; Guilford 1967; Goldschmidt and Tatsa 2005; Pithers and Soden 2000; Runco 2008; Shaheen 2010). Teachers play an essential role in creativity education (Craft, 2005; Davies, 2006) and are considered to have a significant impact on students' development (Scott et al., 2004; Li, 2018). Davids et al. (2014) asserted that the pedagogical and physical environments are necessary for creative learning and conducive to fostering creativity among students. Teachers were recognized as one of the main elements in the pedagogical environment, which prioritizes the extent to which teachers prepare for teaching and learning (D. Davies et al., 2014).

Considering the influence and dominance of the classroom environment in bringing out the best creative output from students is essential (T. Amabile, 1998) because events occurring in the classroom can eventually have a direct impact on the creative thinking ability of students (Beghetto & Kaufman, 2014). According to Hennessey (2004), the interaction between students and their surroundings with the nearest suitable point may stimulate students' creativity. Florida (2014) emphasized that classrooms environment should involve broad-minded teachers who can promote independent learning among students. Because the classroom environment has a significant impact on students, classrooms should be operated carefully and deliberately.

From the student's perspective, various factors including peer support promote creativity (Zhou & Valero, 2016). Peer support in small groups promotes interaction among members and encourages the development of creative abilities among students. Sternberg's (1994) findings indicated that the personal and professional relationships with peers result in greater creativity among students and help students in achieving career goals.

Thus, all factors lying within the context of education, such as the method employed by teachers to prepare for teaching and learning, the classroom environment that allows students to freely express their ideas, and peer support within small groups, foster creative thinking among undergraduate students. Hence, based on the aforementioned three dimensions, the present study developed innovative instructional designs for promoting creativity among students.

2.1.5 Creative thinking methods that may improve creativity

Design education involves several approaches for promoting students' creativity. According to Rutland and Barlex, to enable students to be creative, they must be provided with knowledge and skills (Rutland & Barlex, 2008b). Various creative thinking skills and procedures are available that can be applied to diverse circumstances and disciplines, such as business, product development, and advertising, when developing creativity training exercises for design education (Torrance, 1992; Michalko, 2001). Therefore, design educators should deliberately choose appropriate methods and carefully consider the means for integrating various teaching methods within their teaching module. The contemporary goal of higher education, including design education, is to provide students with tools for solving problems innovatively and a scientific basis for their decision-making processes.

The present study defines the tools or creative thinking methods that can help students generate novel ideas. To identify such methods, literature review was performed and explored the methods for stimulating students' creativity. Although various methods for stimulating creativity, including those in fine arts, pedagogy, business administration, industrial design, marketing, engineering design and architectural and psychology (Clegg, B., & Birch, 2007; Mesquita, 2011), have been described in the literature, the present study discusses only a few of these methods that are commonly used to stimulate creativity among product design students. These methods are described in Table 2.1.

Table 2. 1 Glossary of various methods found in the literature that may stimulate product design creativity (Clegg, B., & Birch, 2007 ; Kowaltowski et al., 2010)

Method	Description
Association	Technique for solving problems by structuring problems and eliminating illogical solutions.
NAF (Novelty, attractiveness and functionality)	Solutions are evaluated on the basis of novelty, attractiveness, and usefulness. Each attribute is graded on a scale of 1-10.
Other people's viewpoints	A technique for encouraging people to consider unfamiliar viewpoints during a problem discussion.
Gallery	Participants are required to create a poster gallery of their ideas and hang them for discussion and contemplation by the rest of the team.
SCAMPER	A combination of Substitute, Combine, Adapt, Modify, Put to other uses, Eliminate, Reduce and Rearrange. These verbs are used to ask about the transformation of an object or process.
5W2H	The inventor uses five English words starting with w (why, what, where, when, who) and two English words starting with H (how, how much) to ask questions, solve problems by finding clues and create inventions.
Analogies	The analogy occurs when two items with certain similarities and differences are compared, and further comparable aspects are inferred from the similarities. The core of analogy is to help individuals comprehend unfamiliar items by comparing them to familiar ones.
Attribute Listing	The attribute listing is a technique that takes an existing product or system, breaks it into its components, identifies various ways of becoming each component, and then recombines these elements to create a new product or system.
Biomimicry	The practice of biomimicry involves learning and mimicking the strategies found in nature to find solutions to human design challenges - and find hope.
Brainstorming	Brainstorming is a group creativity method in which members spontaneously generate a list of ideas to solve a specific problem.
Focus Groups	Focus groups are interviews with a small group of people belonging to the same demographic or having other characteristics/experiences in common.

Mind Mapping	The mind maps engage the author in writing down a central theme and generating new and related ideas which radiate from the central.
TRIZ	"Theory of inventive problem solving " is “the next evolutionary step in creating an organized and systematic approach to problem-solving.
Random stimuli	Random stimulus is generated by randomization and exploration of novel non-intentional associations. The Random Word technique generates new associations by using a random word. In this way, you can come at problems from an entirely different perspective, leading to creative solutions within your mind.
SWOT (Strengths, Weaknesses, Opportunities, Threats)	An evaluation method used to identify the internal and external factors that are favorable and unfavorable to achieving a specific objective by identifying strengths, weaknesses, opportunities, and threats involved in a project

The selection of these methods or techniques in the present study was based on a review of the literature, which helped in determining their potential for being tested in product design. An overview of some of the promising methods for product design processes, namely Analogy, Association, Biomimicry, Brainstorming, Attribute List, Mind mapping, TRIZ, SCAMPER, and 5W2H, is as follows.

Analogy is an effective tool for developing ideas. Designers often design products based on the things they have already seen, and professional designers often use analogies (Christensen & Schunn, 2007; Weisberg, 2006). Analogy involves a comparison between two items with certain similarities and differences and is used to infer further comparable aspects based on the similarities. The core of analogy is to help individuals comprehend unfamiliar items based on a comparison of such items with familiar ones. Product development professionals recognize the value of analogy thinking and actively advocate the usage of multiple analogies to create product designs (Goel, 1997). Sarlemijn and Kroes recommend using functional and form comparisons in training (Sarlemijn & Kroes, 1988).

Association is a tool used to reflect on a problem and thus a valuable technique for designers. To create new design elements and expression, using the Association method around a theme at the beginning of the design process is vital. Association is built on various tactics, including prototypes, precedents, diagrams, visual displays, analogies, and metaphors. The visual presentation is primarily based on Association (Howard et al., 2008).

Benyus (1997) defines Biomimicry as the transfer of technology between life forms and man-made structures. Biomimicry is a pioneering design application that helps promote creativity and sustainability. Biomimicry in design is a system of simulating complex forms in nature by analyzing their structure in another product. It generally imitates forms or functions existing in nature and uses them in creative product design (Bakan & Bakan, 2021).

Brainstorming is probably the excellent method for stimulating creativity, which involves experts from different fields having new ideas without prior judgment. Brainstorming has three basic rules: Concentrate on quantity; Do not criticize; Unusual ideas are welcome since they combine and improve ideas. Brainstorming is a conference technique and was defined by Osborn (1957) as the spontaneous gathering of ideas by a group of people attempting to solve a problem.

Attribute List breaks the problem into parts and then investigates each part. This technique has a potential application in design education and involves identifying essential characteristics of a product or process and evaluating methods for ensuring improvements. Boouillerce and Carre (2004) recommend making an inventory of all aspects of a problem such as types of materials used, dimensions, construction practices, fabrication processes, and users' requirements. Following the creation of the list, priorities are marked and alternatives suggested. Davis (1992) asserted that the number of attributes increases exponentially with the combinations of ideas.

Mind Mapping is a method of arranging and breaking down various aspects of a product around a central point. A mind map represents ideas by using a specific diagram, comprising semantic links and hierarchical connections between concepts. This method was proposed by Tony Buzan to break the linear lecture system, which works in direct opposition to the brain (Loup-escande, 2011).

TRIZ in Russian language means "Theory of Inventive Problem Solving." Altshuller (1984) created this method to discover patterns for predicting breakthrough solutions to problems based on more than 3 million Soviet patents. Research on TRIZ started based on the hypothesis that the foundation for technological innovation is based on universal principles of creativity. Altshuller identified 40 basic inventive principles in his patents, including weight of the moving object, length of the moving object, force, stress, speed, temperature, shape, temperature, power, illumination intensity, substance, loss of energy, time, reliability, information, ease of maintenance, and operation repair. By identifying and codifying these principles, people could be taught how to make the creative process more predictable. This method creates a matrix that can be applied to novel inventions.

SCAMPER is an acronym for a series of mental operations leading to creative thinking, namely "Substitute," "Combine," "Adapt," "Modify," "Put to another use," "Eliminate," and "Rearrange" (Hussain & Carignan, 2013). SCAMPER method is used for innovative product transformations aimed at modernizing the design, construction, and extending the functions of existing products. According to this approach, every novelty is a modification. A list of such questions was developed by Robert Eberle during the mid-20th century. Answering these questions is characterized by a specific logic, and the answers allow people to identify various innovative solutions for the existing problem.

The 5W2H methodology guides management in the planning and decision-making stages by providing answers to 7 questions, which provide information about responsibilities, methods, deadlines, goals, and the associated resources (Kuligovski et al., 2021). The 5W2H stands for the initials of the following questions: What?, Why?, When?, Where?, Who?, How?, and How much?.

We interviewed educators to explore their application of teaching effectiveness, perceptions of, and suggestions for creative thinking methods in their teaching process. The results are presented in Chapter 4.

2.1.6 Evaluation and measurement of creativity

In order to solve individual, organizational and social problems and achieve sustainable development, creativity is considered one of the most valuable assets (Zeng et al., 2011; Lubart et al., 2013). Various definitions exist regarding the concept of creativity. According to Amabile, creativity was regarded as 'the procedure through which something judged (to be creative) is created (T. M. Amabile, 1983). Gilford defined creativity as intellectual operations related to divergent thinking, the capacity for re-explanation and re-expression of meaning and the components of subjects, which occurs when one is sensitive to problems(Guilford, 1956). As he has stated in his book, he has introduced originality, flexibility, fluency, and elaboration as the abilities involved in divergent thinking (see Table 2.2). Since the key to designing products and to enabling innovation lies in creativity. A creative assessment can assist in identifying innovative products and designers and enhance both of them. Hence, these four measures were used as indicators in this study to determine the creative ability of the students. The table below summarizes the Sample rubric anchoring assessment criteria on the definition of creativity.

Table 2. 2 Guilford’s four creative characteristics

Characteristics	Description
Fluency	People have the ability to create a large number of ideas and provide solutions quickly when faced with problems. There are three components involved in fluency: the length of time it takes to generate an idea or answer, the number of answers, and the strength of the associations between answers.
Originality	Originality means people are able to generate ideas that are different from others or unconventional while also considering the practicality of the idea.
Flexibility	When dealing with problems, people can be flexible to change their thinking and find different ways to solve the problem.
Elaboration	Elaboration refers to the carefulness of thinking or the ability to retouch and improve details.

Another method used to measure students' creative thinking is The Torrance Tests of Creative Thinking (TTCT). The Torrance Tests of Creative Thinking (TTCT) is also widely used in education and the business world to measure creativity. TTCT was developed by Torrance in 1966. There have been 5 revisions: in 1974, 1984, 1990, 1998, and 2008 (Kim, 2011). TTCT is an excellent tool to examine changes in creative thinking over time.

TTCT has been translated into more than 35 languages (Millar, 2002) and is widely used around the world. There are two versions of the TTCT, the TTCT-Verbal and TTCT-Figural, each with two parallel forms, Form A and Form B (Kim, 2011). A typical session includes five tasks: ask-and-guess, product improvement, unusual questions, and just suppose. In each task, people are presented with an image to which they must write an answer (Torrance, 1966, 1974). The TTCT-Figural consists of two parallel forms, A and B, which require three activities: picture construction, picture completion, and repeated lines or circles. The Torrance Test of Creative Thinking (TTCT; Torrance, 1974) is a pen-and-paper test taken by test takers which generally depends on divergent thinking, and test takers' responses are judged based on fluency, flexibility, elaboration, and originality (Hickey, 2001; Kyung Hee Kim, 2006). The quantity of responses determines fluency; flexibility is determined by the number of categories in the list; originality is determined by the number of infrequent responses compared with the other group members; and elaboration is determined by the amount of details. Since the research subject is based on the product design major, it focuses more on the visual representation and creativity of products. Therefore, this research takes the TTCT-Figural test as the primary method of testing the students' creative thinking abilities.

	Novice	Developing	Expert
Fluency	Students considered one idea.	Students considered several ideas.	Students considered many[a] ideas.
Flexibility	Students considered one type of idea.	Students considered several types of ideas.	Students considered many types of ideas.
Originality	Student developed a common idea that many other students would have suggested and/or replicated an existing idea.	Student developed an interesting idea that several other students would have suggested and/or minimally added onto an existing idea.	Student developed a unique idea that few other students suggested and/or substantially built upon an existing idea in a unique way.
Elaboration	Students added minimal details and improvements to their ideas.	Students added a few details and improvements to their ideas.	Students added many significant details and improvements to their ideas.

Figure 2. 2 Sample Rubric Anchoring Assessment Criteria on the Definition of Creativity
Source: Davis, G. (2004). Creativity is forever. Dubuque, IA: Kendall Hunt. Starko, A. J. (2010). Creativity in the Classroom: Schools of curious delight (4th ed.). New York, NY: Routledge.

As stated by Torrance, creativity is the ability to recognize gaps and provide solutions for problems (Torrance, 1969). However, the approaches of the two researchers above are quite different in measuring creativity. They tend to base their tests on the qualities of specific thinking, specifically originality, flexibility, fluency, and elaboration, which are attributed to the main role in creativity measurement. Therefore, in the following teaching experiment, we would use the four test indicators of originality, flexibility, fluency, and elaboration in TTCT to finally assess students' creative thinking skills to prove the effectiveness of our teaching method.

2.2 Overview of Project-based Learning

2.2.1 Project-based Learning (PBL)

The origin of project-based learning (PBL) may be traced back to 1959 marked by the work of the educator and philosopher John Dewey (1959). Dewey (1959) created the idea of learning by doing, which has been regarded as the foundation for PBL (Desmond et al., 2002; Grant, 2002). Dewey (1959) claimed that students would become personally invested in the material, if they are challenged to focus on meaningful, real-world tasks and problems. Unlike rigid lesson plans that direct learners along the path of learning outcomes, PBL allows for in-depth exploration of a topic that is worthy of investigation (Helm & Katz, 2016). According to Sun et al., students can develop creativity skills through PBL (Santosh et al., 2015).

PBL is a student-centered form of instruction that is based on three constructivist principles: learning takes place in a particular context; students are actively involved in the learning process; and students achieve their learning objectives through social interaction, knowledge sharing, and understanding (Cocco, 2006). PBL is an inquiry-based instructional method that engages learners in knowledge construction by enabling them to complete meaningful projects and develop real-world products or services (Brundiers & Wiek, 2013; Krajcik & Shin, 2014). PBL is a complicated activity that involves complex questions or issues and requires students to engage in creating, problem solving, decision-making, and research tasks as parts of their active participation. PBL may also be used to enhance creativity, critical thinking, communication, collaboration, self-directed inquiry, and lifelong learning skills (Condliffe et al., 2017). It is considered to be a specific form of inquiry-based learning, where real-world problems and questions are used to inform learning (Al-Balushi & Al-Aamri, 2014a), leading to meaningful learning (Wurdinger et al., 2007).

The purpose of PBL is to provide a meaningful experience to students.

One of the main advantages of PBL is that it promotes learning through active participation in a project, which is likely to increase motivation among learners (Fernandes et al., 2014) and provide students with a sense of satisfaction; these aspects are essential for the development of long-term learning skills (Edström & Kolmos, 2014) and a comprehensive understanding of both the content and process among students, enabling them to learn to work together to solve problems, while promoting the sense of responsibility and independent learning among them (Chau, 2005; Chua, 2014; Wieder & Linehan, 1977). Moreover, PBL helps students acquire knowledge while solving practical and real problems that are connected to the professional world (Terrón-López et al., 2017). PBL integrates and applies (Song & Dow, 2016): 1) structured new knowledge covered in the course, 2) knowledge acquired from other courses, 3) prior life experiential-based knowledge, and 4) new self-acquired knowledge. Researchers believe that PBL is one of the most effective teaching and learning methods that could be used in the classroom to improve students' performance. The revolution in teaching strategies has led to the widespread use of lecture-based methods in large classes; however, these methods are not effective in maximizing the opportunity for interaction between students and teachers and hinder teachers' ability to provide individual guidance (Roehl et al., 2013; Hodgson & Hui, 2017). PBL focuses both on helping students acquire professional knowledge and encouraging them to develop their own projects (Frank et al., 2003).

Product design is a comprehensive interdisciplinary subject that requires product designers to have a "generalist" knowledge structure (Liu & Zhao, 2021). The primary function of product design education is to engage students in problem solving innovatively (Terzioğlu & Wever, 2021). A product designer develops artifacts and services through their understanding of human behavior and physical attributes and then utilizes brainstorming, ideation, sketching, model-making, and engineering skills to solve the given problem. Hence, to develop problem-solving skills among students majoring in product design, they should be given opportunities to work on real-world problems and allowed to construct tangible knowledge in authentic professional contexts, and PBL is an effective means to accomplish these goals (N. Bin Yang, 2010).

2.2.2 Essential Elements for Project-based Learning

The PBL model is characterized by several features (De Graaff & Kolmos, 2007). Previous studies have suggested that the curriculum is generally structured in thematic blocks and that various disciplines are integrated through the application of cases to professional practice. Learning is concentrated on the self-directed study groups that analyze and discuss selected cases (De Graaff & Kolmos, 2003). In the learning process, professors are primarily responsible for assisting students to understand project problems, develop potential solutions, apply solutions to meet criteria and specifications, and construct new knowledge when possible (Chua, 2014). Additionally, the assessment methods should be aligned with the learning process (De Graaff & Kolmos, 2003). The main issues related to project approaches are team work and its assessment (Fernandes et al., 2012).

According to J. Larmer and J. R. Mergendoller (2010), 7 elements are required for a project to qualify for PBL. The specific details are summarized as follows (see Figure 2.3):

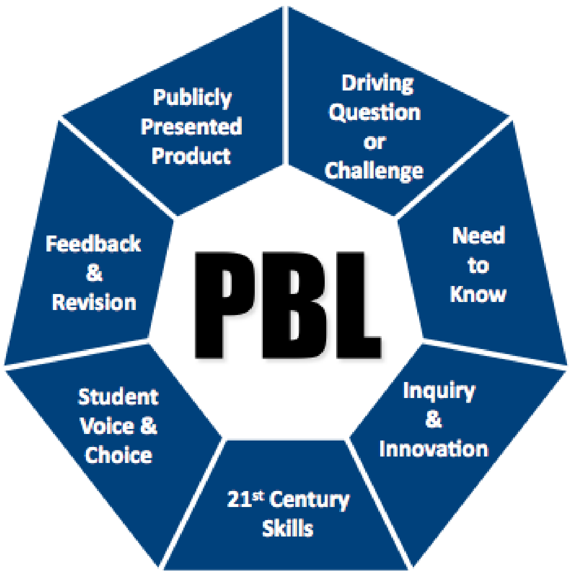

Figure 2. 3 Essential Elements for Project-based Learning
Source: http://modelschoolscnyric.pbworks.com/w/page/40580862/Project-Based%20Learning)

1. A Need to Know. The project content allows students to acquire required skills and knowledge. Teachers play a crucial role in inspiring students to gain knowledge and apply skills to create products through their projects. Therefore, starting with one of the following activities is highly recommended: a video, a discussion, a guest speaker, or a mock correspondence that set the stage for a scenario (John Larmer & Mergendoller, 2010).

2. A Driving Question. Driving questions help us determine the main idea, purpose, and objectives of the project. Students are more likely to connect with a core when questions are provocative, open-ended, and focused on solving a problem(John Larmer & Mergendoller, 2010).

3. Students' Voice and Choice. Students must be provided the opportunity to choose a design style and the product they wish to create. PBL should be managed effectively in terms of time. It should provide each student the opportunity to choose what products they intend to create and what

resources they require(John Larmer & Mergendoller, 2010).

4. Twenty-first Century Skills. Projects stimulate the development of 21st century skills among students, especially collaboration, communication, and critical thinking, and technology usage, which are necessary in the real world(John Larmer & Mergendoller, 2010).

5. Inquiry and Innovation. Through the real inquiry, search for resources, and discovery of answers, students generate new questions, ideas, and conclusions, leading to innovation(John Larmer & Mergendoller, 2010).

6. Feedback and Revision. Exchanging constructive feedback is essential to make learning meaningful and ensure the development of high-quality products(John Larmer & Mergendoller, 2010).

7. A Publicly Presented Product. It's important for students to share their work publicly as part of a project, both to motivate them and to make learning visible and discussable(J. Larmer & Mergendoller, 2015).

In conclusion, the characteristics of an effective PBL as indications of learning objectives include knowledge and a deeper understanding of the fundamental content standards, concepts, competencies, and success skills (often referred to as "21st Century Skills," namely critical thinking, problem-solving, collaboration, and self-management). Another important consideration in making learning more meaningful for students is the complexity of problems or questions because students should be able to not only gain knowledge but also apply it to solve a problem. PBL is viewed as an in-depth time-consuming procedure. Students are given a challenging problem or question and are required to ask questions and find resources to answer them and then ask deeper questions until they find a satisfactory solution or answer. Additionally, projects should be authentic (e.g., solving real-life problems); include real-world processes, tools, and standards; able to improve the lives of others (e.g., improving a community park); and have personal authenticity (addressing students' interests, identities, and issues). Each student should be able to contribute to projects, particularly in generating questions, identifying resources to be used, understanding their tasks and roles, and creating the final products, as well as in using their judgment while solving problems or answering a driving question. To improve PBL, students and teachers should reflect throughout the learning process on the aspect they are learning, the method of learning, and the reasons for learning. Instructions should be provided by teachers on how to provide and receive constructive peer feedback with evidence that will lead to improvements in project processes and products. As a result of PBL, students will be allowed to share their finished product with the public.

2.2.3 Gold Standard Project-based Learning Framework

Larmer, Mergendoller, and Boss utilized the 16th-century "progetti," adding the approaches by William Kirkpatrick and John Dewey, along with characteristics of PBL, to establish a Gold Standard PBL, the gold standard in the PBL field (John Larmer et al., 2015). The Gold Standard PBL approach (John Larmer et al., 2015) is relevant and necessary in the classroom. Larmer (2020) mentioned in a blog post that "in good projects, students apply knowledge to the real world and solve problems, answer complex questions, and create quality products." Accordingly, teachers should strive for the Gold Standard PBL, as it has been considered Larmer and some scholars to be the best form of PBL. The PBL Gold Standard contains two components: the Essential Project Design Elements and Practices in Project-Based Learning (John Larmer et al., 2015).

As shown in Figures 2.4 and 2.5, the Buck institute for Education provides a framework for PBL that is defined by 7 essential elements of a project design and 7 project-based teaching practices.

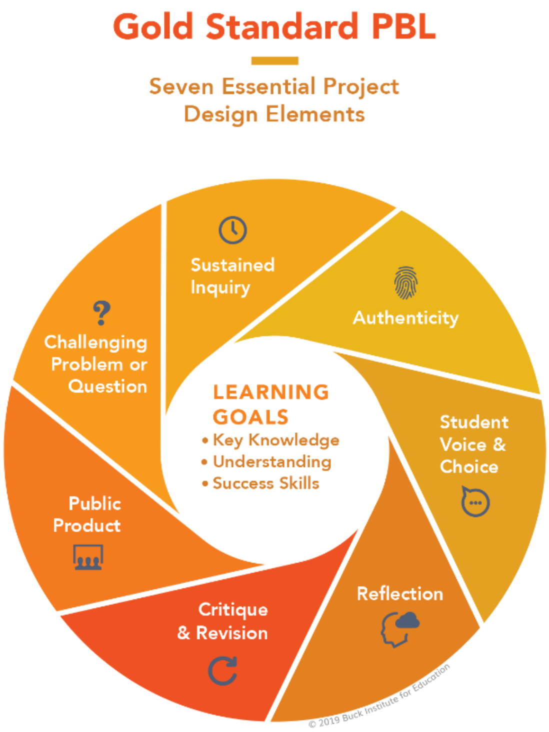

Figure 2. 4 Gold Standard PBL-Seven Essential Project Design Elements as Defined in pblworks.org

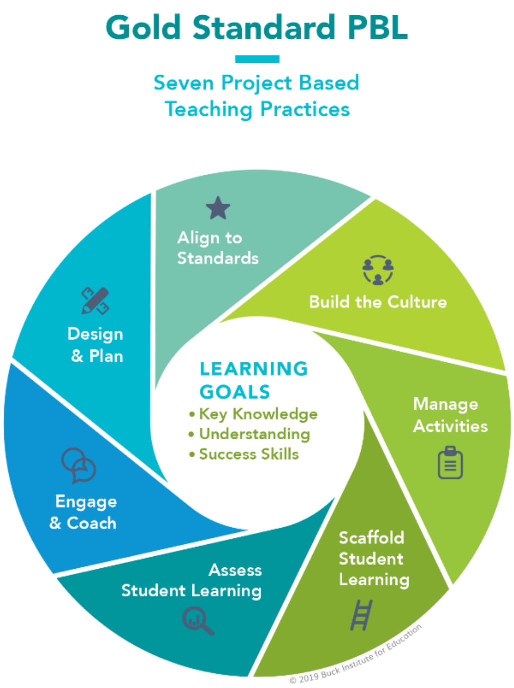

Figure 2. 5 Gold Standard PBL-Seven Essential Project Design Teaching Practices as defined in pblworks.org

Note: Gold standard project design and teaching practice models for project-based learning. Reprinted from “Setting the standard for project-based learning: A proven approach to rigorous classroom instruction,” by J. Larmer, J. Mergendoller, and S. Boss, 2015, ASCD. Copyright 2015 by ASCD. Reprinted with permission

According to this framework, project design involves the following 7 essential elements:

1. Challenging problem: PBL courses encourage students to tackle challenging problems with appropriate levels of complexity.

2. Sustained inquiry: The posed challenging problem should encourage students to gather relevant information and conduct competitive benchmarking at every stage.

3. Authenticity: The challenging problems should not be fictional, and validity of their solutions must be pretested.

4. Students' voice and choice: Students should be given ample opportunity to express their opinions at every stage of the project, and the choices made by students should be evaluated.

5. Reflection: Students, along with their mentor, should be able to quickly reflect and learn from their mistakes.

6. Critique and revision: Teachers should provide feedback to students on their work, in addition to providing them the opportunity to make revisions.

7. Public product: Students should also be provided opportunities to showcase their work.

PBL also identifies project-based teaching practices, as shown in Figure 2.5.

1. Designing and planning: To create a positive learning experience, educators must effectively articulate the activities so that the specific outcomes can be achieved throughout each activity.

2. Aligning to standards: Teachers should ensure that activities are aligned with defined outcomes.

3. Building the culture: Teachers are responsible for providing sufficient opportunities for promoting professional outcomes such as fostering a culture of team spirit, promoting effective communication, and respecting deadlines and morals.

4. Managing activities: Students must be assisted by their teachers in organizing their activities and finding and using resources to complete their activities.

5. Scaffolding students' learning: Educators should ensure and moderate the learning of students to achieve specific outcomes.

6. Assessing students' learning: During formative assessments, teachers should provide inputs to students to help them improve their performance.

7. Engaging and coaching: Teachers should closely associate with students to understand students' requirements of hand-holding, redirection, encouragement, and celebration.

According to the aforementioned Gold standard PBL model, this study redesigned the project design elements and teaching practices and implemented them in the experimental group by using innovative teaching methods.

2.2.4 Product design education and Project-based learning

Design practice in the 21st century differs considerable from that in the past (Wormald & Rodber, 2008). The role of design is becoming increasingly integrated with society, and new practices are emerging (Broadbent & Cross, 2003). Designing products has become challenging for product designers, and it has evolved from focusing solely on aesthetics to encompassing other elements such as services, branding, business strategy, and technology (Council, 2007; Maciver & O'Driscoll, 2010). Different design areas are extending into each other, eradicating boundaries across disciplines. Until now, product design education has only focused on the physical components of products; however, today's designers require skills from multiple disciplines and fields that influence product design (Weightman & McDonagh, 2006). There has been a shift toward user-centered design, strategic planning, innovative product development, sustainable product development, and interdisciplinary collaboration (Beucker, 2004; Kolko, 2005). During the design process, designers need cognitive skills, in addition to other skills such as negotiation, problem-solving, and interpersonal and project management skills, and should be able to take responsibility for outcomes (Lewis & Bonollo, 2002). Due to the increasingly diverse role of a product designer, design education should aim to equip students with transferable skills to work on a range of design problems and prepare them for change (Wormald & Rodber, 2008). Consequently, the teaching environment in design education should be transformed from teaching-centered to learning-centered that enables students to experiment and discover their own potential in and beyond academic programs (Mott et al., 2006).

Most problems faced by designers today are ill-defined and overcoming them requires interdisciplinary skills (Kruger & Cross, 2006), (Jonassen, 2008) (De Vere et al., 2010). Thus, designers are tackling a wider range of design problems involving complex systems and are applying specialist expertise, whenever necessary (Frey & Dym, 2006; Moritz & Blank, 2005). Despite industrial advancements, there is a belief that education does not provide these opportunities and that product design students are not well prepared for employment after graduation (J. Yang, 2005). Therefore, students must be able to acquire complementary skills and be prepared for assuming diverse roles in the industry. According to Hussain et al. (Jabarullah & Hussain, 2019), a total of 13 soft skills can be enhanced and improved through PBL approaches, namely social, teamwork, problem solving, ethics and morals, communication, continuous learning, leadership, crisis management, creative and critical thinking, managing information, and entrepreneurship. PBL can also help students develop creativity and thinking skills, improve communication skills, enhance collaboration skills, build self-directed inquiry capacities, and foster lifelong learning (Condliffe, 2017). Furthermore, PBL is known to support social learning because it serves as a means for students to acquire 21st century skills, including communication, teamwork, and collaboration (Kokotsaki et al., 2016). Quint and Condliffe (2018) asserted that PBL is a complex task that engages students in designing, problem solving, decision-making, and conducting research. PBL is considered an effective approach in higher education to promote students' learning. Moreover, it is an instructional approach that integrates 21st century skills to prepare students to meet the work skill demand and succeed on employment (John Larmer & Mergendoller, 2010). A key feature of PBL is its problem-orientated nature, wherein a problem or question serves as the basis for learning activities. Therefore, enabling students to resolve real-life problems in their studies and reflect in and on their action (Schon, 1983) may promote the process of knowledge restructuring for the development of required expertise. Hence, considering the problems faced by people in the "post-epidemic era" in their daily lives as research topics, we employed PBL to allow students to solve their problems.

CHAPTER 3 An Exploration of Creativity Level and the Influencing Factors of Students (Study 1)

In this chapter…

- Research objective
- Research respondents
- Research methodology
- Calculating reliability and validity
- Results
- Analysis of the influencing factors for students' creativity
- Analysis of the difference between the application of creative thinking methods and students' product design ability
- Conclusions
- Summary of this chapter

Chapter 3 An Exploration of Creativity Level and the Influencing Factors of Students (Study 1)

In this chapter, we present the findings of a questionnaire survey, which was conducted to evaluate the personal creativity level and the influencing factors for college students majoring in product design. We explored the current product design capabilities of the students majoring in product design, their cognition of creative thinking methods, and their perceptions and preferences for teaching methods and course forms. The data collected in this investigation were used to design the teaching method, which is described in the following section.

3.1 Research objective

The present study evaluated the creativity level of product design students and determined the factors that affect the creativity of these students. Students majoring in product design were the study subjects. We examined the dimensions of product design students' current product design ability and their cognition of creative thinking methods. Through the analysis of the results, we intend to provide educators a basis and guidance for more educators in instructional design for enhancing students' creativity.

3.2 Research respondents

The study participants comprised students from the Dalian University of Science and Technology (China) majoring in product design. The participants were studying in the second, third, and fourth years of the course. More than a half of the participants (54.8%) were women, whereas the remaining were men (45.2%).

3.3 Research methodology

We compiled a questionnaire for "An investigation of the situation of personal creativity and influencing factors of college students in product design", as shown in Appendix 1. The questionnaire comprised a total of 47 questions, of which 44 were single-choice questions and 3 were multiple-choice questions. The questionnaire survey was conducted online. A total of 183 questionnaires were distributed to the students, of which 177 were returned; thus, 177 valid questionnaires were recovered, with the recovery rate being 96.72%. The first section of the questionnaire comprised questions pertaining to students' basic information. Afterward, the respondents were asked to rate their creativity level, current product design abilities and their cognition of creative thinking methods on a 5-point Likert scale. The 3 multiple-choice questions in the questionnaire were used to investigate students' ability of using creative thinking methods and their cognition and demand for teaching methods. To ensure the validity and reliability of the scale, we tested samples of measurement data of the scale variables in the questionnaire.

3.4 Calculating reliability and validity

3.4.1 Reliability analysis of scale data

Reliability analysis is used to determine whether the sample answer results are reliable, that is, whether the sample actually answers the scale items. According to Wu and Chang (2016), a Cronbach's α value of >0.7 indicates a high reliability. As shown in Table 3.1, the overall reliability of the questionnaire was high because the Cronbach's α of all dimensions met the criteria. Additionally, the Cronbach's α value for the overall questionnaire was greater than 0.9, indicating that the questionnaire exhibited a high reliability.

Table 3. 1 Reliability analysis of scale data (Cronbach α)

	N of Items	N	Cronbach α
Cognitive validity analysis of the impact of teaching methods and curriculum form on creativity	9	177	0.936
Cognitive validity analysis of product design ability	7	177	0.914
Cognitive validity analysis of creative thinking methods	11	177	0.942

3.4.2 Validity analysis of scale data

3.4.2.1 Cognitive validity analysis of the impact of teaching methods and curriculum form on creativity

Table 3. 2 Validity Analysis of the impact of teaching methods and curriculum form on creativity

Items	Factor Loadings	Communalities
	Factor 1	
Do you think completing homework tasks independently will affect your creativity	0.578	0.414
Do you think working in groups will affect creativity	0.641	0.41
Do you think the understanding of creative thinking methods will affect creativity	0.787	0.619
Do you think the teaching environment will affect your creativity	0.793	0.628
Do you think teachers' teaching methods will affect your creativity	0.853	0.728
Do you think the content of assignments in the course will affect your creativity	0.801	0.642
Do you think the assignment based on competition will affect your creativity	0.878	0.772
Do you think homework tasks based on real-world projects will affect your creativity	0.877	0.77
Do you think the assignment of virtual project proposition will affect your creativity	0.815	0.665
Do you think the design-studio teaching method will affect your creativity	0.876	0.768
Do you think project-based learning will affect your creativity	0.876	0.768
Eigenvalues (Initial)	7.104	-
% of Variance (Initial)	64.579%	-
% of Cum. Variance (Initial)	64.579%	-
Eigenvalues (Rotated)	7.104	-

% of Variance (Rotated)	64.579%	-
% of Cum. Variance (Rotated)	64.579%	-
KMO	0.915	-
Bartlett's Test of Sphericity (Chi-Square)	1624.464	-
df	55	-
p value	0	-

Validity analysis involves factor analysis, a data analysis method, to conduct a comprehensive analysis based on the KMO value, communality, variance interpretation rate value, factor load coefficient value, and other indicators. The analysis helps verify the validity of the data. The KMO (Kaiser-Meyer-Olkin) test statistic is an indicator used to compare simple and partial correlation coefficients between variables. It is mainly used in factor analysis of multivariate statistics. the KMO statistic is taken as a value between 0 and 1. When the sum of squared simple correlation coefficients among all variables is much larger than the sum of squared partial correlation coefficients, the closer the KMO value is to 1, the stronger the correlation between variables, and the more suitable the original variables are for factor analysis. The KMO value is used to determine the suitability of information extraction; the communality value is used to eliminate unreasonable research items; the variance interpretation rate value is used to explain the level of information extraction, and the factor load coefficient is used to examine the corresponding relationship between factors (dimensions) and items. As shown in Table 3.2, the corresponding communality values of all research items were higher than 0.4, indicating that the information of research items can be effectively extracted. In addition, the KMO value was 0.915, which is greater than 0.6, indicating that the data can be effectively extracted. In addition, the variance interpretation rate of one factor was 64.579%, whereas the cumulative variance interpretation rate after rotation was 64.579%, which is greater than 50%, implying that a large amount of information on the research item can be extracted effectively.

3.4.2.2 Cognitive validity analysis of product design ability of the students

As shown in Table 3. 3, the corresponding communality values of all research items were higher than 0.4, indicating that the information of research items can be effectively extracted. In addition, the KMO value was 0.939, which is greater than 0.6, indicating that the data can be effectively extracted. In addition, the variance interpretation rate of one factor was 66.872%, and the cumulative variance interpretation rate after rotation was 66.872%, which is >50%, implying that a large amount of information of the research item can be extracted effectively.

Table 3. 3 Validity Analysis of product design ability of the students

Items	Factor Loadings	Communalities
	Factor 1	
How well do you understand the product design process by studying the product design course	0.766	0.587
How is your capability of product appearance design by studying the product design course	0.88	0.774

How is your material application ability of products by studying the product design course	0.806	0.65
How is your product structure design capability by studying the product design course	0.864	0.747
How is your hand drawing expression ability of product modeling design by studying the product design course	0.766	0.587
How well do you currently prototype with the computer for product design by studying the product design course	0.736	0.542
How is your current ability to identify problems that existed in product design by studying the product design course	0.848	0.718
What do you think of your ability to complete product design independently by studying the product design course	0.856	0.734
How is your current ability to participate in team cooperation by studying the product design course	0.824	0.679
Eigenvalues (Initial)	6.018	-
% of Variance (Initial)	66.872%	-
% of Cum. Variance (Initial)	66.872%	-
Eigenvalues (Rotated)	6.018	-
% of Variance (Rotated)	66.872%	-
% of Cum. Variance (Rotated)	66.872%	-
KMO	0.939	-
Bartlett's Test of Sphericity (Chi-Square)	1168.503	-
df	36	-
p value	0	-

3.4.2.3 Cognitive validity analysis of creative thinking methods used by the students

As shown in Table 3.4, the corresponding communality values of all research items were higher than 0.4, indicating that the information of research items can be effectively extracted. In addition, the KMO value was 0.860, which is greater than 0.6, indicating that the data can be effectively extracted. In addition, the variance interpretation rate of one factor was 66.300%, and the cumulative variance interpretation rate after rotation was 66.300%, both of which are >50%. These data indicate that the amount of information on the research item can be extracted effectively.

Table 3. 4 Validity analysis of the creative thinking methods used by the students

Items	Factor Loadings	Communalities
	Factor 1	
Can you apply the brainstorming method skillfully	0.838	0.702
Can you apply mind mapping skillfully	0.83	0.689
Can you skillfully apply the 5W2H method	0.806	0.65
Can you skillfully use the attribute listing method	0.839	0.704
Can you apply the biomimicry method skillfully	0.756	0.571
Can you skillfully apply the SCAMPER method	0.843	0.711

Can you use the association method skillfully	0.783	0.614
Eigenvalues (Initial)	4.641	-
% of Variance (Initial)	66.300%	-
% of Cum. Variance (Initial)	66.300%	-
Eigenvalues (Rotated)	4.641	-
% of Variance (Rotated)	66.300%	-
% of Cum. Variance (Rotated)	66.300%	-
KMO	0.86	-
Bartlett's Test of Sphericity (Chi-Square)	886.177	-
df	21	-
p value	0	-

3.5 Results

3.5.1 Basic analysis of the students' creativity level

3.5.1.1 Statistical analysis of the students' creativity level

Table 3. 5 Basic analysis of students' creativity level

Items	Categories	N	Percent (%)	Cumulative Percent (%)
Do you have any experience in art training before learning the professional course of product design	Yes	126	71.19	71.19
	No	51	28.81	100
Have you received creativity training before taking the professional course in product design	Yes	69	38.98	38.98
	No	108	61.02	100
I have been trained in design creativity for several years	Less than one year	82	46.33	46.33
	a year	34	19.21	65.54
	two years	21	11.86	77.4
	three years	21	11.86	89.27
	More than three years	19	10.73	100
What do you think of your current creativity	Very poor	6	3.39	3.39
	bad	35	19.77	23.16
	general	104	58.76	81.92
	Better	23	12.99	94.92
	very nice	9	5.08	100
Total		177	100	100

According to basic research on creativity training of the students majoring in product design before they attended the professional course in product design, the proportion of students who received art training and those who did not receive art training was approximately 7:3, whereas the proportion of students who received creativity training and those who did not receive creativity training was approximately 4:6. These results suggest that most of the students who attended the professional course in product design had a certain artistic foundation, but their overall creativity level was poor. Furthermore, the survey of students who had received creativity training indicated that the overall time for the students to receive creativity training was short, and half of the students mentioned that their current creativity level is average or poor (see Table3. 5).

3.5.2 Analysis of the difference between creativity training and students' work

3.5.2.1 Analysis of the difference between creativity training and students' work

We compared the fluency, flexibility, originality, and elaboration of students' works, irrespective of whether they received creativity training or not; both the students who received creativity training and those who did not receive creativity training scored the fluency, flexibility, originality, and elaboration of their personal works as shown in Table3.6. We found that the students who had received creativity training exhibited significantly higher satisfaction in terms of fluency, flexibility, originality, and elaboration of their work, with the difference being significant at the 0.05 level. Therefore, we concluded that the individuals who receive creativity training perform better in all the four dimensions, namely fluency, flexibility, originality, and elaboration.

Table 3. 6 Analysis of the difference between creativity training and students' works

	Have you been trained in creativity (Mean±Std. Deviation)		F	p
	Yes (n=69)	No (n=108)		
Flexibility	3.29±0.82	2.94±0.77	8.001	0.005**
Fluency	3.35±0.72	3.02±0.71	8.916	0.003**
Originality	3.39±0.83	3.12±0.75	5.108	0.025*
Elaboration	3.45±0.80	3.08±0.77	9.193	0.003**

* $p < 0.05$ ** $p < 0.01$

3.5.2.2 Analysis of the difference between creativity training and students' problem identifying and solving ability

Table 3. 7 Analysis of the difference between creativity training and students' problem identifying and solving ability (ANOVA)

	Have you been trained in creativity (Mean±Std. Deviation)		F	p
	Yes (n=69)	No (n=108)		
Ability to identify problems independently	3.43±0.93	3.14±0.78	5.208	0.024*
Ability to solve problems independently	3.45±0.76	3.11±0.74	8.62	0.004**

* $p < 0.05$ ** $p < 0.01$

As shown in Table 3.7, by comparing the students' ability to identify and solve problems independently, we found that the students who had received creativity training had a better evaluation of their ability to identify problems independently than the students who did not receive such training, showing a significant difference at the 0.05 level ($F = 5.208$, $P = 0.024$). In addition, they exhibited a better evaluation of their ability to solve problems independently, with a significant difference at the 0.05 level (F = 8.62, P = 0.004). Therefore, we infer that future education should aim to strengthen students' creativity through training to improve their ability to identify and solve problems independently.

3.5.2.3 Analysis of the difference between the duration of creativity training and students' ability to identify and solve problems independently

A comparative analysis of the students' ability to identify and solve problems independently based on the duration of creativity training indicated that the students who had received creativity training for different duration of time showed significant differences in their ability to identify and solve problems independently at the 0.05 level. As shown in Table 3.8, students' ability to solve problems independently is affected by the duration of creativity training. Moreover, the 19 respondents with >3 years of creativity training were also significantly better at independently identifying and solving problems than those with <1 year of creativity training.

Table 3. 8 Analysis of the difference between the duration of creativity training and students' ability to identify problems and solve problems independently (ANOVA)

	Duration of creativity training (Mean±Std. Deviation)					F	p
	Less than one year (n=82)	a year (n=34)	two years (n=21)	three years (n=21)	More than three years (n=19)		
Ability to identify problems independently	2.91±0.79	3.59±0.70	3.38±0.86	3.57±0.87	3.63±0.83	7.251	0.000**
Ability to solve problems independently	3.01±0.75	3.41±0.66	3.24±0.62	3.48±0.87	3.68±0.75	4.738	0.001**

$* p < 0.05$ $** p < 0.01$

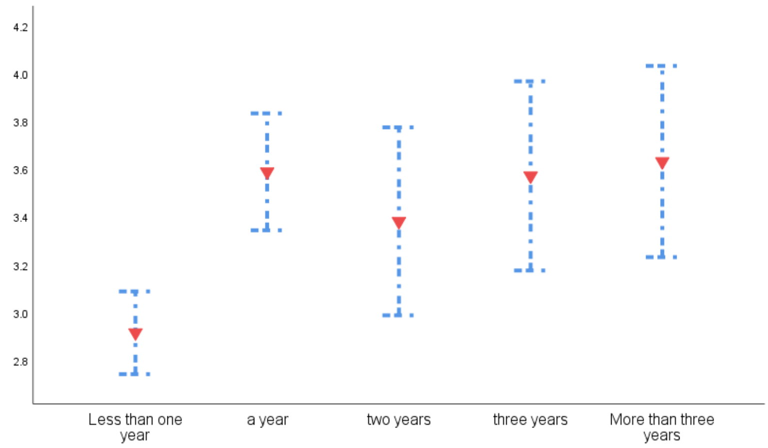

Figure 3. 1 The difference analysis between the duration of creativity training and students' ability to identify problems independently

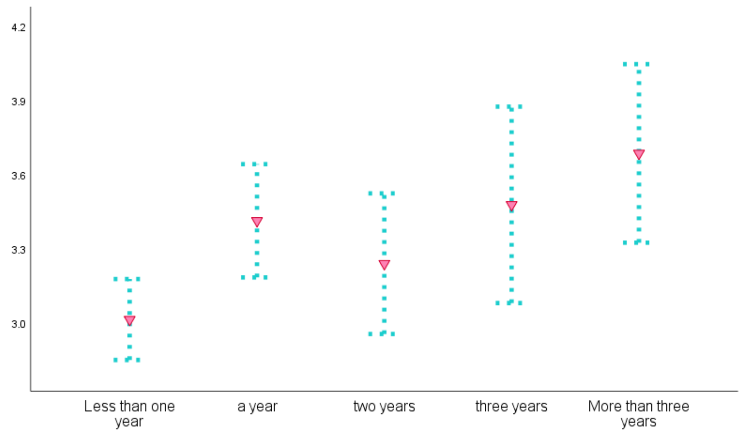

Figure 3. 2 The difference analysis between the duration of creativity training and students' ability to solve problems independently

3.5.2.4 Analysis of the difference between the duration of creativity training and creativity in students' works

Table 3.9 illustrates that the students who received creativity training for different periods of time exhibited significant differences in the fluency, flexibility, originality, and elaboration of their product design at the 0.05 level. Furthermore, the results indicated that the students who received creativity training for more than 3 years had a higher evaluation of the fluency, flexibility, originality, and elaboration of their own products. Consequently, we suggest that creativity training should be continually integrated into the curriculum to improve the quality of students' work in four aspects, namely fluency, flexibility, originality, and elaboration.

Table 3. 9 Analysis of the difference between the duration of creativity training and creativity in students' works

	Duration of training in design creativity (Mean±Std. Deviation)					F	p
	Less than one year (n=82)	a year (n=34)	two years (n=21)	three years (n=21)	More than three years (n=19)		
Flexibility	2.80±0.76	3.32±0.68	3.10±0.54	3.24±0.94	3.63±0.90	6.227	0.000**
Fluency	2.87±0.64	3.44±0.66	3.10±0.54	3.43±0.87	3.58±0.77	7.947	0.000**
Originality	2.98±0.77	3.53±0.66	3.05±0.50	3.52±0.87	3.63±0.83	6.302	0.000**
Elaboration	3.01±0.76	3.50±0.71	3.10±0.62	3.38±0.86	3.63±0.96	4.309	0.002**

* $p < 0.05$ ** $p < 0.01$

3.5.3 Analysis of the application of creative thinking methods by the students

3.5.3.1 Statistical analysis of the application of creative thinking methods by the students

As shown in Table 3.10, all students, except for ten students, had the experience of using creative thinking methods; however, most of the respondents (69.49%) had used them occasionally. Although half of the respondents reported that the use of creative thinking methods was beneficial to their product design achievements and provided them with a positive learning effect, only 24.86% of the respondents reported that they had used creative thinking methods to develop their design work.

Table 3. 10 Basic analysis of the application of creative thinking methods

Items	Categories	N	Percent (%)	Cumulative Percent (%)
How often do you use creative thinking methods?	Never use	10	5.65	5.65
	Use occasionally	123	69.49	75.14
	Often used	44	24.86	100
Do you think using creative thinking methods has helped you complete your product design works	It didn't help at all	1	0.56	0.56
	It helps, but it doesn't help much	32	18.08	18.64
	general	40	22.6	92.66
	Very helpful	91	51.41	70.06
	uncertain	13	7.34	100
How do you think of your learning effect after applying creative thinking methods in product design	Not effective at all	4	2.26	2.26
	Minor effective	31	17.51	19.77
	great effective	93	52.54	72.32
	general	33	18.64	90.96
	uncertain	16	9.04	100
Have you ever used creative thinking methods to assist you with your design work during a product design course	Never use	9	5.08	5.08
	Use occasionally	124	70.06	75.14
	Often used	44	24.86	100
Total		177	100	100

3.5.3.2 Analysis of students' application of creative thinking methods in product design courses

We further investigated the types of creative thinking methods applied by the students in product design courses. We performed the chi-square goodness-of-fit test to analyze whether the proportions of the types of innovative thinking methods used by the students in product design courses were uniformly distributed. As shown in Table 3.11, the goodness-of-fit test showed a significant difference ($\chi^2 = 134.285$, $P = 0.000$; < 0.05) in the proportion of creative thinking methods selected by the students in product design courses, as determined by comparing the response and popularity rates. Specifically, the response rate and popularity rate of Brainstorming, Mind mapping, 5W2H method, and Association method were significantly higher than those of other methods. Thus, we concluded that Brainstorming, Mind mapping, the 5W2H method, and the Association method are the most common creative thinking methods employed by students in product design courses.

Table 3. 11 Response and popularity rates of different creative thinking methods applied in product design courses

Categories	Response		Popularity rate（n=177）
	N	Response rate	
Brainstorming	142	19.37%	80.23%
Mind mapping	127	17.33%	71.75%
5W2H method	121	16.51%	68.36%
Attribute listing method	39	5.32%	22.03%

Biomimicry method	81	11.05%	45.76%
SCAMPER	27	3.68%	15.25%
Association method	114	15.55%	64.41%
Analogy method	82	11.19%	46.33%
Total	733	100%	414.12%
Goodness-of-fit: $\chi^2 = 134.285$; $p = 0.000$			

In the early 20th century, Vilfredo Pareto, an Italian economist, stated that 80% of the wealth in the world is owned by 20% of the population (Al-Rahmi & Zeki, 2017). Pareto chart is named after Vilfredo Pareto. Pareto diagrams are typically useful or ideal when nearly 20% of the attributes have a relative frequency of 80%, revealing critical elements (Al-Rahmi & Zeki, 2017). Typically, the options corresponding to the cumulative ratio in the range of 0%–80% are considered “critical items” (Wilkinson, 2006). In the present study,creative thinking methods, namely Brainstorming, Mind mapping tool, 5W2H method, Association method, and Analogy method, exhibited a cumulative ratio of 0%–80% (Figure 3.2). Hence, we inferred that the respondents considered Brainstorming, Mind mapping tool, 5W2H method, Association method, and Analogy method as the most crucial methods in product design courses. Generally, options with a cumulative ratio of 80%–100% are considered “insignificant items” (Wilkinson, 2006). In our study, the methods with cumulative ratios in the 80%–100% range included the Biomimicry method, Attribute listing method, and SCAMPER (Figure 3.2), indicating that these creative thinking methods were not primarily utilized by the respondents during the course.

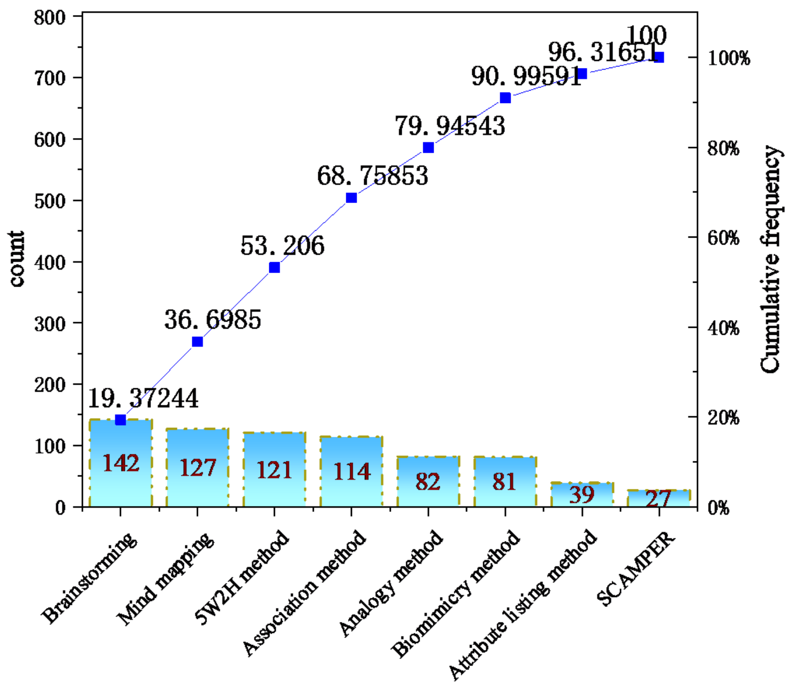

Figure 3. 3 Pareto Diagram of the types of creative thinking methods employed by students

3.5.3.3 Analysis of the effects of receiving creativity training versus familiarity with creative thinking methods

We performed a difference analysis of whether the students received creativity training and their familiarity with various creative thinking methods. The results of the variance analysis indicated that the students who had received creativity training and those who had not received creativity training exhibited a significant difference at the 0.05 level when using the Brainstorming method ($F = 4.953$, $p = 0.027$). Additionally, the students who received creativity training and those who did not receive creativity training exhibited a significant difference in using the creative thinking method "Mind Mapping" at the 0.05 level ($F = 4.982$, $p = 0.027$). The students who received creativity training and those without creativity training showed a significant difference at the 0.001 level ($F = 13.022$, $p = 0.000$) in using the "Association method" of creative thinking. Thus, we inferred that the students who receive creativity training could better apply the three creative thinking methods, Brainstorming, Mind Mapping, and Association method, than those without creativity training.

Table 3. 12 Analysis on the difference of familiarity between creativity training and the use of creative thinking methods

	Have you been trained in creativity (Mean±Std. Deviation)		F	p
	Yes (n=69)	No (n=108)		
Can you apply the brainstorming skillfully	3.46±0.81	3.19±0.81	4.953	0.027*
Can you apply mind mapping skillfully	3.51±0.82	3.23±0.79	4.982	0.027*
Can you skillfully apply the 5W2H method	3.30±0.97	3.13±0.97	1.365	0.244
Can you skillfully use the attribute listing method	3.03±1.06	2.81±0.85	2.406	0.123
Can you apply the biomimicry method skillfully	3.13±0.86	3.00±0.83	1.012	0.316
Can you skillfully apply the SCAMPER method	2.83±1.03	2.61±0.93	2.082	0.151
Can you use the association method skillfully	3.51±0.87	3.04±0.83	13.022	0.000**

* $p < 0.05$ ** $p < 0.01$

3.6 Analysis of the influencing factors for students' creativity

3.6.1 Statistics of the influencing factors for students' creativity

We further explored the factors that influence the creativity of students. A chi-square goodness-of-fit test was used to determine whether the factors affecting students' creativity were equally distributed. According to Table 3.13, the goodness-of-fit test revealed a significant result ($\chi2 = 47.823$, $p = 0.000$; *0.05), indicating that the selection proportion of factors affecting students' creativity varied significantly. By comparing the response rate and popularity rate of all items, we found that the "Teacher's teaching methods" and "lack of understanding of creative thinking methods" were the main factors that affected the creativity of the respondents (see Table 3.13).

Table 3. 13 Response and popularity rates of the influencing factors of students' creativity

Categories	Response		Response rate（n=177）
	N	Response rate	
Teacher's teaching methods	109	33.23%	61.58%

Not interested in homework proposition	53	16.16%	29.94%
Other	42	12.80%	23.73%
lack of understanding of creative thinking methods	78	23.78%	44.07%
Rigid teaching environment	46	14.02%	25.99%
Total	328	100%	185.31%

Goodness-of-fit: $\chi^2 = 47.823$ p = 0.000

Regarding the influencing factors that affect students' creativity, we found that the main influencing factors with a cumulative ratio ranging from 0% to 80% included teacher's teaching methods, lack of understanding of creative thinking methods, and no interest in homework proposition (Figure 3.4). The results further indicated that teachers' teaching methods, a lack of understanding of creative thinking methods, and a lack of interest in homework propositions were the most important items selected by the respondents in response to the question "Factors Affecting Students' Creativity." As mentioned earlier, options corresponding to the cumulative ratio of 80%–100% are considered "insignificant items." Items with the cumulative ratio in this range includes rigid teaching environments and other factors, indicating that the respondents considered the aforementioned factors as having less influence on their creativity.

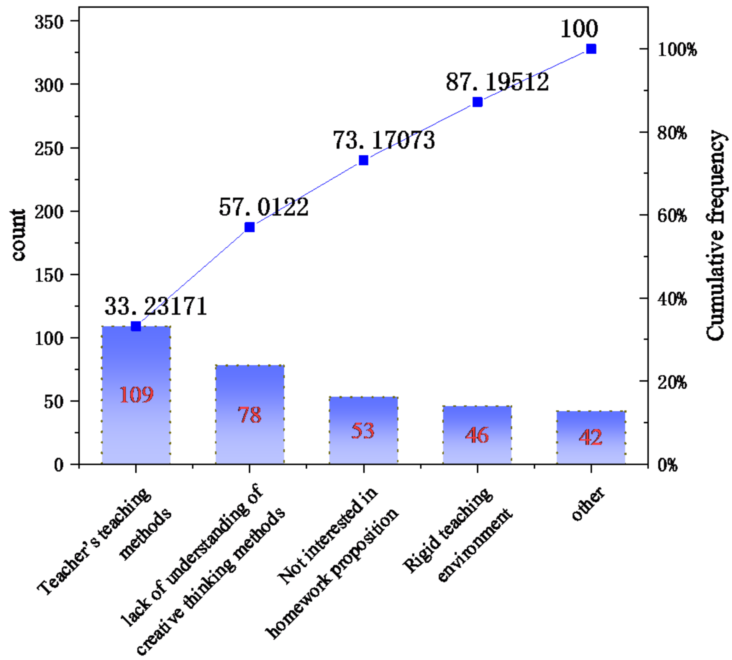

Figure 3. 4 Pareto statistics of the influencing factors of students' creativity

3.6.2 Analysis of the preference of students for the forms of the courses

We further investigated the preference of students for the forms of the courses. Furthermore, we conducted a chi-square goodness-of-fit test to determine whether the proportion distribution of the preferences of students for the forms is uniform. The goodness-of-fit test showed a significant result ($\chi2 = 76.289$, P = 0.000; *0.05), indicating that the students' preferences for the course format differed significantly (Table 3.14). A comparison of the response rate and popularity rate indicated that the option "Focusing on practical projects" was chosen by most respondents, indicating that most of the students preferred the courses focusing on practical projects.

Table 3. 14 Analysis of the response rate and popularity rate of students' preference for the forms of the courses

Categories	Response		Response rate（n=177）
	N	Response rate	
Focus on competition topics	74	24.34%	41.81%
Focus on practical projects	136	44.74%	76.84%
other	63	20.72%	35.59%
Focus on virtual topics	31	10.20%	17.51%
Total	304	100%	171.75%

Goodness of fit: $\chi^2 = 76.289$ p=0.000

Figure 3.5 depicts the form of the courses preferred by the students. As shown in the figure, the options with a cumulative ratio in the range of 0%–80% included "focus on practical projects" and "focus on competition topics," indicating that these two items were considered by the respondents in response to the question "Students' preferred course format." The cumulative proportions of the "Focus on virtual topics" and "Other" categories ranged between 80% and 100%, indicating that the respondents did not consider these two items in their preferred course formats.

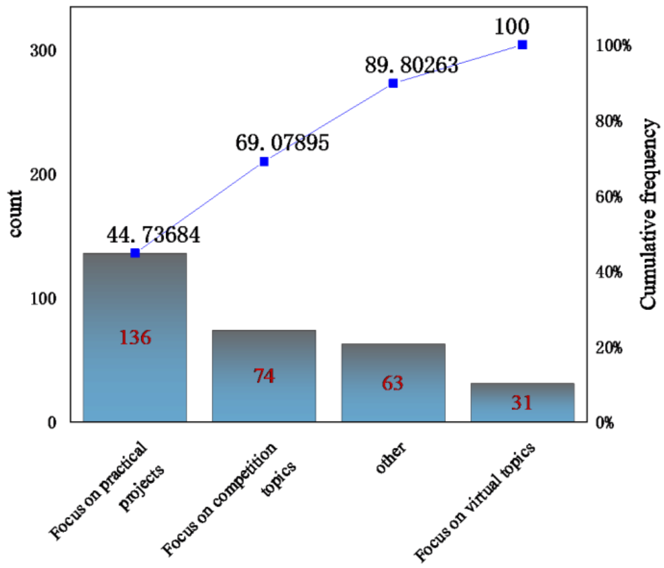

Figure 3. 5 Pareto statistics of the students' preference for the forms of the courses

3.6.3 Analysis of students' needs for guiding creative thinking methods for teachers

Table 3. 15 Analysis of the students' needs for guiding creative thinking methods for teachers

Items	Categories	N	Percent (%)	Cumulative Percent (%)
Would you like teachers to guide creative thinking methods in product design courses at this stage	No	2	1.13	1.13
	Optional	9	5.08	6.21
	depending	66	37.29	43.5
	I would like to	70	39.55	83.05
	essential	30	16.95	100
Total		177	100	100

As shown in Table 3.15, we found that a vast majority of the respondents expect to be guided by teachers to use creative thinking methods and believe that teachers' guidance can improve their design work during the course. Therefore, teachers should consider explaining creative thinking methods in the courses.

3.6.4 Statistical analysis of the influencing factors of creativity in students of different genders

We explored the factors that influence the creativity of both male and female students. The factors affecting personal creativity mentioned by the male respondents included completing homework tasks independently, working in groups, understanding creative thinking methods, teachers' teaching methods, project proposition forms, and project learning methods, whereas those mentioned by the female respondents included the teaching environment, competition-based assignments, and design-studio teaching (Table 3.16).

Table 3. 16 Statistical analysis of the influencing factors of creativity in students of different genders

Items	Gender		Total
	male	female	
Do you think completing homework tasks independently will affect your creativity	3.063	3	3.028
Do you think working in groups will affect creativity	3.2	3.165	3.181
Do you think the understanding of creative thinking methods will affect creativity	3.325	3.278	3.299
Do you think the teaching environment will affect your creativity	3.362	3.371	3.367
Do you think teachers' teaching methods will affect your creativity	3.5	3.351	3.418
Do you think the content of assignments in the course will affect your creativity	3.5	3.505	3.503
Do you think the assignment competition-based assignments will affect your creativity	3.362	3.381	3.373
Do you think homework tasks based on real-world projects will affect your creativity	3.3	3.278	3.288
Do you think the assignment of a virtual project proposition will affect your creativity	3.288	3.247	3.266
Do you think the design-studio teaching method will affect your creativity	3.25	3.34	3.299
Do you think project-based learning will affect your creativity	3.337	3.278	3.305

3.7 Analysis of the difference between the application of creative thinking methods and students' product design ability

By comparing the differences between students' use of creative thinking methods and their product design ability in the process of completing product design, we found that the students who had never used creative thinking methods exhibited a poor understanding of the product design process (Table 3.17). Furthermore, this comparative analysis indicated that the students who had never used creative thinking methods as aid had a poor understanding of the product design process. Their self-evaluation of product appearance design capability, material application ability, structural design capability, hand drawing expression ability of product modeling design, prototype with the computer for product design, problem identifying ability, independent completion ability, and participate in team cooperation ability level were significantly weaker than those of the students who had occasionally used or those who often use the creative thinking methods; the difference was significant at the level of 0.001, indicating that the use of creative thinking methods has a greater impact on students' product design ability, prototype with the computer for product design, ability to identify problems that existed in product design, ability to complete product design independently, and participate in teamwork. The significance of the difference at the 0.001 level indicated that the application of creative thinking methods has a great impact on students' product design ability.

Table 3. 17 The difference between the application of creative thinking methods and the effect of students' product design ability

	Have you ever used creative thinking methods to assist in the completion of design (Mean±Std. Deviation)			F	p
	Never use (n=9)	Use occasionally (n=124)	Often used (n=44)		
Understanding the product design process	2.78±0.97	3.39±0.66	3.93±0.79	14.34	0.000**
Product appearance design capability	2.33±0.87	3.24±0.65	3.84±0.68	23.622	0.000**
Material application ability of products	2.44±0.88	3.12±0.73	3.68±0.80	14.074	0.000**
Product structure design capability	2.56±1.01	3.03±0.74	3.73±0.73	17.074	0.000**
Hand drawing expression ability of product modeling design	2.56±1.01	3.16±0.80	3.86±0.80	16.266	0.000**
Prototype with the computer for product design	2.44±1.33	3.26±0.67	3.93±0.73	21.681	0.000**
Ability to identify problems that existed in product design	2.56±1.24	3.22±0.62	3.91±0.68	23.79	0.000**
Ability to complete product design independently	2.67±1.22	3.21±0.57	4.00±0.53	33.817	0.000**
Ability to participate in team cooperation	2.67±1.22	3.27±0.64	3.89±0.62	18.923	0.000**

* $p < 0.05$ ** $p < 0.01$

3.8 Conclusions

In this study, we conducted a questionnaire survey in 177 students majoring in product design to explore their creativity level and the factors influencing their creativity.

Data analysis indicated that the creativity level of the students is generally poor. We also examined the reasons for low creativity levels among the students. Questionnaire data analysis demonstrated that low creativity in students is primarily a result of teachers' inferior teaching methods. Additionally, a lack of understanding of creative thinking methods, disinterest in homework propositions, and a rigid teaching environment contributed to the lack of creativity among students. The aforementioned influencing factors provide a basis for designing innovative teaching methods in the future.

The majority of the 177 participants in our study had received art training; however, only 38.98% of them had been taught systematic creativity. Most students received creativity training for a short period, and half of these students indicated their creativity levels as average or poor. Thus, we must focus on enhancing creativity among students.

Based on the questionnaire survey results, we put forward the following recommendations:

- Creativity education should be integrated into the curriculum and teaching

The data suggest that the students' involvement in creativity training increases their creativity level. Furthermore, creativity training improves fluency, flexibility, originality, and elaboration of students' work. Additionally, training significantly affects students' ability to identify and solve problems. We recommend fully integrating creativity education into the product design curriculum. Teachers must provide fundamental product design knowledge to students and develop specific teaching strategies to enhance their creativity.

- Educators must teach creative thinking methods effectively

Through analysis of the results, we indicated that although more than a half of the students believe that creative thinking methods can assist them in completing product design and provide them with better learning techniques, 69.49% of students occasionally use these methods. Based on the data in Table 3.13, we inferred that students' lack of understanding of creative thinking methods and inappropriate teaching methods might be the reasons for the infrequent usage of creative thinking methods by the students. Thus, educators should adjust traditional teaching methods to emphasize using different types of creative thinking methods during product design and help students develop flexibility in applying these methods.

- Educators should teach varied creative thinking methods to students

Table 3.11 revealed that Brainstorming, Mind mapping, 5W2H methods, and Association methods are the most common creative thinking methods used in product design courses. However, inculcating creativity among students should not be limited to these three commonly used methods. Teachers must provide students with varied creative thinking methods at different phases of the design process.

- Adjusting the course form to a practical project

A comparative analysis of the response rate and popularity rate indicated that most students chose the option "Focusing on practical projects," indicating that most students preferred courses focused on practical projects (Table 3.14). Hence, we recommend that educators should set up practical projects in their courses to motivate students to participate in the learning process. Additionally, the homework propositions should be related to subjects that interest the students to enhance their creativity.

3.9 Summary of this chapter

The present study involved a questionnaire survey, wherein the questionnaire was administered to 177 students majoring in product design to explore their creativity level and the influencing factors. According to the data analysis, students' creativity, in general, was poor. The teaching method was the major reason for the low creativity among the students. Additionally, the lack of understanding of creative thinking methods, disinterest in homework assignments, and the rigid teaching environment were identified as the factors contributing to the lack of creativity among the students. The findings of this study serve as a reference for designing an efficient teaching method in the future to enhance students' creativity by considering the aforementioned influencing factors.

CHAPTER 4 An Exploration of Teachers' Teaching Suggestions on Improving Students' Creativity (Study 2)

In this chapter…

- Research objectives
- Participants
- Research method
- Results and Finding
- Conclusions
- Summary of this chapter

Chapter 4 An Exploration of Teachers' Teaching Suggestions on Improving Students' Creativity (Study 2)

In this chapter, we outline the results of Study 2 which included a semi-structured interview with eight respondents. It helps explore their application of teaching effectiveness, perceptions, and suggestions for creative thinking methods in their teaching process. It also outlines the research objectives, participants, research methods, results and findings, a discussion of study 2, and the chapter summary. The research finding will be included in the teaching method design in the next chapters.

4.1 Research objectives

We conducted an exploratory study through semi-structured interviews with eight respondents to explore their application, teaching effectiveness, perceptions, and suggestions for creative thinking methods in the teaching process.

4.2 Participants

Eight educators from different countries and educational backgrounds participated in the semi-structured interview. The educators had an average experience of 15.75 years of learning product design and 8.75 years of teaching product design. Furthermore, all the interviewees had rich practical experience in product design. Table 4.1 presents the basic information of the interviewees.

4.3 Research method

We designed a series of open-ended questions allowing the interviewees to develop answers to each question. Researchers could add additional questions to semi-structured interviews to obtain more information. Moreover, the semi-structured interviews enabled the researcher to ask more questions relevant to the study other than those listed in the written list of guiding questions. Excluding one Korean interviewee, we conducted the interviews in English. All other interviews were conducted in the interviewee's native language (i.e., Chinese) to avoid language barriers when conveying information.

Respondents were coded serially from A1 to A8 to protect their privacy. We presented each interviewee with informed consent before conducting the interview. A clear explanation of the purpose of the interview was provided to all respondents, and online interviews were conducted with their consent. Eight respondents answered all the questions listed in Appendix 2, and there were six questions in the interview. We mainly explored the following creative thinking methods during the interview to assess the respondents' application of, teaching effectiveness in, perceptions of, and suggestions for creative thinking methods in the teaching process.

For instance, the methods included the following: Analogy, Association, Biomimicry, Brainstorming, Attribute Listing, Mind Maps, TRIZ, SCAMPER, and the 5W2H. Question 1 (Q1) investigated the basic information of the interviewees. Question 2 (Q2) explored the respondents' application, teaching effectiveness, and perceptions of creative thinking methods. The statistical evaluation of the interview results in Question 2 (Q2) was mainly analyzed as a percentage response. In our research, we utilized the SPSS （version 25） 25.0 toolbox to conduct a "Chi-square test" to assess the cognition, application scenarios, advantages, disadvantages, and teaching effects of eight creative thinking methods among educators with different educational backgrounds.

Due to the small sample size of this interview, the results were considered to be statistically nonsignificant. However, the proportional distribution enabled us to infer the differences in applying eight creative thinking methods by educators from different educational backgrounds. Tables 4.2 to 4.9 present the results of this study. Question 3 (Q3) explored the reasons for the lack of creativity among the students taught by the interviewees. In questions 4–6, the interviewees described their method of improving students' creativity through interviews. Interview data were recorded, fully transcribed, and translated into English by the researchers. The researcher double-checked and corrected the translations to ensure the reliability of the data. Thereafter, we conducted a thematic analysis to reveal the opinions and suggestions of eight educators concerning improving creativity in education.

Table 4. 1 Basic information of interviewees

Interviewee	Graduated school	Education background	Working places	Position title	Learning product design (years)	Teaching product design (years)
A1	Illinois institute of technology	Master	Dalian University of Science and Technology	Lecture	10	3
A2	Japan Advanced Institute of Science and Technology	Ph.D.	Dalian Polytechnic University	Associate Professor	20	16
A3	Tama art University	Master	Dalian University of Science and Technology	Lecture	13	4
A4	Dalian Polytechnic University	Master	Dalian University of Science and Technology	Lecture	11	3
A5	Japan Advanced Institute of Science and Technology	Ph.D.	Jingdezhen Ceramic Institute	Associate Professor	25	17
A6	Dalian Polytechnic University	Master	Dalian Jiaotong University	Associate Professor	27	21
A7	University of Minnesota	Ph.D.	Ewha Woman's University	Research Professor	10	3
A8	University of Georgia	Ph.D.	Shandong University of Technology	Lecture	10	3

Mean					15.75	8.75

4.4 Results and Finding

4.4.1 Results and finding for Question 2 (Q2) in the interview

4.4.1.1 Cognition of analogy and association methods among educators with different educational backgrounds

Table 4. 2 Teachers' cognition of the analogy and association methods in different educational backgrounds

Items	Categories	Education background (%)		Total	χ^2	p
		Master	Ph.D.			
Know or not	Known, but not used	2(50.00)	2(50.00)	4(50.00)	0	1
	Known a lot, used frequently	2(50.00)	2(50.00)	4(50.00)		
Total		4	4	8		
Most applied in	Product appearance design	3(75.00)	3(75.00)	6(75.00)	2	0.368
	Product appearance design, the cultural and creative product design	0(0.00)	1(25.00)	1(12.50)		
	Product modeling design	1(25.00)	0(0.00)	1(12.50)		
Total		4	4	8		
Advantages	Easy to produce creative ideas	2(50.00)	0(0.00)	2(25.00)	2.667	0.102
	Intuitive in comparing and associating objects	2(50.00)	4(100.00)	6(75.00)		
Total		4	4	8		
Disadvantages	Influenced by knowledge level	3(75.00)	2(50.00)	5(62.50)	1.2	0.549
	Influenced by knowledge level, and personal insights	1(25.00)	1(25.00)	2(25.00)		
	Not applicable to products with strong industrialization.	0(0.00)	1(25.00)	1(12.50)		
Total		4	4	8		
Pedagogical results	General	2(50.00)	0(0.00)	2(25.00)	3	0.223
	Satisfactory	1(25.00)	3(75.00)	4(50.00)		
	Very satisfactory	1(25.00)	1(25.00)	2(25.00)		
Total		4	4	8		

* $p < 0.05$ ** $p < 0.01$

We compared the cognition of analogy and association methods among educators with different educational backgrounds and observed an equal proportion of the results of "known but not used" and "known a lot, used frequently." According to the eight interviewees, analogy and association methods were utilized in product appearance design, cultural and creative product design, and product modeling design. In our research, we observed that only one teacher with a master's degree applied analogy and association methods to product modeling design. Meanwhile, an educator with a PhD mentioned using analogy and association methods for product appearance design and cultural and creative product design. Most educators preferred analogy and association as methods for product appearance design. Furthermore, the proportion of educators with master's degrees and teachers with doctoral degrees was similar. The analogy and association methods were considered advantages such as "Easy to generate creative ideas" and "Intuitive." An equal proportion of respondents held these views. Interviewees with doctoral degrees emphasized "Intuitive" as the key advantage of this method.

Moreover, the eight respondents listed three disadvantages of analogy and association methods: personal knowledge level and personal insight would affect the use of analogy and association methods, which would not apply to some highly industrialized products. However, most educators believe the knowledge level of an individual is the limiting factor when using the analogy and association methods. Furthermore, interviewees with doctoral degrees were all satisfied or extremely satisfied with the teaching effect created by the aforementioned methods. However, only 50% of the educators with master's degrees believed that the methods created a satisfactory teaching effect, whereas 50% of the respondents indicated that the methods created a general teaching effective.

4.4.1.2 Cognition of biomimicry method among educators with different educational backgrounds

We compared the cognition of biomimicry among teachers with different educational backgrounds and observed a significant difference at the 0.05 level ($p = 0.018 < 0.05$). According to the three interviewees with master's degrees, most of them knew the biomimicry method and used it more frequently in their teaching process. Nevertheless, four educators with doctoral degrees indicated that although they were aware of biomimicry, they seldom used it. In addition, eight interviewees listed the applications of biomimicry, such as the design of daily necessities, housewares, product appearance design, and vehicle design. The application of biomimicry was relatively higher in product appearance design and vehicle design. Interviewees mentioned two advantages of the biomimicry method: "There are many bionic objects to choose from" and "Quickly able to find associations objective." In addition, they mentioned "Easy to find associations," "Suitable for product appearance design," and "very suitable for the design of product form" as other advantages. Some educators with master's and doctoral degrees indicated that biomimicry could sometimes lead some designers to make bionic designs only by relying on the appearance of animals and plants, and some teachers believed that it would take a long time to study biomimetic objects using the biomimicry method. Thus, further research is needed. Students who used this method sometimes designed bionic products based on the appearance of animals or plants, thereby leading to weak product design innovations. A comparison of the teaching effect using the biomimicry method among the group of educators with master's degrees and those with doctoral degrees indicated that the teaching effect of educators with master's degrees was great.

Table 4. 3 Teachers' cognition of the biomimicry method in different educational backgrounds

Items	Categories	Education background (%)		Total	χ²	p
		Master	Ph.D.			
Know or not	Known, but not used	1(25.00)	0(0.00)	1(12.50)	8	0.018*
	Known a lot, but not used	0(0.00)	4(100.00)	4(50.00)		
	Known a lot, used frequently	3(75.00)	0(0.00)	3(37.50)		
Total		4	4	8		
Most applied in	Daily necessities design	0(0.00)	1(25.00)	1(12.50)	3.333	0.504
	Houseware design	1(25.00)	1(25.00)	2(25.00)		
	Product appearance design	1(25.00)	2(50.00)	3(37.50)		
	Vehicle design	1(25.00)	0(0.00)	1(12.50)		
	Vehicle design, Product appearance design	1(25.00)	0(0.00)	1(12.50)		
Total		4	4	8		
Advantages	Easy to find associations	1(25.00)	0(0.00)	1(12.50)	3.333	0.504
	Quickly able to find associations objective	1(25.00)	1(25.00)	2(25.00)		
	Suitable for product appearance design.	1(25.00)	0(0.00)	1(12.50)		
	Many bionic objects can be referenced in creation	1(25.00)	2(50.00)	3(37.50)		
	Very suitable for the design of product form.	0(0.00)	1(25.00)	1(12.50)		
Total		4	4	8		
Disadvantages	conducting time-consuming in-depth research	1(25.00)	1(25.00)	2(25.00)	2	0.572
	Further research is needed	1(25.00)	0(0.00)	1(12.50)		
	some designers make bionic designs relying on the appearance of animals and plants.	2(50.00)	2(50.00)	4(50.00)		
	The innovation of product design by this method is weak.	0(0.00)	1(25.00)	1(12.50)		
Total		4	4	8		
Pedagogical results	General	1(25.00)	2(50.00)	3(37.50)	0.533	0.465
	Satisfactory	3(75.00)	2(50.00)	5(62.50)		
Total		4	4	8		

* $p < 0.05$ ** $p < 0.01$

4.4.1.3 Cognition of brainstorming among educators with different educational backgrounds

We compared the cognition of brainstorming among educators with different educational backgrounds and observed that all the interviewees were familiar with brainstorming. Furthermore, most teachers fully utilized brainstorming in their teaching process. Seven teachers mentioned using the brainstorming method in the idea generation stage. More frequently, interviewees mentioned advantages that unexpected ideas sometimes occurred and could generate many unlimited ideas. However, more than half of the respondents mentioned that some ideas generated by students were useless. Three-quarters of the teachers considered that brainstorming positively affected teaching, and one-fourth considered a general effect of brainstorming on teaching.

Table 4. 4 Teachers' cognition of brainstorming in different educational backgrounds

Items	Categories	Education background (%)		Total	χ^2	p
		Master	Ph.D.			
Know or not	Known a lot,	1(25.00)	0(0.00)	1(12.50)	1.143	0.285
	Known a lot, used frequently	3(75.00)	4(100.00)	7(87.50)		
Total		4	4	8		
Most applied in	Idea generation	3(75.00)	4(100.00)	7(87.50)	1.143	0.285
	Use it to find a solution	1(25.00)	0(0.00)	1(12.50)		
Total		4	4	8		
Advantages	A lot of ideas came up	1(25.00)	1(25.00)	2(25.00)	3.333	0.343
	Can generate a lot of ideas	1(25.00)	0(0.00)	1(12.50)		
	unexpected ideas sometimes occurred	2(50.00)	1(25.00)	3(37.50)		
	could generate a lot of ideas unlimited	0(0.00)	2(50.00)	2(25.00)		
Total		4	4	8		
Disadvantages	Different disciplines and different fields are effective	1(25.00)	0(0.00)	1(12.50)	1.2	0.549
	some ideas generated by students are useless	2(50.00)	3(75.00)	5(62.50)		
	Sometimes it goes off-topic	1(25.00)	1(25.00)	2(25.00)		
Total		4	4	8		
Pedagogical results	General	1(25.00)	1(25.00)	2(25.00)	0.667	0.717
	Satisfactory	1(25.00)	2(50.00)	3(37.50)		
	Very satisfactory	2(50.00)	1(25.00)	3(37.50)		
Total		4	4	8		

* $p < 0.05$ ** $p < 0.01$

4.4.1.4 Cognition of the attribute listing method among teachers with different educational backgrounds

We compared the cognition of the attribute listing method among teachers with different educational backgrounds and observed that the eight teachers interviewed had a basic understanding of this method; however, the frequency of applying this creative thinking method was low. Only 1 of the 8 interviewed teachers had frequently used the attribute listing method. The respondents mentioned that the attribute listing method was commonly applied in examining the dimension of creative ideas, product function and material design, product function and structure design, product improvement design, and product research. The application proportion for the five situations was the same. Regarding the advantages of the attribute listing method, the respondents mentioned products with high feasibility more frequently. Respondents frequently mentioned that the method could limit their ideas. Regarding teaching effectiveness using the attribute listing method, three-quarters of the teachers felt that the method was generally effective.

Table 4. 5 Cognition of teachers from the different educational backgrounds on the attribute listing method

Items	Categories	Education background (%)		Total	χ^2	p
		Master	Ph.D.			

Know or not	Not known	1(25.00)	0(0.00)	1(12.50)	2.667	0.264
	Known not used	2(50.00)	4(100.00)	6(75.00)		
	Known a lot, used frequently	1(25.00)	0(0.00)	1(12.50)		
Total		4	4	8		
Most applied in	Examining the dimension of creative ideas	1(25.00)	1(25.00)	2(25.00)	2	0.736
	Product function and material design	0(0.00)	1(25.00)	1(12.50)		
	Product function and structure design	1(25.00)	0(0.00)	1(12.50)		
	Product improvement design	1(25.00)	1(25.00)	2(25.00)		
	Product research	1(25.00)	1(25.00)	2(25.00)		
Total		4	4	8		
Advantages	excellent logic	1(25.00)	0(0.00)	1(12.50)	3.333	0.343
	make the idea more comprehensive	1(25.00)	1(25.00)	2(25.00)		
	Strong logic	0(0.00)	2(50.00)	2(25.00)		
	The product has higher feasibility	2(50.00)	1(25.00)	3(37.50)		
Total		4	4	8		
Disadvantages	it can limit ideas	3(75.00)	3(75.00)	6(75.00)	2	0.368
	Too rational	1(25.00)	0(0.00)	1(12.50)		
	Too rational and can limit ideas	0(0.00)	1(25.00)	1(12.50)		
Total		4	4	8		
Pedagogical results	General	3(75.00)	3(75.00)	6(75.00)	2	0.368
	Satisfactory	0(0.00)	1(25.00)	1(12.50)		
	Very satisfactory	1(25.00)	0(0.00)	1(12.50)		
Total		4	4	8		

* $p < 0.05$ ** $p < 0.01$

4.4.1.5 Cognition of mind mapping among educators with different educational backgrounds

We compared the cognition of the mind mapping method among teachers with different educational backgrounds and discovered that eight respondents equally responded "known not used" and "known a lot, used frequently." The main application scenario mentioned by interviewees was idea generation. The interviewees perceived advantages such as "ideas are logical" and "easy to find connections between objectives." However, the educators mentioned that students might sometimes confuse the mind mapping method with brainstorming. Overall, half of the educators considered that the teaching effect of the mind mapping method was relatively general, whereas the other half of the respondents believed that the mind mapping method could bring better teaching effects to the classroom.

Table 4. 6 Teachers' cognition of mind mapping method in different educational backgrounds

Items	Categories	Education background (%)		Total	χ^2	p
		Master	Ph.D.			
Know or not	Known not used	2(50.00)	1(25.00)	3(37.50)	0.533	0.465
	Known a lot, used frequently	2(50.00)	3(75.00)	5(62.50)		

Total		4	4	8		
Most applied in	Generate ideas	2(50.00)	2(50.00)	4(50.00)	0	1
	Idea generation stage	1(25.00)	1(25.00)	2(25.00)		
	Organized ideas	1(25.00)	1(25.00)	2(25.00)		
Total		4	4	8		
Advantages	discover connections between objects	1(25.00)	0(0.00)	1(12.50)	6	0.306
	easy to find connections between things	0(0.00)	2(50.00)	2(25.00)		
	ideas are logical and can inspire people to generate more ideas	0(0.00)	1(25.00)	1(12.50)		
	ideas are logical	1(25.00)	0(0.00)	1(12.50)		
	Ideas are logical, can inspire people to generate more ideas	1(25.00)	1(25.00)	2(25.00)		
	Ideas are logical, can inspire people to keep thinking	1(25.00)	0(0.00)	1(12.50)		
Total		4	4	8		
Disadvantages	It's easy to get sidetracked	1(25.00)	1(25.00)	2(25.00)	3.333	0.504
	Sometimes it can limit ideas	1(25.00)	0(0.00)	1(12.50)		
	Sometimes the generated ideas were not accurate	0(0.00)	1(25.00)	1(12.50)		
	Sometimes confused with brainstorming	1(25.00)	2(50.00)	3(37.50)		
	5	1(25.00)	0(0.00)	1(12.50)		
Total		4	4	8		
Pedagogical results	General	2(50.00)	2(50.00)	4(50.00)	1.333	0.513
	Satisfactory	2(50.00)	1(25.00)	3(37.50)		
	Very satisfactory	0(0.00)	1(25.00)	1(12.50)		
Total		4	4	8		

* $p < 0.05$ ** $p < 0.01$

4.4.1.6 Cognition of TRIZ among educators with different educational backgrounds

We compared teachers' cognition of TRIZ and observed that the eight interviewed teachers were not fully aware of TRIZ. Furthermore, none of the teachers had applied TRIZ in their teaching process. The respondents inferred that the TRIZ method might be appropriate for product improvement design, even though none teachers had used TRIZ. The interviewees indicated that TRIZ was rarely used because it was too professional. They agreed that the application of TRIZ to teaching was not satisfactory.

Table 4. 7 Teachers' cognition of TRIZ in different educational backgrounds

Items	Categories	Education background (%)		Total	χ^2	p
		Master	Ph.D.			
Know or not	Not known	2(50.00)	1(25.00)	3(37.50)	2.667	0.264
	Known, but not used	0(0.00)	2(50.00)	2(25.00)		
	Known not used	2(50.00)	1(25.00)	3(37.50)		

Total		4	4	8		
Most applied in	Not used	4(100.00)	2(50.00)	6(75.00)	2.667	0.102
	Product improvement design	0(0.00)	2(50.00)	2(25.00)		
Total		4	4	8		
Advantages	Not used	4(100.00)	3(75.00)	7(87.50)	1.143	0.285
	More rational	0(0.00)	1(25.00)	1(12.50)		
Total		4	4	8		
* p < 0.05 ** p < 0.01						

Frequency				
Items	Categories	N	Percent (%)	Cumulative Percent (%)
Disadvantages	Too professional	8	100	100
Pedagogical results	Not satisfactory	8	100	100
Total		8	100	100

4.4.1.7 Cognition of the SCAMPER method among educators with different educational backgrounds

We compared the cognition of SCAMPER among educators with different educational backgrounds and observed that the eight interviewed teachers were fully aware of the SCAMPER method. Six teachers indicated that they applied it often in their teaching process. The interviewed teachers mentioned that they most often applied SCAMPER to the teaching of product improvement design. Furthermore, three-quarters of the respondents mentioned that they could easily make changes to the products using the SCAMPER method. Lack of innovation was a disadvantage, and the adjustments were made by simply altering the original product. All educators indicated that SCAMPER could produce satisfactory teaching effects in education based on the results.

Table 4. 8 Teachers' cognition of the SCAMPER method in different educational backgrounds

Items	Categories	Education background (%)		Total	χ²	p
		Master	Ph.D.			
Know or not	Known, but not used	1(25.00)	1(25.00)	2(25.00)	0	1
	Known a lot, used frequently	3(75.00)	3(75.00)	6(75.00)		
Total		4	4	8		
Most applied in	Generate ideas	1(25.00)	0(0.00)	1(12.50)	3.2	0.362
	Product function and material design	0(0.00)	1(25.00)	1(12.50)		
	Product functional design and product appearance design	0(0.00)	1(25.00)	1(12.50)		
	Product improvement design	3(75.00)	2(50.00)	5(62.50)		
Total		4	4	8		
Advantages	Could inspire people to come up with new ideas	1(25.00)	0(0.00)	1(12.50)	2	0.368
	Could easily make changes to the products	3(75.00)	3(75.00)	6(75.00)		
	Ideas are logical, can inspire people to generate more ideas	0(0.00)	1(25.00)	1(12.50)		

Total		4	4	8		
Disadvantages	Lack of innovation, the adjustments just made partial adjustments based on the original product	1(25.00)	0(0.00)	1(12.50)	8	0.092
	the adjustments were made by simply altering the original product.	0(0.00)	2(50.00)	2(25.00)		
	The results were a lack of innovative	0(0.00)	1(25.00)	1(12.50)		
	The results were not very innovative	3(75.00)	0(0.00)	3(37.50)		
	The results will be similar to existing products	0(0.00)	1(25.00)	1(12.50)		
Total		4	4	8		
Pedagogical results	Satisfactory	3(75.00)	2(50.00)	5(62.50)	0.533	0.465
	Very satisfactory	1(25.00)	2(50.00)	3(37.50)		
Total		4	4	8		

* $p < 0.05$ ** $p < 0.01$

4.4.1.8 Cognition of the 5W2H method among teachers with different educational backgrounds

We compared the cognition of the 5W2H method among educators with different educational backgrounds. We observed that eight teachers fully comprehended the method and that five teachers were likely to use it in their classes. The 5W2H method was mainly applied to producing solutions and product positioning. The respondents mentioned advantages such as “a great way to test ideas,” “filter out your thoughts quickly,” “verify the effectiveness of the product,” and “verify the validity of the method” in equal proportion. Respondents also mentioned that sometimes, 5W2H methods limit one’s thinking. Overall, we inferred that the interviewees were satisfied with the effectiveness of the 5W2H method.

Table 4. 9 Teachers’ cognition of the 5W2H method in different educational backgrounds

Items	Categories	Education background (%)		Total	χ^2	p
		Master	Ph.D.			
Know or not	Known a lot	1(25.00)	0(0.00)	1(12.50)	3.2	0.202
	Known a lot, used frequently	3(75.00)	2(50.00)	5(62.50)		
	Known, but not used	0(0.00)	2(50.00)	2(25.00)		
Total		4	4	8		
Most applied in	General design	0(0.00)	1(25.00)	1(12.50)	5.333	0.149
	Generating solutions	3(75.00)	0(0.00)	3(37.50)		
	Product positioning	1(25.00)	2(50.00)	3(37.50)		
	When verifying the effectiveness of the product	0(0.00)	1(25.00)	1(12.50)		
Total		4	4	8		

Advantages	A great way for validating students' ideas	2(50.00)	0(0.00)	2(25.00)	4	0.261
	Filter out your thoughts quickly	1(25.00)	1(25.00)	2(25.00)		
	verify the effectiveness of the product	1(25.00)	1(25.00)	2(25.00)		
	Verify the validity of the method	0(0.00)	2(50.00)	2(25.00)		
Total		4	4	8		
Disadvantages	Being too specific ignores the potential users of your solution.	0(0.00)	1(25.00)	1(12.50)	3.2	0.362
	It is useless if the answers to most questions are unknown	1(25.00)	0(0.00)	1(12.50)		
	Serious stereotyping will limit thinking	0(0.00)	1(25.00)	1(12.50)		
	Sometimes will limit your thinking	3(75.00)	2(50.00)	5(62.50)		
Total		4	4	8		
Pedagogical results	General	0(0.00)	2(50.00)	2(25.00)	2.667	0.264
	Very satisfactory	2(50.00)	1(25.00)	3(37.50)		
	Satisfactory	2(50.00)	1(25.00)	3(37.50)		
Total		4	4	8		

* $p<0.05$ ** $p<0.01$

4.4.2 Results for Question 3 (Q3) in the interview

The interview data presented in Table 4.10 reveal the reasons for low student creativity, as cited by the eight educators. Interview data of all respondents were recorded, transcribed, and translated by the researchers into English. The translated data were double-checked and corrected by the investigators for the reliability of the data. We conducted a thematic analysis of the data to reveal the eight educator's perceptions of the low creativity of students. Our analysis of the interview data revealed the following reasons for the low creativity of students.

- Due to a lack of life experience, students found it difficult to discover the problems in their daily life, making it difficult for them to develop innovative products.
- The students failed to observe the objectives in an effective and scientific way in their daily life.
- The students had a poor capacity for independent thinking and excessively relied on teachers and electronic devices in the learning process.
- The imperfect curriculum design resulted in students' lack of training in creative thinking methods.
- Students had poor time management and self-management skills.
- The rigid teaching environment and the unreasonable classroom layout negatively affected students' creativity.
- There is a lack of novelty and attractiveness toward the course assignment proposition.

- The teaching method lacked innovation, and the teaching content was monotonous.

In our research, our teaching experiment design for the next chapter will be based on the aforementioned results of the interviews.

Table 4. 10 Interview contents extracted from the interview for Question 3

Interviewee	Description
A1	*"I think the **lack of life experience** is the main factor affecting students' creativity. Life serves as the primary source of inspiration for product design. However, most students are primarily engaged in campus activities. They are primarily focused on attending classes and completing their studies, so they **have little experience in daily life**, and it is **hard to find problems with existing products in their daily lives**, which makes it difficult to generate ideas for product innovations."*
A2	*"Products of high quality can improve our lives. It requires designers to be sensitive to users' needs and identify problems through careful observation and research. However, most of our **students have little or no life experience** and **don't know how to observe life or what life is**, thus making it difficult for them to understand users and generate solutions to their problems."*
A3	*"I found that students **have poor independent thinking ability** as I observed during the teaching process. Students tend to **rely on electronic devices** or **ask their teachers for answers** when they have a problem. They usually **blindly copy the work of their predecessors** when completing their design work, which makes it very difficult for them to generate good ideas."*
A4	*"Due to the **imperfect curriculum setting**, there is **no systematic training in creative thinking methods** in most curriculums, owing to which students **could not choose the appropriate methods** to generate good ideas when designing products."*
A5	*"Nowadays, students cannot **self-management properly** and **delay their homework until the deadline**. Most students **have a perfunctory attitude** toward design works because of **the limited time**, leaving a lack of creativity and novelty in their work, and the overall quality of their work is also substandard."*
A6	*"I think an overly **rigid teaching environment** can lead to low levels of student creativity. The teaching environment for design majors should be different from that of other majors. I have tried to **adapt the classroom space** to a **face-to-face layout** so that students can better achieve **group discussions** and **group work**. When the classroom layout was changed, it positively impacted students' learning status and learning outcomes. There are more opportunities for students to **communicate with each other**, and at the same time, students' ideas are more diverse."*
A7	*"A **lack of novelty or attraction in course assignment propositions** can also negatively affect creativity among students. According to my previous teaching experience, students showed **great enthusiasm** when the assignment propositions I set for the course were **closely related to them** or were of **interest to them**. Additionally, the **teaching content** is also essential. I often **update the courseware** to ensure that the cases I teach are interesting to students. **Assignment propositions from the real world** could motivate students to learn and generate good design ideas."*
A8	*"I think both **traditional teaching methods** and **monotonous teaching content** lead to low levels of creativity in students. I often reinforce the interaction between teachers and students in the course and **encourage students to interact among themselves**. During the lectures, I not only explain theoretical knowledge according to the syllabus but also **focus on the needs of students***

	at different learning stages, ***answering their questions and offering guidance and assistance*** *as necessary. Additionally, I* ***supplement the knowledge points*** *according to the research direction chosen by the students to encourage the students to generate more creativity."*

4.4.3 Results for Question 4 (Q4) in the interview

Table 4. 11 Interview contents extracted from the interview for Question 4

Interviewee	Description
A1	*"When students cannot generate good ideas, I usually* ***share with them some good design examples*** *and* ***explain the designers' creative ideas*** *to them by* ***analyzing the design examples****."*
A2	*"Occasionally, I ask students to use the* ***SWOT method*** *to analyze the* ***strengths, weaknesses, opportunities, and threats*** *of the product to identify the existing problems of the products. I think it's easier to find solutions when students have identified problems. I think it's relatively easy to* ***generate creative ideas*** *as long as the problem with the product is discovered."*
A3	*"I would like to* ***share several great design cases*** *with students and have them complete* ***written analyses of these design cases.*** *I hope that the students will be inspired and motivated by the analysis process."*
A4	*"I often ask students to* ***discuss the problem in small groups*** *with other students.* ***Discussions*** *with other students often result in more creative ideas among students."*
A5	*"When I stimulate students' creativity, I usually use the* ***Random Stimuli*** *method. For instance, I often use* ***random photos or events*** *to guide the students' thinking. Interestingly, this method sometimes allows students to* ***generate unexpected ideas****."*
A6	*"In my opinion, students could* ***better understand the real needs of users*** *by using the* ***"Role-playing****" method. Students would be able to* ***identify the problems with the product*** *by acting as users. It is beneficial for students to design* ***user-centered products*** *with this approach."*
A7	*"I always* ***share many great design examples*** *with students during my lectures. We aim to help students become more creative by* ***analyzing the cases*** *and letting them understand the creative approach of those great design works."*
A8	*"As part of my lectures, I often have students* ***work in small groups*** *to* ***explore solutions to problems****. My experience is that the products that come out of group work are* ***more creative and viable****."*

The interview data revealed five approaches mentioned by the interviewees that could stimulate students' creativity. Table 4.11 illustrates the interview contents extracted from the interview for Question 4. Through analysis of the data, methods that improve students' creativity suggested by respondents included, such as sharing good design examples, employing SWOT analysis, working in groups, using random stimuli, and engaging in role-playing. Three out of eight interviewed educators (e.g., interviewees A1, A3, and A7) indicated that they would share many excellent design cases with students during the course. It would become more accessible for students to generate more creativity by clarifying the designer's design ideas. Two interviewees mentioned the method of working and discussing in groups (e.g., interviewee coded A4, A8). The two educators believed that students generally get more creative ideas during discussions with other classmates. Moreover, the feasibility of the product can be improved.

Three other respondents offered different approaches. An educator coded A2 mentioned that he would guide them to use SWOT analysis to develop creative solutions to help students solve existing problems with the product. According to an educator coded A5, random stimuli could sometimes encourage students to develop unexpected ideas. An educator coded A6 mentioned that the "role-playing" approach is beneficial to students in designing user-centered products. The methods provided by the interviewees were being applied to the next step of teaching design.

4.4.4 Results for Question 5 (Q5) in the interview

The fifth question in our interview mainly explored the creative thinking methods that interviewees think can help generate creative ideas at different stages of product design. We conducted our study to get suggestions regarding the use of creative thinking methods by interviewing eight educators with previous teaching experience. A detailed transcription of the interviewees' responses is presented in Table 4.12. We summarized our findings as follows:

Four educators (e.g., interviewees A2, A3, A5, and A6) among the respondents indicated that the observational method helped them identify problems during the problem definition stage. Additionally, three respondents mentioned that brainstorming (e.g., interviewees A1, A7, and A8) was another way to identify problems. Moreover, the respondents with code A4 recommended the disadvantage listing method to identify the issues of existing products by listing their shortcomings.

During the product research stage, "immersive experience" and "product & marketing research" thrice. Participants believed conducting product & marketing research and engaging in immersive experiences of a product would help designers to understand the product better. As mentioned by two other respondents, the attribute listing method can help discover product attributes during product research.

The observational and interview methods were mentioned most frequently by respondents during user research, which was mentioned six and five times, respectively. Most educators believed that interviewing and observing users was a useful way to assess user needs. Role-playing was mentioned twice in the responses of educators coded A2 and A8. The educators believed that designers could act as users to discover the problems experienced by users while using products. Two respondents coded A5 and A7 recommended a user persona, customer journey map, and questionnaire.

Table 4. 12 Interview contents extracted from the interview for Question 5

Interviewee	Design process	Description
A1	*Problem definition*	*Brainstorming*
	Product research	*Product & Marketing Research*
	User research	*Observational method/Interview*
	Idea generation	*Brainstorming*
	Idea selection	*Vote*

	Idea verification	*User testing*
A2	*Problem definition*	*Observational method*
	Product research	*Immersive experience*
	User research	*Observational method/Interview/Role-playing*
	Idea generation	*Brainstorming/Mind mapping/SCAMPER*
	Idea selection	*Vote*
	Idea verification	*Questionnaire/Interview*
A3	*Problem definition*	*Observational method*
	Product research	*Attribute listing*
	User research	*Observational method/Interview*
	Idea generation	*Brainstorming*
	Idea selection	*Vote*
	Idea verification	*Prototyping and testing*
A4	*Problem definition*	*Disadvantage listing method*
	Product research	*Immersive experience*
	User research	*Observational method/Interview*
	Idea generation	*Work in group*
	Idea selection	*Interview*
	Idea verification	*Prototyping and testing*
A5	*Problem definition*	*Observational method*
	Product research	*Immersive experience*
	User research	*User persona/customer journey map*
	Idea generation	*Work in group*
	Idea selection	*Teacher assisted selection*
	Idea verification	*Stakeholder scoring and evaluation*
A6	*Problem definition*	*Observational method*
	Product research	*Product & Marketing Research*
	User research	*Observational method/Interview*
	Idea generation	*Brainstorming*
	Idea selection	*5W2H method*
	Idea verification	*User testing*
A7	*Problem definition*	*Brainstorming*
	Product research	*Attribute listing*
	User research	*Observational method/Interview/Questionnaire*
	Idea generation	*Brainstorming*
	Idea selection	*5W2H method*
	Idea verification	*Prototyping and testing*
A8	*Problem definition*	*Brainstorming*
	Product research	*Product & Marketing Research*
	User research	*Role-playing/Observational method*
	Idea generation	*SCAMPER*

	Idea selection	*Gallery*
	Idea verification	*Prototyping and testing*

Brainstorming was mentioned the most by respondents during the idea generation stage, with five mentions. In other words, educators believed that brainstorming was a useful technique for their idea generation. SCAMPER and work in groups were both mentioned twice by respondents. The results indicated that some respondents believed that working in a group can enhance a designer's ability to generate ideas. Furthermore, mind mapping did not seem to be favored by educators for idea generation, as only one teacher mentioned mind mapping.

Three respondents considered voting (e.g., interviewees A1, A2, and A3) to be an effective method in the idea selection stage. Voting allowed them to choose what design options the audience preferred quickly. The two educators coded A6 and A7 believed that designers could screen out feasible solutions using the 5W2H method. Further, a respondent coded A4 mentioned that designers could interview users to understand users' perceptions of design concepts. A respondent coded A5 emphasized the importance of teachers in assisting students in choosing effective programs. A respondent coded A8 referred to the gallery.

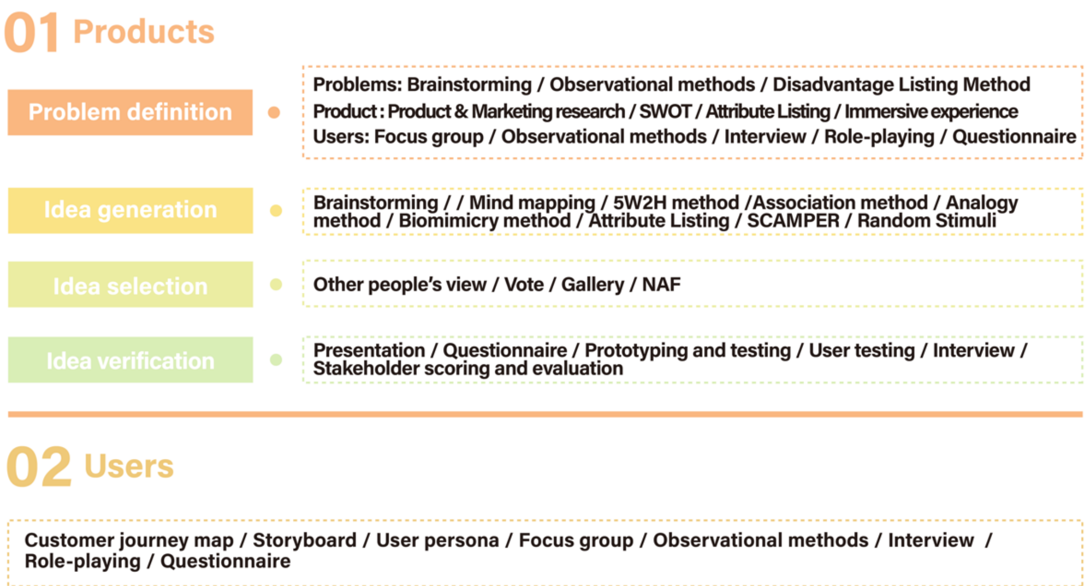

Figure 4. 1 Creative thinking methods at different stages of product design suggested by respondents

Prototyping and testing were considered effective methods during the idea verification stage. Four educators mentioned prototypes and testing in the interviews (e.g., interviewees A3, A4, A7and A8). Both respondents coded A1 and A6 indicated that designers could verify the rationality of design ideas through user testing. The respondent coded A5 mentioned that product stakeholders played a critical role in idea verification. Inviting stakeholders to score and evaluate design work could help designers assess their products' effectiveness.

The data of this interview were rearranged in Figure 4.1 below to make it more intuitive to understand. We aimed to provide advice for more educators and designers to increase their creativity. Meanwhile, the results from this part of the interview also contribute to our teaching design in Chapter five.

4.4.5 Results for Question 6 (Q6) in the interview

The sixth question in the interview outline aimed to obtain suggestions and ideas from educators with rich teaching experiences on teaching methods to enhance student creativity. In Table 4.13, we present the complete responses from eight respondents. Based on the basic information provided in Question 1, we know that the respondents studied product design for an average of 15.75 years and taught product design for an average of 8.75 years. Hence, we believed that the data provided by the interviewees had a certain reference value. We transcribed and translated the data and performed a thematic analysis of the data to reveal recommendations from eight educators on teaching methods that could enhance student creativity. The interviews were coded according to topics related to pedagogical methods that could enhance students' creativity. The analysis of the interview data is presented in Table 4.14.

From the interview data in Table 4.14, respondents proposed teaching methods for enhancing students' creativity from five perspectives: assignment propositions, teaching methods, teaching activities, students' learning behaviors, and teaching content. Three educators offered suggestions on the assignment propositions. They suggested that the assignment proposition should be based on real-world problems to improve students' observation and critical thinking about the surrounding environments and social issues. Educators could select current social issues or topics students were interested in as a way to stimulate students' enthusiasm for learning. Three of the eight educators described specific teaching methods, and two of them (e.g., interviewees A1 and A3) reported that teaching through project-based learning could enhance students' creativity. Another interviewee stated that the scenario-based teaching method could help students to better observe life and understand users' needs, allowing them to identify problems from their surroundings. The participants also offered insights into the specific teaching activities of teachers during the teaching process. For instance, students could be provided with photos, videos, news, etc., to stimulate their observation of problems or set the appropriate milestones. A respondent coded A6 even claimed that classroom layout also affected students' creativity. Students could be provided with a better learning environment by changing the layout of the classroom so that teachers can participate in each group discussion and provide timely guidance and help to them. One of the eight respondents made suggestions regarding students' learning behaviors. The respondent emphasized the importance of group discussions and collaboration by introducing his previous learning experiences. Moreover, respondent coded A4 identified the need for the teaching content to include an overview of creative thinking methods to enable students to choose appropriate methods to complete their work during the product design process.

Table 4. 13 Interview contents extracted from the interview for Question 6

Interviewee	Description
A1	*"The lack of life experience students have made it difficult for them to identify problems in life. Thus, teachers can ensure that* ***the assignment propositions are directed toward solving real-world problems****. The assignment can also aim to* ***solve current social issues*** *to strengthen students' observation and critical thinking about their surroundings and social problems. Thus, I think the* ***project-based learning*** *teaching method can increase students' creativity by* ***setting driven questions****."*
A2	*"A* ***scenario-based*** *teaching method can help students better* ***observe life and understand the real***

	needs of users, *which will enable students to* ***identify problems*** *from the situation and investigate the inconvenience of users in the process of using the product. We can* ***provide students with scenarios*** *like photos, videos, news, to stimulate their observation of problems, ultimately benefiting their generation of creative ideas."*
A3	*"In my opinion,* ***project-based learning*** *can enhance students' creativity. The project-based learning teaching method is our main teaching method at Tama Art University in Japan, where I graduated with a master's degree program. My personal experience with this teaching method leads me to believe it is very effective. We* ***worked in groups*** *and completed projects during the lecture. We were all active and serious during the project completion process since we all desired to have our design work selected eventually. We have generated more creative ideas through* ***discussion and collaboration with partners****. The different groups even* ***competed against*** *each other to motivate each other to do our best to design better work."*
A4	*"It's important for teachers to* ***explain to students how to use different creative thinking methods*** *during the course based on their learning needs so that they may choose appropriate methods for solving problems at different stages of product design. It is important to* ***teach students various creative thinking methods*** *in advance, and educators can* ***prepare rich learning materials for students*** *in advance."*
A5	*"Educators could* ***introduce real projects into the curriculum****, which would give students a better understanding of the operation process of real projects and enable them to accomplish better* ***self-management*** *in project management. It is important that educators assist students with* ***breaking down projects*** *and* ***setting the appropriate milestones*** *to help them better* ***time management*** *for completing the project. Additionally, real projects are more achievable, and students will result in greater* ***participation and motivation****."*
A6	*"I suggest that* ***adjusting the student's learning environment*** *by* ***changing the classroom layout*** *can enhance students' creativity. Our classroom can be* ***set up as a design studio****, facilitating students'* ***communication and cooperation*** *with other students to work together and produce solutions. Students can deal with the problems by* ***sharing learning resources****, resulting in a positive mutual influence. Hence, the course proposition might be* ***group cooperation*** *to solve* ***real-world problems****.* ***Teachers can participate in each group discussion*** *during the teaching process to* ***provide timely guidance and help to students****."*
A7	*"Students' enthusiasm for learning will be improved if educators* ***choose topics they are interested in*** *and* ***design courseware and assignment propositions*** *appealing to them. The* ***real-world assignment propositions*** *not only enhance students' thinking about real-world problems and give them a strong motivation to learn and to generate creative ideas."*
A8	*"****Managing courses like real projects*** *by educators. It is appropriate for students to lead the project, and* ***teachers should act as assistants*** *providing students with* ***timely guidance and assistance*** *as needed. To foster continuous improvement in student work and enhance the innovation of students' works, educators can* ***invite more tutors to participate in the course evaluation****, which will enable students to obtain* ***more diverse comments and evaluations****."*

The results of the thematic analysis of the interviewer's data are shown in Table 4.14.

Table 4. 14 Examples of interview data on teaching method-related issues

Issues	Interviewees	Interview Data Examples

Assignment proposition	A1	*"Teachers can ensure that **the assignment propositions are directed toward solving real-world problems**. The assignment can also aim to **solve current social issues** to strengthen students' observation and critical thinking about their surroundings and social problems.*
	A6	*"The course proposition might be group cooperation to solve **real-world problems**."*
	A7	*"Students' enthusiasm for learning will be improved if educators **choose topics they are interested in** and design courseware and assignment propositions that are **appealing** to them."*
Teaching methods	A1	*"I think the **project-based learning** method can increase the creativity of students by **setting driven questions**."*
	A2	*"A **scenario-based** teaching method can help students better observe life and understand the real needs of users, which will enable students to identify problems from the situation and investigate the inconvenience of users in the process of using the product."*
	A3	*"In my opinion, **project-based learning** can enhance students' creativity."*
Teaching activities	A2	*"We can **provide students with scenarios** like photos, videos, news, to stimulate their observation of problems."*
	A4	*"Educators can **prepare rich learning materials** for students in advance."*
	A5	*"Educators could **introduce real projects into the curriculum**, and It is essential that educators assist students with **breaking down projects** and **setting the appropriate milestones** to help them better time management for completing the project.*
	A6	*"I suggest that **adjusting the student's learning environment** by **changing the classroom layout** can enhance students' creativity. **Teachers can participate in each group discussion** during the teaching process to **provide timely guidance and help to students**."*
	A8	*"**Teachers should act as assistants** providing students with **timely guidance and assistance** as needed."*
Students' Learning behavior	A3	*"We **worked in groups** and completed projects during the lecture. We have generated more creative ideas through **discussion and collaboration with partners**."*
Teaching contents	A4	*"It's important for teachers to **explain to students how to use different creative thinking methods** during the course based on their learning needs so that they may choose appropriate methods for solving problems at different stages of product design."*

4.5 Conclusions

We conducted an exploratory study through semi-structured interviews with eight educators from various countries and educational backgrounds to explore their application, teaching effectiveness, perceptions, and suggestions for creative thinking methods in the teaching process.

First, we presented all the respondents with eight different creative thinking methods. Our research explores the application, teaching effect, perceptions, and suggestions on the eight creative thinking methods in their teaching process. Our instructional design will be based on the suggestions in the next chapter, followed by a summary of the data from the Q2 portion of the interview:

- **Analogy and Association method:** According to the respondents, the teaching effect provided by analogy and association was general. They argued that the analogy and association method could be applied to product appearance design, cultural and creative product design, and product modeling design. They stated that students could easily generate creative ideas using analogy and association methods, and they are intuitive in comparing and associating objects. However, the use of this method would depend on each student's knowledge and personal vision levels, and particularly, the knowledge level of students will influence their creative outcome. In addition, one interviewee stated that the method is not suitable for products with a high degree of industrialization. We recommend that the educators emphasize the importance of knowledge reserves when teaching analogy and association and provide students with relatively rich reference resources.

- **Biomimicry:** In their interviews, eight educators listed different application scenarios of the biomimicry method, including daily necessities design, houseware design, product appearance design, and vehicle design. They stated that the biomimicry method is applied more frequently in designing vehicles and product appearances. As many bionic objects can be referenced in creation, responders considered that students could easily find associative objects. Biomimicry is an ideal method for designing the product's appearance and the product form. However, one disadvantage of using the biomimicry method includes conducting time-consuming in-depth research. Since the biomimicry method is often adapted from the appearance of animals or plants, the works produced by this method tend to be less innovative. Therefore, educators should implement a standard approach to teaching the biomimicry method, including instructing students to regard the appearance, internal structure, and functional properties of released objects to ensure effective bionic design.

- **Brainstorming:** Most of the eight respondents applied the brainstorming method to help students conduct idea generation during the teaching process. The brainstorming method has a better effect on teaching. Respondents reported that brainstorming helps creators generate novel ideas and provide unexpected results. Although brainstorming can produce several ideas, half of the respondents realized that not all ideas are helpful. We recommend that the educators clarify the strengths and weaknesses of the method when teaching brainstorming to increase the efficiency of students.

- **Attribute listing:** The respondents were familiar with this method, but they only use it occasionally, and only one respondent stated to use it frequently. They said that listing the attributes of a product could sometimes limit their thinking. However, the attribute listing method helps test the dimensions of creative ideas, so it can be effective in product function and structure design, product improvement design, and conducting product research. Therefore, educators are advised to use this method when teaching product improvement design and assist students in creating functional and structural designs for their products by attribute listing.

- **Mind mapping:** Respondents commonly used mind mapping at the idea generation stage. According to the respondents, mind mapping allowed creators to organize ideas and discover connections between objects. Nevertheless, users could confuse mind mapping with brainstorming, and sometimes the generated ideas were not accurate. Hence, educators must assist students to use this method appropriately by demonstrating and distinguishing it from brainstorming.

- **TRIZ:** TRIZ is a professional method, and most of the respondents were not aware of it. Additionally, none of the respondents had taught TRIZ during their teaching process. We do not recommend this method because all the respondents believed that the method was not suitable for students' current professional competence.

- **SCAMPER:** All respondents considered SCAMPER a more effective teaching method than other creative thinking methods. The method is commonly used in product improvement designs since it can enable creators to make changes to the product. Nevertheless, since this method was used to make partial adjustments based on the original product, it could sometimes result in a lack of innovation in design work. We recommend that educators apply this method to product improvement design and guide students in making adjustments to the original product from multiple dimensions to enhance the novelty and innovation of their final work.

- **5W2H method:** Among the eight respondents, 5 indicated they would apply the 5W2H method when teaching to assist students in generating solutions and product positioning. Respondents considered the 5W2H method useful for validating student ideas. Students who used 5W2H could filter out their thoughts quickly and test the validity of their work. However, the 5W2H method was ineffective if students were not aware of the answers to most questions. Therefore, we recommended that educators state the methods and conditions of the methods in teaching to ensure that the method could be effective in implementation.

We employed the above-mentioned feedback from interviewees and combined the benefits of creative thinking methods in the teaching experiments in the following chapters, avoiding the disadvantages mentioned by the interviewees. We aimed to provide better results for our future teaching experiments.

Second, according to the analysis of the interview data of Question 3 (Q3) among 8 interviewees, the reasons for low creativity among students are as follows:

- Lack of life experience among students makes them inefficient at identifying problems in their daily lives
- Observational skills are lacking among students
- The Independent thinking ability of students is poor and should be inculcated
- The curriculums are poorly designed
- Students have poor time management and self-management skills
- The teaching environment and the classroom layout setting are unreasonable
- Course assignments lack novelty and attractiveness
- Teaching methods and teaching content lack innovation

Therefore, educators should consider the above influences when designing teaching methods in future education in order to avoid their negative effects on students' creativity.

Third, the respondents suggested five ways to stimulate students' creativity in Question4 (Q4) of the interview, including sharing excellent design cases with students, recommending SWOT analysis, working and discussing in groups, random stimulation, and role-playing. As part of the next stage of instructional design, we would employ the methods provided by the respondents in the interviews as scaffolding to use by students.

Fourth, we asked respondents about different methods for generating creative ideas at various stages of product design in our fifth question. The respondents' suggestions are summarized in Figure 4.1 after analyzing and sorting the interview data from the respondents. As part of the future teaching experiments, this data provided students with scaffolding. Students would be provided with creative thinking methods at different stages of their work completion to promote creativity based on the results.

Finally, educators with excellent teaching experience were asked to offer suggestions and advice on teaching methods to improve students' creativity. Through thematic analysis of the interview data, as shown in Table 4.14, the respondents put forward teaching methods to enhance students' creativity: assignment proposition, teaching methods, teaching activities, students' learning behaviors, and teaching contents. For instance, our instruction should be based on a project-based approach to enhance creativity in students. Incorporating project-based learning into our curriculum to improve creativity in students. Setting real-world questions and selecting current social issues or topics in which students were interested were used to inspire students' enthusiasm for learning. In addition, providing students with scenarios, such as photos, videos, and news, stimulate their observation of the problem. Setting appropriate milestones to help students develop time management and self-management skills is also required. Finally, the teaching method could be improved by altering the classroom layout to create a better learning environment, where teachers could participate in group discussions and provide timely assistance and guidance to students.

4.6 Summary of this chapter

In this chapter, we presented the results of interviews with eight educators with different educational backgrounds. Semi-structured interviews were conducted to explore respondents' application of creative thinking methods regarding teaching effectiveness, perceptions of, and suggestions for in their teaching process. Additionally, the respondents' suggestions for teaching creativity are summarized in this section. We conducted an in-depth analysis of each interview question to inform the teaching method design in the following chapters.

CHAPTER 5 The Experiment of "PIEPR" Teaching Method (Study3)

In this chapter…

- Experimental Design
- Research method
- Analysis of the experimental effect of our innovative "PIEPR" teaching method
- Findings and Conclusions
- Summary

Chapter 5 The Experiment of "PIEPR" Teaching Method (Study 3)

In this chapter, according to the experimental findings from Study 1 and Study 2, we proposed new teaching methods called the "PIEPR" teaching method formulated on the basis of project-based learning (PBL). We organized experimental and control groups to evaluate the effectiveness and practicability of the teaching method. In addition, we conducted pre-and post-tests of the teaching experiment to determine students' creative thinking levels by using the Torrance Test of Creative Thinking-Figural (TTCT-Figural). Furthermore, we investigated the teaching effect following the experiment to determine the effects of the teaching method on students' creative thinking levels.

5.1 Experimental Design

5.1.1 Research objectives

The experiment aimed to design and implement a new teaching method centered on PBL. We utilized the innovative teaching method to train students majoring in product design. Accordingly, we analyzed the teaching experiments and results and verified whether the teaching method can effectively enhance the creative thinking ability of students majoring in product design.

5.1.2 Research participants

We selected 54 students from classes 19-1 and 19-3 of the third year of product design majors at the Dalian University of Science and Technology as the research participants. The experimental group of 19-3 comprised 28 students, and the control group of class 19-1 comprised 26 students. Our inquiries about the average grades of the above two classes in the past and the feedback of other teachers indicated that the two classes were at the same level in both their daily classroom performance and professional learning abilities. Moreover, the gender ratio was close, and no significant difference existed between them. The same teacher trained the students in the teaching practice.

5.1.3 Introduction of the course

In this experiment, we considered the course "Product Innovation Design" as an example. The course lasted 8 weeks and comprised 48 class hours. The course lengths are the same for both classes. The teacher instructed students once a week, with one class lasting 4hours. PBL was the primary teaching method utilized in our teaching process. The experimental group was trained after we redesigned the teaching procedures which are defined as the "PIEPR" teaching method. Students were grouped independently, and they participated in teaching experiments in a cooperative learning environment during the experimental group. The students were grouped independently based on the principle of homogeneous grouping. Students in the experimental group were divided into 7 groups, with 4 students in each group. The students would receive three credits upon completion of this course. Face-to-face instruction was provided to the students, and they were required to cooperate in the creative process to apply knowledge, integrate knowledge, and create real-world solutions to problems. The control group was conducted using the traditional teaching method.

"Product Innovation Design" is one of the core courses for students majoring in product design. The course mainly aims to foster the ability of third-year university students to comprehensively apply the basic knowledge of their majors. The course provides students with the opportunity to integrate their knowledge into practice in product design. In this course, we aimed to prepare students to be capable of designing products by using innovative processes. As a part of this course, the students were required to master the fundamental theories and general procedures of product innovation design; master and become familiar with the application of creative thinking tools and generate creative ideas to solve problems; master research methods based on users and products; conduct product modeling design; master product functional design; and master product expression and presentation skills. The program has laid a solid foundation for students' future study and graduation. Students in our course are systematically trained to develop comprehensive design skills and solve critical real-world problems.

5.1.4 An assessment tool for students' creative thinking: the Torrance Test of Creative Thinking

Torrance, a psychology professor at the University of Minnesota, developed the Torrance Test of Creative Thinking (TTCT) in 1966. The TTCT is the most widely used test to measure creative thinking and an excellent tool to examine changes in creative thinking over time. Two versions of the TTCT are the TTCT-Verbal and TTCT-Figural, each with two parallel forms, namely Form A and Form B (Kim, 2011). The TTCT-Figural comprises two parallel forms, A and B, which require three activities: picture construction, picture completion, and repeated lines or circles. The TTCT (Torrance, 1974) is a pen-and-paper test that generally depends on divergent thinking, and test takers' responses are judged based on fluency, flexibility, elaboration, and originality (Hickey, 2001; Kyung Hee Kim, 2006). The tests are presented as games to make the subjects feel relaxed and enjoy the process. The industry considers the TTCT as the most reliable method to identify creative thinking. Our research subject focuses on the students majoring in product design. We selected TTCT-Figural to test students' creative thinking abilities, as the product design major focuses on the visual performance of products.

In our study, TTCT-Figural was utilized to evaluate students' creative thinking abilities, which included three activities: picture construction, picture completion, and repeated lines or circles. According to the characteristics of the product design major, we created the "The Torrance Creative Thinking Test Questionnaire for College Students Majoring in Product Design" (Please see Appendix 3 for details). The designed questionnaire was tested twice, once before the teaching experiment and once thereafter. The specific design of the questionnaire is presented in Table 5.1. Throughout the test, the testee was required to follow the teacher's instructions. During the testing session, the teacher was required to direct the test takers and control the response time to ensure a quiet environment so that the testee could take the test seriously and complete it independently. Finally, the educator evaluated scores according to the test results submitted by the students. To ensure the validity of the results, another teacher who was familiar with the TTCT test was invited to rate the students' results. Students' final scores were taken from the average of the scores given by the two teachers. The evaluation dimensions were based on the four indicators of creative thinking abilities: flexibility, fluency, originality, and elaboration. Flexibility was determined by the number of categories in the list; fluency was determined by the number of responses; originality was determined by the number of infrequent responses compared with that of the others, and elaboration was determined by the number of details. The level of students' creative thinking ability was divided into three levels, from low to high, and their scores increased by one level after every 7 points. A high final score indicated strong innovation ability and creative thinking ability. Table 5.2 presents the corresponding evaluation criteria for creative thinking ability indicators.

Table 5. 1 The Test Design for the Creative Thinking Test for Product Design Students

Pictures paradigm	Picture construction	Picture completion	Repeated lines or circles
Item number	1	2 and 3	4
Time setting	10 min	10 min and 10 min	10 min

Table 5. 2 The Corresponding Evaluation Criteria for Creative Thinking Ability Indicators

Indicators	Low level (0–7 points)	Intermediate (8–15 points)	High level (16–23 points)
Flexibility	Students considered one type of idea.	Students considered several types of ideas.	Students considered many types of ideas.
Fluency	Students considered a single idea.	Students considered several ideas.	Students considered many ideas.
Originality	Students developed a common idea that many other students would have suggested and/or replicated an existing idea.	Students developed an interesting idea that several other students would have suggested and/or minimally added to an existing idea.	Students developed a unique idea based on the ideas suggested by a few other students and/or substantially built upon an existing idea in a unique manner.
Elaboration	Students added minimal details and improvements to their ideas.	Students added a few details and improvements to their ideas.	Students added many crucial details and improvements to their ideas.

5.2 Research method

The teaching experiment involved the following three steps:

(1) Conducting a uniform pre-experimentation test by using "The Torrance Creative Thinking Test Questionnaire for College Students Majoring in Product Design" to determine the initial level of creativity in the experimental and control groups before teaching experiments.

(2) Applying our innovative teaching method which was defined as the "PIEPR" teaching method to the experimental group and administering a post-test to both the experimental and control groups at the end of the experiment.

(3) Finally, comparing the pre-test and post-test data of experimental and control groups for examining the differences in students' creative thinking, analyzing the experimental results, and drawing conclusions.

5.2.1 Pre-test

We conducted a pre-test before the teaching experiment to determine the level of students' creative thinking ability before and after the experiment. To eliminate environmental interference, the students were asked to turn off their cell phones, computers, and other communication devices before distributing the questionnaire. All students were asked to follow the teacher's instructions and maintain silence during the test. The instructor controlled the student response time in accordance with the requirements of each question, and questionnaires were distributed and collected in a standardized manner. After collecting the questionnaires, the students' scores in both experimental and control groups were statistically analyzed to determine the level of students' creative thinking ability before the teaching experiment.

5.2.2 Research procedure

The experimental group followed our redesigned teaching method which is defined as the "PIEPR" teaching method based on the PBL to help students acquire creative thinking skills. The control group followed the traditional teaching plan, as indicated in Table 5.3. Our innovative teaching method "PIEPR" was applied to the experimental group to verify the effectiveness of our designed teaching method. The control group was taught with a lecture-based strategy, and the teaching process of the control group was shown in Table5.3. In the control group, the Project-based learning pedagogy was not employed but only the traditional teaching method which was the lecture-based strategy was utilized. The teacher's teaching activities included 1) explanation of theoretical knowledge, which involved teaching students about product design methods and processes. 2) design positioning, which involved teaching students about product positioning and market positioning. 3) investigation and survey, which involved guiding students to complete the task of data collection and analysis. 4) designing ideas, which involved supervising and guiding students in their idea generation and sketching. 5) design and implementation, which involved supervising and guiding students through sketching, making product models, and designing exhibition boards. In the control group, the teacher only imparted knowledge to the students, assigned course tasks, and supervised their design process. Meanwhile, students were not provided with more scaffolding or creative thinking methods during their learning process.

Table 5. 3 The Teaching Method for Control Group

Teaching Activities	Class Hour	Teaching Contents	Teachers' Activities	Students' Activities
Explanation of theoretical knowledge	8	Product design method and process	Imparting knowledge	Listening to the lecture
Design positioning	8	Product positioning Market positioning	Imparting knowledge	Listening to the lecture

Investigation and survey	8	Data collection	Assigning the task	Data collection Data analysis
Designing ideas	8	Idea generation and sketch preparation	Offering suggestions for guidance	Analyzing design ideas and moving forward
Design and implementation	16	Drawing sketches, building product models, and designing exhibition boards	Monitoring students' progress	Designing scheme and production

5.2.3 Project design of the experimental group

The Gold Standard PBL approach (John Larmer et al., 2015) is relevant and necessary in the classroom. Larmer (2020) mentioned in a blog post that "in good projects, students apply knowledge to the real world and solve problems, answer complex questions, and create quality products." Accordingly, teachers should strive for the Gold Standard PBL, as it has been considered by Larmer and some scholars to be the best form of PBL. The PBL Gold Standard contains two components: the Essential Project Design Elements and Practices in Project-Based Learning (John Larmer et al., 2015). According to the Gold Standard PBL models, we redesigned the project design elements and teaching practices and implemented them in the experimental group by using our innovative teaching methods. We define our innovative teaching method as the "PIEPR" teaching method. Figure 5.1. illustrates the details of the design elements of PBL in our teaching experiment.

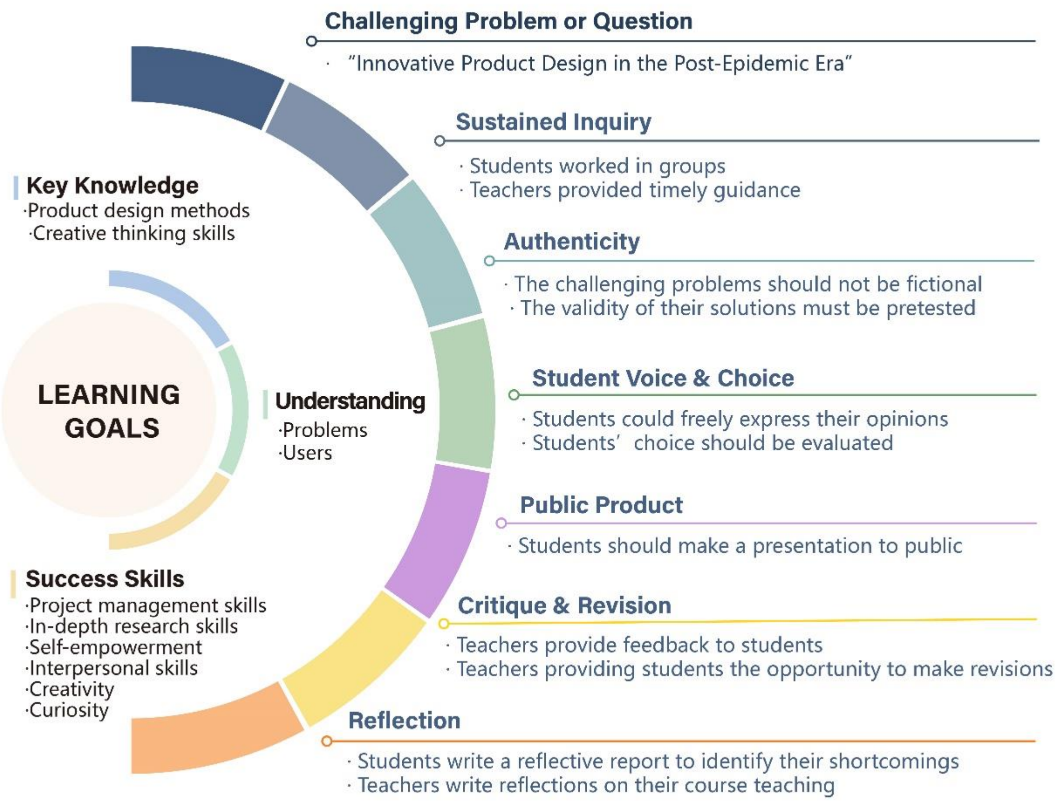

Figure 5. 1 Design elements of project-based learning in the "PIEPR" teaching method

In our project designs, we strictly adhered to 7 essential design elements of the Gold Standard PBL. Our teaching experiment comprised the following design elements of PBL:

1) **Challenging Problem or Question:** We designed a driving question for the project, "Innovative Product Design in the Post-Epidemic Era," to design products that can solve the problems of people during the COVID-19 epidemic.

2) **Sustained Inquiry:** Students worked in groups during our teaching experiments to solve the problems they encountered during the design process. As facilitators, teachers provided timely suggestions for modifications and creative thinking strategies during the design process.

3) **Authenticity:** Students collaboratively worked to solve real-life problems in our teaching experiments to increase their engagement and interest in learning.

4) **Student Voice & Choice:** Students could select their team members and the type of product they wanted to design during this project.

5) **Public Product:** Students were required to make a presentation and present their product designs after finishing their works.

6) **Critique & Revision:** The instructor and external experts helped evaluate the student's work and offered suggestions for improvement. The students were required to revise their product again in response to the comments.

7) **Reflection:** The students were required to write a reflective report after the course to identify their shortcomings. Educators were required to write reflections on their course teaching aimed at future teaching.

Thus, we designed the project to be implemented in the experimental group as shown in Figure 5.2.

Project Design Based on the Project-based Learning		
Project Name	"Product Innovation Design in the Post-Epidemic Era"	
Subject	Product Inovation Design	
Project Schedule	2021. 11.01—2021.12.24 / Last 8 weeks	
Grade	Junior year	
Learning Objectives	· Mastering the methods of product innovation design; · Being familiar with creative thinking methods; · Solving problems in innovative ways; · Mastering the user research and product market research; · Developing comprehensive design skills; Improving product creative thinking, logical thinking, oral communication skills, and other core literacy abilities.	
21st Century Skills	· Collaboration & Communication	· Research ability on products and users
	· Critical thinking & Problem-solving	· Self-management & Self-development
	· Creativity & Creative thinking skills	· Dealing with diversity
Oriented-problem	Solving people's problems encountered during the Covid-19 epidemic	
Situation Setting	· Inspiring students by photographs, vieods and anecdotes	
Type of work	1) Conducting a product design	2) Making a presentation
Required resources	· Online resources —social media, current news websites, Youtube, etc. · Technical equipment — creative thinking tools; cameras · Materials —newspaper, photos, product design, anecdotes happened during Covid-19	

Figure 5. 2 Project design for the experimental group based on the Project-based learning

The project for the teaching experiment was named as “Product Innovation Design in the Post-Epidemic Era.” We designed the problem to be “Designing products that solve problems that arise around people during an epidemic,” with its subject of “Product Innovation Design in Post-Epidemic Era.” The project was implemented in the Product Innovation Design Course—the project lasted 8 weeks from November 1, 2021, to December 24, 2021. The project was implemented for students majoring in product design in their third year of college. The project aimed to train students to master the methodology of product innovation design. The students were trained to become familiar with various creative thinking tools and learn how to creatively solve problems. Furthermore, the students were trained to conduct user research and product market research. The project also helped students acquire integrated design skills, such as product modeling, product functional design, and product expression. This program aimed to develop core competencies in students, such as innovative product thinking, logical thinking, and oral communication skills. The training goals for this program were based on 21st-century competencies, which included collaboration and communication; critical thinking and problem-solving; creativity and creativity thinking; research and information fluency skills; self-management and self-development, self-regulation; and dealing with diversity. We utilized photographs, videos, and anecdotes to highlight changes in people’s lives since the beginning of the COVID-19 pandemic, prompting students to think about the inconveniences created by the epidemic and to find solutions. The students were required to create a product design to address the problems caused by the pandemic and make a public presentation of their work. We provided students with the necessary resources, including online resources, technical equipment, and materials, during the project.

5.2.4 Teaching implementation process of the experimental group

We designed our educational experiments in strict compliance with 7 project-based teaching practices of the Gold Standard PBL. We also incorporated the four stages of the creative process defined by Kneller, namely preparation, incubation, inspiration, and validation (KNELLER, 1978). Furthermore, we improved the original PBL teaching practice framework with particular approaches that may enhance students’ creativity for the design process and product design methodologies to supplement the existing teaching practice standards. All creative thinking methods were chosen based on the results we obtained in Study1 and Study2. Our invention focused on improving the composition of the scaffolding process for students. We aimed to enhance students’ creativity by providing them with rich scaffolding and creative thinking methods. The teaching process was organized into the following phases: preparation, impartion, exploration and implementation, presentation and evaluation, and reflection and improvement. We define our innovative teaching process as the "PIEPR" teaching method. The "PIEPR" teaching method is named after the initials of each of our teaching processes. We followed the four stages of the creative process in our teaching process and adhered to the 7 project-based teaching practices of Gold Standard PBL. The following Figure 5.3. illustration explains the unique framework model of our teaching design.

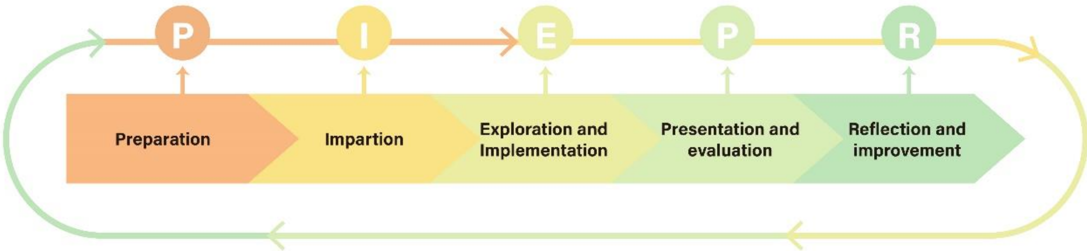

Figure 5. 3 The framework model of the "PIEPR" teaching method

(1) The first stage of teaching: Preparation

The first stage of instructional design was preparation, which is an investigation stage to become familiar with the problem environment (KNELLER, 1978). In this teaching phase, the Gold Standard of PBL teaching practice is reflected through "build the culture" and "design and plan" concepts. The specific teaching practice process is shown in Figure 5.4.

Teaching Practices Design Based on Project-based Learning 1

Teaching process	Project-based LearningTeaching Practices	Learning Stages	Teacher Behaviour	Student Activities	Types of Learning Activities	Class Hour
P preparation	*Build the Culture*	*Preparing*	*· Establishing class norms with students; · Explaining the project; · Defining the expected learning outcomes; · Describing the learning tasks; · Describing the assessment criteria; · Creating a flexible seating and working spaces.*	*· Establishing class norms with teacher and classmates; · Learning about the project details, course requirements, and evaluation criteria; · Participating in the construction of the learning environment.*	*Individual*	*2*
	Design and Plan	*Planning and Scheduling*	*· Finding inspiration from the real world and students' interests; · Improving project quality by discussing the project's feasibility with other colleagues and industry experts; · Developing a schedule and evaluation calendar for the project; · Arranging resources, experts, product users, and real audiences; · Planning Learning Scaffolding and Assessment Schedule.*	*· Finding inspiration from oriented problems; · Participating in class discussions; · Self-organising a team; · Clear division of team members; · Developing a project schedule.*	*corlaboration*	*2*

Figure 5. 4 The teaching process of "Preparation" in the "PIEPR" teaching method

The concept of "building the culture" in project-based teaching refers to the cooperation between teachers and students to create a classroom culture. Students who experience an appropriate classroom culture gain independence, develop cooperation, cultivate a growth mindset, support risk-taking, encourage high-quality work, and foster an environment of inclusion and equity (Boss & Larmer, 2018). Therefore, at this stage, our teaching activities were as follows: 1) Establishing class norms with students: we first explained to students the requirements and precautions to be taken in class and about self-monitoring by the students. 2) Explaining the project: we explained the purposes of implementing the PBL method, importance of completing the project, and schedule and deadlines. Teamwork was considered essential for project completion. 3) Defining the expected learning outcomes: students were assigned a specific type of learning outcome. For instance, they were required to create a product design by the end of the course to address the inconvenience of the epidemic. Eventually, they were required to deliver a public presentation of their work. 4) Describing the learning tasks: students were informed about the theoretical knowledge to be learned during the course and the professional skills to be acquired. We provided them with all the tasks to be completed throughout the course. 5) Describing the assessment criteria: students were presented with the assessment criteria in the form of a multimedia presentation to help them understand the rules and evaluation methods of the course so that they could follow the rules and perform the tasks according to the evaluation methods throughout the course. 6) Creating a flexible seating and working space: we worked with the students to rearrange the classroom and create a space more conducive for collaboration and communication after a joint discussion.

"Design and Planning" in PBL refers to choosing, designing, and planning a project (Boss & Larmer, 2018). Our teaching activities in this phase were as follows: 1) Finding inspiration from the real world and students' interests: we used real-life situations as oriented questions to discuss and identify the proposed project topic with the students. As a general rule, the project topic should be chosen from events happening in the students' lives, their interests, current news, current events, popular culture, and community happenings, and the topic should be familiar and interesting to the students to ensure active participation. After discussing with the students, we developed the theme of designing a product to solve the new epidemic's problems in everyday life. The outbreak of the COVID-19 pandemic in 2019 has affected everyone's life in different ways. Thus, we focused on this issue to stimulate active thinking in the students who attended the project. 2) We discussed the project's feasibility with other colleagues and industry experts before finalizing the project topic and also discussed the theoretical knowledge and materials required to complete the project to improve the project by collaborating with colleagues and seeking feedback from multiple channels. Finally, after reaching a consensus, we decided on the final project topic, which was to complete a product design to address the problems caused by the epidemic. 3) Developing a schedule and evaluation calendar for the project. The duration of the entire project was explained to the students. Students were provided detailed instructions about a precise schedule of the entire project, and they were asked to form groups of four people independently and divide the work so that they could anticipate the task objectives to be accomplished at different stages of the course and understand the specific timing of the assessment in advance to plan their work and prepare themselves. 4) Arranging resources, external experts, product users, and real audiences. We prepared relevant learning resources for students in advance, including reference resources on related topics and links to websites on epidemic-related events. Furthermore, we invited external experts in advance to join us in the final evaluation of the course, in addition to teachers and students from other majors on the campus to participate in the final presentation as real users and listeners to provide additional comments to the students. 5) Planning learning scaffolds and assessment schedules;As observed in Study 1, the students lacked creativity due to misunderstanding of the design process and a lack of mastery of creative thinking methods, which made the selection of appropriate methods by them to generate ideas during the product design phase challenging. Furthermore, based on interviews with 8 educators having decades of experience in teaching product design in Study 2, we planned the scaffolding students would use to support problem-solving and creative thinking throughout the product design process. Additionally, with regard to the planning of learning scaffolds and assessment schedules, we planned the timing and details of the assessment, as the evaluation did not simply rely on the assessment of the final product but on the process evaluation of the students' final grades.

(2) Second stage of teaching: Impartion

The second phase of instructional design, defined as the "impartion" phase, corresponded to the "incubation" phase of the creative process. "Incubation" is preparing to find solutions over a long period, unconsciously rejecting assumptions by moving away from the problem (KNELLER, 1978). We introduced the basic theoretical knowledge to the students and allowed them to complete the incubation stage of the creative process. We followed the Gold Standard of the PBL teaching practice in this process, which was reflected in "Align to standards" and "Manage activities." This process aimed to help students understand the basic methods of innovative product design and creative thinking methods, manage their project activities in preparation for the final product. Figure 5.5. illustrates the specific teaching practice in "impartion" process.

Teaching Practices Design Based on Project-based Learning 2

Teaching process	Project-based LearningTeaching Practices	Learning Stages	Teacher Behaviour	Student Activities	Types of Learning Activities	Class Hour
Impartion	*Align to Standards*	*Importing Knowledge*	*· Provoking students with an introductory session that creates a connection emotionally; · Teaching according to curriculum standards and establishing performance evaluation criteria; · Choosing scaffolding and evaluation methods highly compatible with the curriculum standards; · Establishing clear learning objectives for students.*	*· Understanding the course evaluation criteria; · Understanding learning goals.*	*Individual*	*4*
	Manage Activities	*Importing Knowledge*	*· Managing students' time for individual and teamwork; · Ensuring balanced grouping based on project conditions and student needs; · Supporting students' self-management, independence, and collaboration using project management tools (such as group diaries, team meetings, to-do lists, milestones, deadlines, briefings, and so on); · Verifying that students fully immersed in the project; · Promoting students' understanding of the value of collaboration.*	*· Confirming the responsibilities of the team members; · Creating group diary, schedule team meetings, creating to-do lists, milestones, project deadlines; · Fully participating in teamwork.*	*Individual/ corlaboration*	*8*

Figure 5. 5 The teaching process of "Impartion" in the "PIEPR" teaching method

"Align to standards" requires teachers to develop the content and establish assessment criteria according to the curriculum standards and select an appropriate scaffolding to facilitate student learning based on the curriculum standards (Boss & Larmer, 2018). The following teaching activities were performed in this phase: (1) Provoking students with an introductory session that creates a connection emotionally: we guided students into our course by using photographs, videos, and anecdotes to provoke their thinking about the project topic. The cases were chosen from our daily lives to facilitate empathy with students. Each student was given the opportunity to respond to the open-ended question, "How has the COVID-19 pandemic affected our lives?" 2) Teaching according to curriculum standards and establishing performance evaluation criteria: we developed specific instruction contents based on the course objectives. This course aimed to train students to master the process of product innovation design. Participation in the course required students to comprehend and master the general principles and procedures of product innovation design. Furthermore, it required them to master and become familiar with the methods of creative problem-solving and the application of creative thinking to generate solutions to complex problems. Students were required to master research methods for user and product studies, product functionality design, product expression, and product presentations, among other comprehensive skills. The evaluation criteria also considered students' teamwork and self-management capabilities. 3) Choosing scaffolding and evaluation methods highly compatible with the curriculum standards: we taught each knowledge point according to the course content and standards. We enabled students to achieve precedent-based learning through specific case studies. We screened scaffolds to ensure that they were appropriate and explained innovative thinking methods to students on a case-by-case basis to help them solve problems and generate ideas. We aimed to provide each student with the theoretical knowledge, creative thinking methods, and reference materials that the curriculum standards required students to possess. 4) Establishing clear learning objectives for students: we clarified the skills students were required to master in the course to help them self-test their learning before the start of each lesson.

"Manage activities" in PBL requires teachers to manage students' behavior in the classroom by effectively guiding the implementation of instruction (Boss & Larmer, 2018). Our teaching activities in this phase were as follows: 1) Managing students' time for individual and teamwork: we conducted both whole-class lectures and tutorials for each group in the classroom. We informed students that the entire project required teamwork and provided them with a plan for the next phase, i.e., after the labor division, students individually worked to collect and analyze the data. Later, they worked together as a team to discuss and analyze the results. 2) Ensuring balanced grouping based on project conditions and student needs: we encouraged students to form their teams based on objective project conditions and individual student needs, with students having complete voice and choice. (3) Supporting students' self-management, independence, and collaboration using project management tools (such as group diaries, team meetings, to-do lists, milestones, deadlines, briefings, and so on): each group should create a project diary and hold regular team meetings, create to-do lists as the project progresses, set milestones and deadlines, and conduct briefings in stages to determine the project's research progress so that students can manage their work accordingly (see Appendix 5 and 6). 4) Verifying that students fully immersed in the project: instructors closely monitored the progress of the groups on the project and each student's learning progress during the teaching session. 5) Promoting students' understanding of the value of collaboration: we explained collaboration and project progress planning for successful design teams in stages to help students better manage their teams.

(3) Third stage of teaching: c

The third stage of our teaching method was “Exploration and implementation”. This was the most important part of the PIEPR teaching method. The “inspiration” of the creative process occurs when ideas are reconstructed and integrated into the search for solutions (Cross, 1997). Our teaching process followed the Gold Standard of PBL practice to enhance students’ participation and guidance: “scaffolding student learning” and “engage and coach.” We aimed to assist students in effectively acquiring theoretical knowledge and utilize creative thinking methods throughout the design process to find better design solutions and generate more design ideas. The following Figure 5.6. illustrated the specific teaching practices employed in the “Exploration and implementation” phase.

Teaching Practices Design Based on Project-based Learning 3

Teaching process	Project-based LearningTeaching Practices	Learning Stages	Teacher Behaviour	Student Activities	Types of Learning Activities	Class Hour
E *Exploration and Implementation*	*Scaffold Student Learning*	*Exploring*	*· Providing students with guidance and scaffolding (Ex: tools for product survey, users survey, and creative thinking methods); · Predicting project difficulties and preparing scaffolding; · Breaking down problems into smaller units when students experience difficulties in learning; · Providing various scaffolds for each step of the product design process to assist students in solving problems at different stages.*	*· Choosing appropriate scaffolding and creative thinking tools for product research and user research; · Timely feedback on difficulties in the research process; · Completing the analysis of the research data and determining the problem to be solved; · Recording the group diary, schedule team meetings; · Reporting the results of data analysis in group meetings.*	*Individual/ corlaboration*	*8*
	Engage & Coach	*Design and Production*	*· Focusing on the characteristics and interests of students and applying their strengths and experiences to enhance their potential; · Providing timely and individualized assistance to students during the problem-solving process; · Providing scaffolding for students to present their product modeling expression; · Recognizing and praising students when appropriate for their achievements.*	*· Making use of your personal strengths in teamwork; · Understanding the types of outcomes; · Generating ideas, defining target users, positioning the product; · Sketching; · Idea selection and modification; · Prototyping and detailed design; · Completing the product design; · Providing teachers and team members with timely feedback; · Recording the group diary, schedule team meetings.*	*Individual/ corporation*	*16*

Figure 5. 6 The teaching process of "Exploration and Implementation" in the "PIEPR" teaching method

“Scaffolding student learning” in PBL requires teachers to provide students with various tools and strategies based on curriculum standards and students’ problems to guide students’ inquiry and advance their projects (Boss & Larmer, 2018). Our teaching activities in this stage were as follows: 1) Providing students with guidance and scaffolding: we provided students with the necessary reference materials and creative thinking methods in the teaching process based on the course standards. We provided scaffolds for product research methods, user research methods, and creative thinking methods to students based on the product design process. During the course, we comprehensively described the usage and advantages of each method to help students choose the proper method to finish their tasks at different stages of the project. 2) Predicting project difficulties and preparing scaffolding: we closely monitored the progress of each group's project while anticipating the difficulties they would encounter and prepared scaffolding for students in advance so that they could deal with the difficulties as they arose. 3) Breaking down problems into smaller units when students experience difficulties in learning: we noted that product feature innovation was a challenging task for students during the project; hence, we divided the problem into several smaller units. For instance, students were asked to overview the relevant product and competitor analysis to understand the current design trends and the basic situation of the products. Furthermore, students were required to complete the part of user research, which included mainstream, potential, and target users of the product. Thus, they could learn about users' needs and expectations to help them develop product feature design opportunities. 4) Providing various scaffolds for each step of the product design process to assist students in solving problems at different stages: according to the results of Study 1, and combined the teaching suggestions provided by the eight participants in Study 2, we were informed that unfamiliarity with the product design process and methods of creative thinking resulted in low creativity among students. Hence, this study contributes to improving the composition of the scaffolding process, and we provided a variety of scaffolds to the students to motivate them. We aim to enhance students' creativity by providing some scaffolding and creative thinking methods. For example, various scaffolds for each step of the product design process were provided to assist students in solving problems at different design stages and different methods of creative thinking were taught in different stages of product design to stimulate students' creative ideas. We improved the scaffolding content in product design education for the product design process to provide educators with pedagogical references. (See Figure 5.7.)

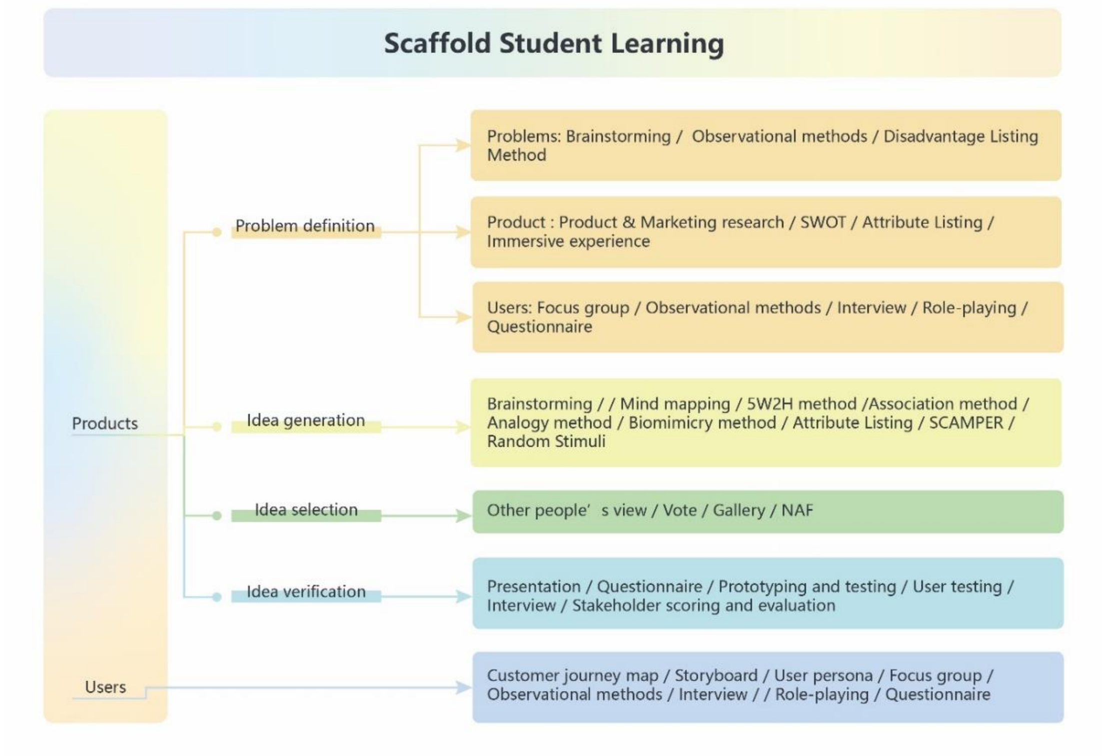

Figure 5. 7 Scaffold student learning

"Engage and Coach" aspect of PBL requires educators to establish a relationship with the students as a coach, motivating the students to participate and providing them with guidance and support (Kaushik, 2020). Teachers act as facilitators rather than leaders in the student's project and provide timely information about the needs of each student. We used the information to design instructional strategies according to each student's strengths, interests, background, and life experiences. Educators should choose appropriate teaching scaffolding and content according to curriculum standards while implementing a teaching method. Our teaching strategies in this stage were as follows: 1) Focusing on the characteristics and interests of students and applying their strengths and experiences to enhance their potential: we were cautious about each student's unique characteristics throughout the project, identifying their strengths and helping them develop their strengths in teamwork to encourage their creativity and potential. 2) Providing timely and individualized assistance to students during the problem-solving process: unlike traditional education, our teaching approach emphasized listening to students' requests and opinions and providing timely feedback and help according to their needs. Occasionally, we sat in the middle of a team of students, helping them when necessary with their problem-solving. We aimed to help students reorient themselves to ensure that they remained interested and confident in the project while encountering difficulties. 3） Providing scaffolding for students to present their product modeling expression: we provided students with sketching cases and product design modeling cases during the design idea generation phase of the course to assist them in effectively presenting their creative ideas. 4) Recognizing and praising students when appropriate for their achievements: we praised students for every small achievement they made during teaching, and we let them show their achievements to other students.

(4) Fourth stage of teaching: Presentation and Evaluation

The fourth stage in our teaching process is "Presentation and Evaluation". The design of a product should be verified before it is developed. Verification occurs when the solution is revised, analyzed, judged, and tested (KNELLER, 1978). As a part of the Gold Standard of the PBL teaching practice, "Assess student learning" was used to assess student design solutions. "Assess student learning" involves frequent and regular assessment of students' achievement of course objectives and successes through multiple dimensions (Dias & Brantley-Dias, 2017). The following Figure 5.8. illustrated the specific teaching practices employed in the "Exploration and implementation" phase. Our teaching activities in this stage were as follows: 1) Using multiple tools to evaluate processes frequently and regularly: our assessments included formative and summative evaluations. We comprehensively examined all the processes involved in completing the project: synthesis of the student's performance in the preparation process, participation in the course, and research and implementation of the design, presentation, reflection, and improvement. Our evaluation focused on students' understanding of the learning objectives and the development of comprehensive literacy skills, including the ability to work in teams, critical thinking, and public speaking. In addition, we evaluated students' learning progress and effectiveness of the teaching approach with the help of a group diary (see Appendix 7), thereby providing a reference for teachers to adjust their teaching plans and improve their teaching methods at any time. 2) Establishing criteria for assessing product design based on the quality of work and effectiveness of the presentation (see Appendix 8 to Appendix 12): a final exhibition of students' work was held at the end of the course to provide students a multidimensional assessment and comments of their work (see Appendix 8) , with assessment criteria consistent with curriculum standards and criteria for students' skill development. 3) Evaluating students' learning outcomes from multiple dimensions (including teacher evaluation, student self-evaluation, student inter-evaluation, and expert evaluation): we developed multidimensional evaluation criteria to ensure the validity and diversity of the assessment results (see Appendix 9 to Appendix 12). Students' public speaking skills were included in the assessment criteria. The evaluations were designed to demonstrate the learning effects for students and encourage them to learn better.

Teaching Practices Design Based on Project-based Learning 4

Teaching process	Project-based LearningTeaching Practices	Learning Stages	Teacher Behaviour	Student Activities	Types of Learning Activities	Class Hour
P *Presentation and evaluation*	*Assessing Student Learning*	*Works Show*	· *Using multiple tools to evaluate processes frequently and regularly;* · *Establishing criteria for assessing product design based on the quality of work and effectiveness of the presentation .*	· *Displaying the final product design;* · *Understanding the evaluation criteria.*	*Gallery*	*4*
		Presentation	· *Evaluating students' learning outcomes from multiple dimensions (including teacher evaluation, student self-evaluation, student inter-evaluation, and expert evaluation).*	· *Making a presentation and obtaining revision comments;* · *Completing a self-assessment and student mutual evaluation.*	*Presentation*	

Figure 5. 8 The teaching process of "Presentation and evaluation" in the "PIEPR" teaching method

Figure 5. 9 Photo of students' presentations at the course

Figure 5. 10 Photo of external experts evaluating student design work

(5) Fifth stage of teaching: Reflection and Improvement

The fifth stage in our teaching process is "Reflection and Improvement". Closing reflections were added to the Gold Standard PBL teaching practice. We helped students modify their product in response to the comments and opinions received during the presentation and encouraged them to keep a reflective journal to sum up the experiences they gained from the course (see Appendix 13). As teachers, we kept reflective journals. Four aspects of this project were: teaching content, project design, teaching methods, and teaching effectiveness (see Appendix 14). The purpose of the reflective journals was to provide a reference for future teaching practices. On one hand, it helps teachers to adjust their teaching strategies to produce a better effect in the next lesson. On the other hand, it also helps students to review what they have learned through the course and fill in the gaps in knowledge. Meanwhile, it also allows teachers to be better informed about students' expectations for future courses. Figure 5.11 shown the teaching practices employed during "Exploration and Implementation".

Teaching Practices Design Based on Project-based Learning 5

Teaching process	Project-based LearningTeaching Practices	Learning Stages	Teacher Behaviour	Student Activities	Types of Learning Activities	Class Hour
R Reflection and improvement	*Closing Reflections*	*Modifying and Inprovement*	*· Providing students with critical feedback and revisions.*	*· Modifying the design work in response to the comments and evaluations.*	*Corporation*	*3*
		Closing Reflections	*· Writing a reflective journal from four aspects: teaching content, project design, teaching methods, and teaching effectiveness.*	*· Creating a reflective journal to reflect on the knowledge you gained and your own shortcomings.*	*Individual*	*1*

Figure 5. 11 The teaching process of "Reflection and improvement" in the "PIEPR" teaching method

Students in control group were required to simply submit the required homework project to the teacher after completing the design.

5.2.5 Post-test

We examined the effectiveness of the “PIEPR” teaching method by conducting a post-test with 54 students from the experimental and control groups at the end of the course. The Torrance Test of Creative Thinking-Figural (TTCT-Figural) questionnaire used in the post-test was the same as that for the pre-test. We collected and administered the questionnaire uniformly. The post-test questionnaire was issued with the exact requirements for the pre-test. Post-test questionnaires were distributed to the experimental and control groups when the teaching experiment concluded to compare the students’ creative thinking levels in the two classes. Finally, we analyzed and compared the pre-test and post-test results of both the classes to verify whether the creative thinking skills of the experimental group students improved.

5.3 Analysis of the experimental effect of our innovative “PIEPR” teaching method

5.3.1 Comparative analysis of creative thinking ability in pre-test stage between

control group and experimental group

According to Table 5.4, we employed the independent sample t-test to explore the primary creative thinking level of grade 19 students majoring in product design. Class 1 of grade 19 represented the control group of our innovative “PIEPR” teaching method, and class 3 represented the experimental group. In the current study, we compared students' primary levels of creative thinking in Class 19-1 and Class 19-3 across four dimensions: flexibility, fluency, originality, and elaboration. As shown in Table 5.4, no significant difference was observed between students in Class 19-1 and Class 19-3 at the initial stage of the experiment indicating that initially, students in Class 19-1 and Class 19-3 have consistent performance across the four dimensions. Thus, we could conduct further teaching experiments.

Table 5. 4 Independent t-test of the primary creative thinking level of experimental group and control group

	group (Mean±Std. Deviation)		t	p
	experimental group (n=28)	control group (n=26)		
Flexibility	14.04±4.64	13.73±4.93	0.234	0.816
Fluency	15.11±5.06	14.12±3.05	0.88	0.384
Originality	13.96±3.80	13.54±3.82	0.411	0.683
Elaboration	14.21±3.41	13.96±3.27	0.277	0.783

* $p<0.05$ ** $p<0.01$

5.3.1.1 Kappa conformance test in the pre-test

As can be seen from Table 5.5, flexibility's kappa = 0.939, corresponding to refinement, fluency's kappa =0.960, corresponding to flexibility, originality’s kappa =0.959, corresponding to fluency, and elaboration kappa = 0.938, corresponding to the originality of this study. Cohen's kappa coefficient is typically distributed between –1 and 1, and greater consistency exists when Cohen's kappa coefficient is closer to 1. Therefore, it can be seen that in the pre-test stage of the experimental design, the two scoring teachers have a strong consistency in scoring the students in terms of flexibility, fluency originality, and elaboration.

Table 5. 5 Consistency test of teacher scoring of students in the pre-test

		Value	Asymptotic Standard Error [a]	Approximate T [b]	Approximate Significance
Flexibility	Measure of Agreement Kappa	.939	.034	23.262	.000
Fluency		.960	.028	24.534	.000
Originality		.959	.028	22.730	.000
Elaboration		.938	.035	21.025	.000

a. Not assuming the null hypothesis. b. Using the asymptotic standard error assuming the null hypothesis.

5.3.2 Comparison and analysis of creative thinking level of students in experimental group and control group in pre-test and post-test

5.3.2.1 Comparison and analysis of creative thinking level of students in the

experimental group in pre-test and post-test

In the experimental group, we conducted a normality test to allot creative thinking level scores to the students. As shown in Table 5.6, in the present study, the sample size was greater than 50, so we utilized the Kolmogorov–Smirnov statistic (K–S) test to assess the reliability of the data. Students' creative thinking level in the experimental group exhibited significant (p > 0.200*) results in pre-test and post-test, signifying that the data accepted the original hypothesis follows a normal distribution. Consequently, we used the parametric test method to compare the level of creative thinking in the experimental group in the pre-test and post-test stages.

Table 5. 6 The normality test for the students' creative thinking level in the experimental group

	time	K-S			S-W		
		Statistics	F	sig	Statistics	F	sig
Flexibility	pre test	.124	28	.200*	.959	28	.324
	post test	.090	28	.200*	.977	28	.768
Fluency	pre test	.116	28	.200*	.968	28	.539
	post test	.136	28	.200*	.958	28	.311
Originality	pre test	.126	28	.200*	.940	28	.112
	post test	.168	28	.041	.950	28	.194
Elaboration	pre test	.206	28	.004	.882	28	.004
	post test	.123	28	.200*	.965	28	.447

Analysis of variance (ANOVA), also called the "F test," determines the significance of differences between the means of two or more samples. ANOVA was invented by R. A. Fisher. The data from our study demonstrated fluctuations due to several factors. Data fluctuation can be divided into two categories: random factors that cannot be controlled and controllable factors that affect the results of the behavior employed in the study. Table 5.7 reveals that ANOVA was employed to explore the differences in the creative thinking of experimental students in pre-test and post-test. All scores for flexibility (F = 13.917, p = 0.000), fluency (F = 13.692, p = 0.001), originality (F = 19.685, p = 0.000), and elaboration (F = 29.73, p = 0.000) of students in the experimental group in the pre-test stage and post-test stage exhibited a 0.05 level of significance. F values are commonly used to analyze differences between groups. The F value indicates the significance of the entire fitting equation. A large F value indicates a more significant equation and a better fitting degree. The p-value is an index to measure the difference between the experimental and control groups. A p-value of less than 0.05 indicates a significant difference between the two groups. When the p-value is less than 0.01, the difference between the two groups is extremely significant. Combined with the boxplot results, we observed that the experimental group students significantly improved their flexibility, fluency, originality, and elaboration with our "PIEPR" teaching methods experimental activities.

Table 5. 7 Comparison and analysis of students' creative thinking level in pre-test and post-test in the experimental group

	time (Mean±Std. Deviation)		F	p
	pre test (n=28)	post test (n=28)		

Flexibility	14.04±4.64	18.79±4.89	13.917	0.000**
Fluency	15.11±5.06	19.21±2.99	13.692	0.001**
Originality	13.96±3.80	18.21±3.36	19.685	0.000**
Elaboration	14.21±3.41	18.86±2.94	29.73	0.000**

* p<0.05 ** p<0.01

The researcher used the mean to compare specific differences and employed the effect size to evaluate the magnitude of the difference in instances where the ANOVA results illustrated a significant difference ($p < 0.05$). In ANOVA, the partial ETA square represents the effect amount (i.e., difference amplitude). The larger the value, the more significant is the difference. The critical points for distinguishing small, medium, and large effects are 0.01, 0.06, and 0.14, respectively. The formula of partial ETA square value is SSB / SST. Cohen's f can also be used to represent the effect amount, and its calculation formula is sqrt (partial ETA square / (1 - partial ETA square)) when Cohen's f indicates the effect size, and the critical points for distinguishing small, medium, and large effect sizes are 0.10, 0.25, and 0.40, respectively. As shown in Table 5.8, students in the experimental group demonstrated more significant differences in the four dimensions of flexibility, fluency, originality, and elaboration than those in the control group.

Table 5. 8 The Effect size of students' creative thinking level in pre-test and post-test in the experimental group

Items	SSB	SST	Partial η^2	Cohen's f
Flexibility	315.875	1541.554	0.205	0.508
Fluency	236.161	1167.554	0.202	0.504
Originality	252.875	946.554	0.267	0.604
Elaboration	301.786	849.929	0.355	0.742

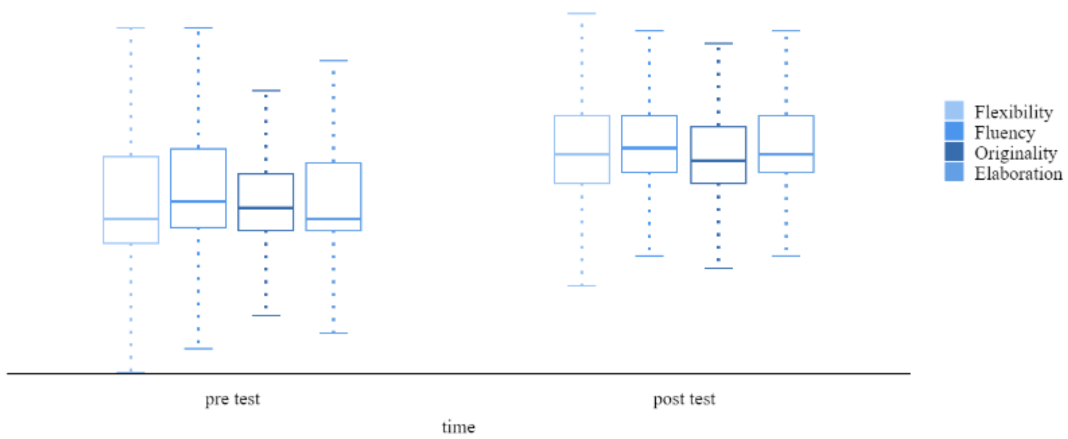

Figure 5. 12 Comparison and analysis of students' creative thinking level in pre-test and post-test of the experimental group

5.3.2.2 Comparison and analysis of creative thinking level of students in the control group in pre-test and post-test

We conducted a normality test on the creative thinking scores of the students in the control group. Table 5.9 shows that the students in the control group exhibited a significant level of creative thinking in the pre-test and post-test ($p > 0.200$*), signifying that they accepted the original hypothesis of the normal data distribution. Hence, the parameter test method could be considered to compare the creative thinking level of the students in the pre-test and post-test stages.

As shown in Table 5.10, we used ANOVA to test the differences in the level of creative thinking of the students in the control group in the pre-test and post-test stages. Students' performance in flexibility (F = 1.709, p = 0.197), fluency (F = 7.285, p = 0.009), originality (F = 3.34, p = 0.074), and elaboration (F = 3.054, p = 0.087) in the control group in the pre-test and post-test illustrated a significant difference of 0.05 level on their fluency, indicating that in the post-test stage, the fluency level of the students in the control group was significantly higher than that of the initial stage. However, the flexibility, originality, and elaboration levels were slightly improved, and the improvement effect was not apparent and did not exhibit statistical significance. Moreover, combined with the boxplot results, although the levels of flexibility, originality, and elaboration of the students in the control group increased slightly, the improvement effect was not statistically significant.

Table 5. 9 The normality test for the students' creative thinking level of the control group

	time	K-S			S-W		
		Statistics	F	sig	Statistics	F	sig
Flexibility	pre test	.136	26	.200*	.959	26	.378
	post test	.106	26	.200*	.960	26	.389
Fluency	pre test	.141	26	.200*	.955	26	.305
	post test	.128	26	.200*	.948	26	.203
Originality	pre test	.171	26	.048	.941	26	.141
	post test	.147	26	.157	.934	26	.098
Elaboration	pre test	.111	26	.200*	.951	26	.250
	post test	.144	26	.173	.944	26	.164

Table 5. 10 Comparison of creative thinking level of control group students in pre-test and post-test in the control group

	time (Mean±Std. Deviation)		F	p
	pre test (n=26)	post test (n=26)		
Flexibility	13.73±4.93	15.42±4.39	1.709	0.197
Fluency	14.12±3.05	16.23±2.58	7.285	0.009**
Originality	13.54±3.82	15.15±2.39	3.34	0.074
Elaboration	13.96±3.27	15.58±3.40	3.054	0.087

* $p<0.05$ ** $p<0.01$

Table 5. 11 Effect size of students creative thinking level in pre-test and post-test in the control group

Items	SSB	SST	Partial η^2	Cohen's f
Fluency	58.173	457.442	0.127	0.382

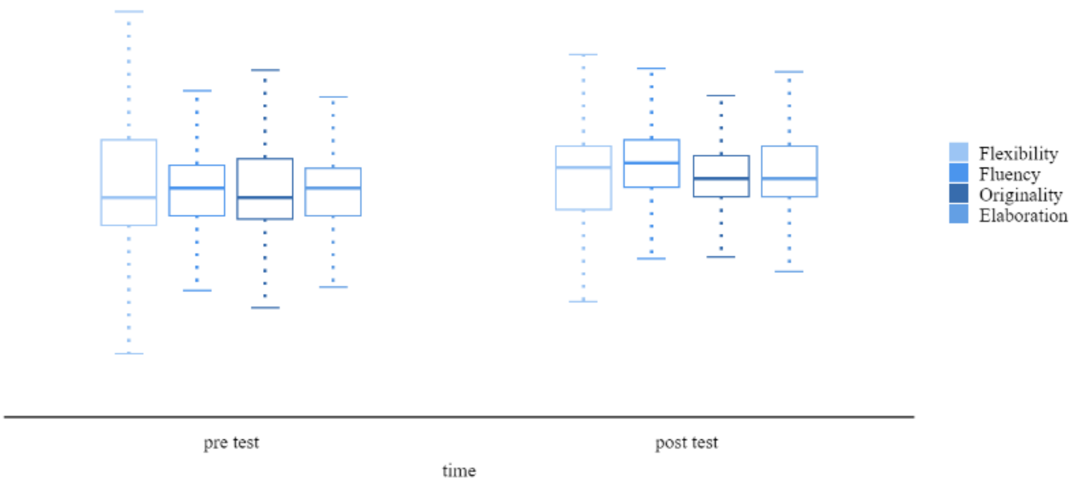

Figure 5. 13 Comparison and analysis of students' creative thinking levels in pre-test and post-test of the control group

5.3.2.3 A comparative analysis of the creative thinking level of students between the experimental group and the control group in the post-test

The independent sample's t-test requires that two groups of observed variables have equal variance. The variance values for each group are displayed in the description table, as shown in Table 5.13 below. According to the results, f = 0.525 and p = 0.469, which correspond to flexibility, indicate that the data variance is homogeneous (judgment standard, if p-value >0.05, it indicates that the variance is homogeneous), which conforms to the variance homogeneity test. The results of the independent samples t-test show that the score difference between the experimental and control groups at the flexibility level is 3.123. The t-test results are t = 9.942, p = 0.000<0.05, indicating that there are differences in flexibility between the experimental and control groups, with the former being higher than the latter.

Fluency is represented by f = 5.276, p = 0.022. According to the results of independent samples t-test, the difference between the experimental and control groups at the fluency level is 2.739. The t-test results show that t = 15.092, p = 0.000<0.05, indicating that there are differences in fluency between the experimental and control groups, with the former being higher than the latter.

The original value of f = 11.072, p = 0.001. The difference between the students in the originality level experimental group and the control group is 2.769, according to the results of independent samples t-test. The t-test results show that t = 14.718, p = 0.000<0.05, indicating that there are differences between the students in the original level experimental group and the control group, with the former being higher.

The corresponding f = 21.642, p = 0.000, of the elaboration indicates that the data variance is homogeneous (the judgment standard, if the p-value >0.05 indicates that the variance is homogeneous), which conforms to the variance homogeneity test. The results of independent samples t-test show that the score difference between the experimental and control groups at the elaboration level is 3.010. The t-test results show that t = 14.156, p = 0.000<0.05, indicating that there are differences between the experimental and control groups at the elaboration level, with the former scoring higher.

Table 5. 12 Statistical values of students' performance in the experimental and control groups in the post-test

	group	N	Mean	Std. Deviation	Std. Error Mean
Flexibility	experimental group	528	18.85	4.951	.215
	control group	405	15.73	4.488	.223
Fluency	experimental group	528	19.19	2.949	.128
	control group	405	16.45	2.583	.128
Originality	experimental group	528	18.11	3.260	.142
	control group	405	15.34	2.485	.123
Elaboration	experimental group	528	19.30	2.846	.124
	control group	405	16.29	3.479	.173

Table 5. 13 Results of independent samples test of student performance in the experimental and control groups in the post-test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Flexibility	Equal variances assumed	.525	.469	9.942	931	.000	3.123	.314	2.507	3.740
	Equal variances not assumed			10.072	905.461	.000	3.123	.310	2.515	3.732
Fluency	Equal variances assumed	5.276	.022	14.831	931	.000	2.739	.185	2.376	3.101
	Equal variances not assumed			15.092	914.753	.000	2.739	.181	2.383	3.095
Originality	Equal variances assumed	11.072	.001	14.212	931	.000	2.769	.195	2.386	3.151
	Equal variances not assumed			14.718	930.967	.000	2.769	.188	2.399	3.138
Elaboration	Equal variances assumed	21.642	.000	14.531	931	.000	3.010	.207	2.604	3.417
	Equal variances not assumed			14.156	769.770	.000	3.010	.213	2.593	3.428

5.3.2.4 Kappa conformance test in the post-test

To ensure the validity of the two teachers' scores, an internal consistency test was conducted on the two teachers' scores for each student. The following Table 5.14 shows that Cohen’s kappa = 0.960 corresponds to elaboration, Cohen’s kappa = 0.938 corresponds to flexibility, Cohen’s kappa

= 0.958 corresponds to fluency, and Cohen’s kappa = 0.959 corresponds to the origin of this study. In general, Cohen’s kappa coefficient ranges between -1 and 1. If Cohen’s kappa coefficient is less than zero, it means that the observation consistency rate is lower than the opportunity consistency rate, which is uncommon in real-world research. If Cohen’s kappa coefficient is equal to zero, the observation consistency rate equals the opportunity consistency rate, and the result is entirely determined by opportunity factors. If Cohen’s kappa coefficient is greater than zero, it indicates that the subjects are fairly consistent. The greater the consistency, the closer Cohen’s kappa coefficient is to 1. Therefore, it is clear that the consistency of students' scores in the experimental design's post-test stage is strong in terms of flexibility, fluency, originality, and elaboration.

Table 5. 14 Consistency test of teacher scoring of students in the post-test

			Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Elaboration	Measure of Agreement	Kappa	.960	.028	26.496	.000
Flexibility			.938	.035	21.022	.000
Fluency			.958	.029	20.957	.000
Originality			.959	.028	23.074	.000

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

5.3.3 Survey and analysis of teaching effectiveness

5.3.3.1 Analytical results based on classroom observations

We observed students in the experimental group during the teaching experiment and found that most students were highly motivated in class. Rarely, students were found to play on their cell phones with their heads down in class. The students enthusiastically answered our questions and actively interacted with us. Students would progress with their work based on their assigned tasks, especially after forming groups. The presentations at the end of the course and our reflection and improvement significantly improved the quality and completion of student assignments as well as the format and layout of assignment reports and PowerPoints. Compared with the control group, the experimental group students submitted higher quality hand-drawn expression rendering assignments (see Figure 5.14.). Meanwhile, the students in experimental group was able to achieve better visual effects with their homework display boards (see Figure 5.15 and Figure 5.16). The ability of the students to express themselves and respond to various situations was finally improved.

Hand-drawn renderings of students in the experimental group VS Hand-drawn renderings of students in the control group

Figure 5. 14 Comparison of the hand-drawn results of students in the experimental group and the control group

Figure 5. 15 The homework display boards submitted by the students in the experimental group

However, we observed that a few students chose inappropriate methods for conducting user research, resulting in a lack of comprehensive exploration of users’ needs. Additionally, we found that students’ methods of analyzing the data for research results were not standardized when conducting the statistical analysis. The instructor immediately provided guidance and demonstrations to respond to these problems, ensuring a smooth and precise implementation of teaching experiments.

Figure 5. 16 The homework display board submitted by the students in the control group

5.3.3.2 Analysis of questionnaire results

After the teaching experiment, we distributed a questionnaire to the students to assess the effectiveness of our teaching methods. We used the Questionnaire Star tool, an open-ended survey on students' feelings and suggestions about the course. Furthermore, we used the "extract keywords" function to extract keywords from the questionnaire results. The keyword extraction was automatically performed according to the order of word frequency, as presented in Figure 5.17.

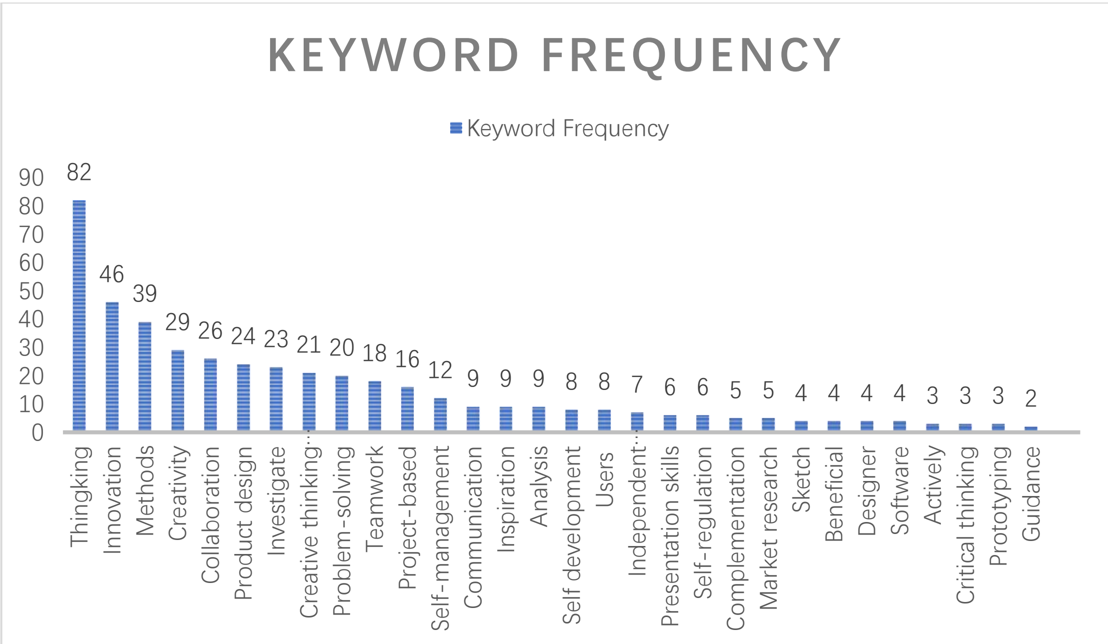

Figure 5. 17 Results of keyword extraction for the questionnaire on students' opinions of the course

The Figure 5.17 depicts that the students mentioned the word "thinking" more frequently in their responses to the questionnaire, with 82 times indicating that the word was frequently mentioned. This was followed by "innovation" and "method," which were mentioned 46 times and 39 times, respectively, indicating that these terms were frequently mentioned. The 6 keywords "creativity," "collaboration," "product design," "research," "creative thinking," and "problem-solving" were mentioned 20–30 times, indicating that these terms were mentioned more frequently. Furthermore, the keywords "teamwork," "project-based," and "self-management" were mentioned 10–19 times, indicating that these words were mentioned quite frequently. Further, 10 keywords were mentioned 5–9 times, and 8 keywords were mentioned 2–4 times, indicating that they were mentioned in the process of students' responses to the questionnaire but not mentioned very frequently compared with the aforementioned keywords. According to the analysis of the keyword extraction results in Figure 5.15 and the actual situation in the teaching experiment, we believe that students focused on various creative thinking methods. Specifically, they gained a deeper understanding of creative thinking methods and problem-solving approaches. The students successfully utilized the creative thinking methods provided by the teacher to overcome difficulties and solve problems by cooperating with other participants in the group. All the students could complete the project and course. Furthermore, the students learned how to work in teams and manage projects by using project management tools. Timely guidance provided by the instructor helped the students strengthen their sketching and prototyping skills. During the pre-research phase of the project, the students learned to conduct effective market research for different consumer groups and users based on scaffolding provided by the instructor. Therefore, we inferred that the "PIEPR" teaching method improved students' creative thinking skills, problem-identification and problem-solving abilities, independent thinking skills, and presentation skills.

5.3.3.3 Analysis of the interview results

Analysis of the questionnaire survey results indicated that all the students responded positively and that none of them commented negatively regarding the implementation of the teaching experiment. Thus, we selected a representative from each group in the experimental group to conduct an interview. Each interviewee provided informed consent before the interview. Informed consent was obtained from the interviewees after clearly informing them of the purpose of the interview. The interview was conducted to know students' experiences and feelings during the teaching experiment in project-based learning. The interviewees were 4 men and 3 women who participated in our course. We coded the 4 male interviewees as M1, M2, M3, and M4 and the 3 female interviewees as W1, W2, and W3. Some of the transcripts of the interviews are presented in Tables 5.15 and 5.16.

Table 5. 15 Interview feedback from 4 male respondents

Interviewee	Description
M1	*"The instructor taught us many* ***useful creative thinking techniques*** *that* ***helped us solve problems and generate ideas*** *and* ***inspiration during different stages of product design****. We* ***reinforced our product design methodology and process by completing projects****. Additionally, I* ***liked the evaluation method*** *of the course, which was different from that of other courses in that our final grades were evaluated in terms of* ***multiple dimensions*** *and not by a single teacher. This*

	evaluation method is ***more objective and fairer*** *than other methods. The* ***final presentation*** *helped us* ***receive valuable feedback*** *from external experts, other on-campus instructors, and students, who* ***provided us with many helpful suggestions****, enabling us to* ***improve our work*** *and tailor it to suit users' needs."*
M2	*"The course was very different from the previous professional courses. Unlike other courses that involve completing the design work independently, we could* ***work with our teacher and classmates*** *to* ***solve the problems*** *that were encountered during the project, which* ***enhanced the efficiency and quality of our work****. It also* ***enhanced our teamwork skills****. I also* ***benefited from the teachers' explanations of creative thinking methods*** *during the course. We were able to find a product design solution for solving problems by using these methods and complete the project in this course. These methods also* ***helped us gain confidence*** *in pursuing other courses and* ***working in a workplace in the future****. We learned from our teacher how to use these methods effectively, which will* ***provide us more career opportunities*** *in the future."*
M3	*"This course helped me* ***taste the team-oriented atmosphere*** *I may encounter at work in the future. It enabled me to* ***cooperate and communicate better with my colleagues*** *in the future. As we completed* ***a real project*** *in college for the first time, we all took the course very seriously because we wanted the final design to* ***be recognized by more people****. The course allowed us to* ***use project management tools*** *for the first time, which* ***helped us manage our small team efficiently*** *and also* ***manage time to complete our project****. I intend to utilize these useful project management tools to continue* ***improving myself in the future****. Additionally, I* ***practiced my presentation skills*** *by elaborating on our design work, which* ***made my logic clearer*** *and I* ***felt more confident****. This project experience* ***helped us feel confident about our future professional studies****, thus* ***strengthening our career plans****."*
M4	*"The course allowed us to* ***have a full voice and choice****; our classmates and I were a****ble to discuss and decide on a topic of the assignment*** *relevant to our lives. The instructor* ***respected our opinions*** *throughout the project and* ***allowed us to form the team we liked****. The teacher's* ***teaching methods motivated us during the project****. During the course, we learned both the* ***basic innovation design methods*** *and processes and many* ***useful techniques for creative thinking****. Furthermore, we were provided* ***a wealth of design case studies*** *during our course, which* ***helped us expand our ideas*** *and* ***strengthen our hand-drawing abilities*** *through copying. I also learned about* ***product prototyping*** *from the other team members since we worked together during the project completion phase."*

Table 5. 16 Interview feedback from 3 female respondents

Interviewee	Description
W1	*"We* ***gained insights into the process and product development methods*** *through the course. The instructor explained us* ***many techniques for creative thinking****, which* ***enhanced our problem identification*** *and* ***problem-solving skills*** *and* ***stimulated us to come up with many novel ideas*** *for the* ***successful completion of the final project outcome****. Moreover, we* ***learned many methods for researching and analyzing products and users*** *that helped us* ***identify problems with the products and identify the users' needs****. It further* ***helped us identify design opportunity points*** *and* ***improve our critical thinking skills****. Additionally, my ability to* ***collaborate with others has improved*** *after participating in the course. This course allowed us to* ***utilize our strengths in the***

	team *through teamwork, and we were also able to* ***identify our weaknesses****, which will allow us to* ***address those gaps in our future studies*** *and* ***in the pursuit of continuous self-development****."*
W2	*"Our project topic involved a problem that we are experiencing and facing in our everyday life. By discussing and collaborating with other partners in the class during early stages of the project, I could* ***generate many creative ideas*** *to* ***solve the problem****. With the teacher's* ***timely guidance and assistance****, we* ***standardized the product design processes and methods*** *during every project stage, from problem identification to problem-solving and final presentation. I also learned how to* ***better cooperate with my team members****. Moreover, the* ***project management tools*** *allowed us to* ***manage our team*** *during the project progress better and helped us* ***improve our self-management*** *and* ***time-management skills****, allowing us to* ***better deal with diversity issues****, which will be* ***very helpful in our future career*** *development."*
W3	***"I really enjoyed this course because in other courses, we are frequently asked to complete virtual projects, which makes us feel that the final product we design is irrelevant. This time, when we received the opportunity to work on a real project, we could design a product that would help users solve a real-life problem. It made us feel that the product we designed was valuable. Although we encountered many difficulties during the project, our teachers always provided timely assistance and guidance, which boosted our confidence and inspired us to complete the work. Moreover, we were motivated to work with our partners to complete projects when we were convinced that our products could help solve real-life problems."***

The findings according to sorting and analysis of the interview transcripts are as follows:

① The "PIEPR" teaching method helped students better standardize the methods and processes for designing products

According to 4 of the 7 interviewees, our "PIEPR" teaching method developed in the teaching experiment could better standardize the methods and processes for students designing the product. W1 mentioned that the course helped students gain an in-depth understanding of product design methods and processes. W2 also reported that the teacher's timely guidance and assistance helped them standardize their approach and process of product design from problem identification to problem-solving and final presentation. The two male respondents, coded as M1 and M4, also held the same opinion. Thus, the "PIEPR" teaching method allows students to meet the course's learning objectives. Educators should pay considerable attention to students' learning situations and provide timely guidance and assistance throughout the course of the project to better standardize the methods and processes used by the students involved in product designing.

② The "PIEPR" teaching method improved students' problem-solving skills

Transcripts of the interviews indicated that the students could generate more creative ideas to solve problems if the teachers provide rich and effective scaffolding such as innovative thinking methods. For example, W1 mentioned that the creative thinking methods provided by the instructor during the course helped them identify and solve problems and generate various innovative ideas for the final project outcome. The same opinion was help by the respondents coded as M1 and M2, who stated that the instructor's explanation of creative thinking methods stimulated their creativity, inspired them to create more ideas, and helped them find product design solutions to solve problems. Furthermore, the respondents coded as W2 and M2 mentioned that discussions and collaborations with the instructor and other partners allowed them to generate more creative ideas in the problem-solving process and also improved the efficiency and quality of their design work. These results suggested that educators could improve students' problem-solving skills by providing scaffold and thoroughly explaining the process of using creative thinking methods and engaging in student discussions in “PIEPR” teaching method. These approaches can inspire students to be creative and encourage them to experiment with various feasible problem-solving strategies while utilizing creative thinking methods throughout the design process.

③ The “PIEPR” teaching method could improve students' collaboration and communication skills.

Of the 7 respondents, 4 (coded as W1, W2, M2, and M3) mentioned that the “PIEPR” teaching method based on the project-based learning implemented in the experiment improved their ability to cooperate and communicate with their team members. Additionally, the discussion and cooperation with other partners inspired them to generate more creative ideas and improve the quality of their products. Hence, we recommend strengthening students' ability to work in teams and encouraging them to explore feasible solutions for solving problems through group cooperation. Future education courses should focus primarily on discovering appropriate teaching methodologies that can allow students to utilize their characteristics to experiment with real team operations and accomplish their tasks to improve the study outcome.

④ The “PIEPR” teaching method allowed students to achieve better self-management and self-improvement

W1 mentioned that the teamwork in the course allowed her to utilize her strengths and identify her weaknesses, which will enable her to efficiently address the gaps in her future studies to achieve continuous self-development. Among the male interviewees, M2 stated that the teaching method is beneficial both in pursuing further studies on other courses and achieving career goals. M3 stated that the project management tools provided in our course were extremely effective and that he would use them for self-development in the future. Furthermore, he mentioned that the presentation at the end of the course has improved his presentation and logical thinking skills, and this has boosted his confidence in pursuing future professional studies and made him more determined in future career plans. Similarly, M4 stated that our innovative teaching method improved his ability to express the design work professionally. He mentioned that his hand-drawing ability has improved by studying the cases provided by the teacher and that he has learned new techniques for product prototyping from his fellow group members. Both male and female interviewees, coded as W2 and M3, agreed that the project management tools helped them manage their projects and improved their self-management and time-management skills and the ability to deal with diversity. Thus, we recommend that educators should plan their teaching methods more scientifically and develop effective teaching strategies. Educators should also guide students to complete projects by using sound project management tools. Moreover, they should conduct a presentation session at the end of the course to help students improve their presentation skills. To help students learn self-management and self-improvement, educators should provide efficient design cases, which can inspire students to expand their ideas according to the syllabus of the product design program.

⑤ The “PIEPR” teaching method can increase students’ motivation for the course.

W3 mentioned that she really enjoyed attending the course because designing a product that could help people solve their real-life problems makes students feel that their product is valuable, eventually motivating and driving them to complete the whole project with their partners. Furthermore, our timely help and guidance during the course helped students regain confidence after being faced with difficulties. M1 appreciated our evaluation method because it involved external experts and other real users who provided students valuable feedback and suggestions, which assisted them in improving their design work and allowed them to make it more relevant to the users’ needs. M3 stated that participation in the project provided them an early exposure to the teamwork atmosphere of their future workplaces. It was the first opportunity for the students to complete a college project; therefore, they actively participated in the project as they wanted their final design to be viewed by a broad audience, which encouraged them to participate more actively in the course. The respondent coded as M4 stated that they had full voice and choice in the course, both in choosing the assignment topic and forming the team, which motivated and drove them to complete the project. Thus, we suggest replacing traditional virtual projects with real-world projects to motivate students to participate in the course. The course task should be based on real-world projects, particularly those related to students' lives. Additionally, to enhance student engagement, instructors should ensure that their students comprehend the design process and the importance of participating in real-world projects. Moreover, they should choose topics based on students' interests to encourage their active participation in real-world projects. To ensure a fair and objective course evaluation, educators can invite external experts or real users to participate in the course evaluation process so that students can receive valuable comments and help to improve their products. We further recommend that educators should pay attention to students' wishes and respect their voice and choice in future education to increase their motivation to participate in the course.

⑥ The “PIEPR” teaching method can improve students' research and analysis skills and critical thinking about products and users.

A female interviewee, coded as W1, stated that the research and analysis methods provided by the teacher about the product and users prompted them to reflect on the problems of existing products and helped them easily identify the design flaws and users’ needs. These teaching methods also helped students effectively generate ideas. The students mentioned that the course has also improved their critical thinking skills. Therefore, we recommend that educators should pay attention to students' research skills on products and users, in addition to teaching them creative thinking methods, in future education. Enabling students to learn appropriate research and analysis methods can help them identify the problems with existing products and the real needs of users. It can also help students generate design ideas for product efficiency by dialectically analyzing existing design works.

5.4 Findings and Conclusions

We drew our conclusions after analyzing the interview data and the pre-and post-test results of experimental and control groups and reflecting on how the course was conducted. According to the interview data and the pre-test and post-test results of the experimental and control groups and our observation of the course process, both experimental and control groups exhibited improvement in all four criteria of creative thinking abilities. By comparison and analysis of creative thinking level of students in the experimental group in pre-test and post-test. We revealed that the experimental group students significantly improved their flexibility, fluency, originality, and elaboration with our "PIEPR" teaching methods experimental activities. However, the levels of flexibility, originality, and elaboration of the students in the control group increased slightly, and the improvement effect was not statistically significant. Hence, we indicated that the improvements in the experimental group students' creative thinking skills in terms of each evaluation criterion were more significant than those in the control group students. It demonstrated the "PIEPR" teaching method, which was designed based on the golden standard, is implementable and valuable in cultivating creative thinking skills among product design students. We present the specific teaching practice of "PIEPR" in Appendix 4. Taking this course as an example, the traditional teaching methods of product design majors are not efficient in fulfilling the needs of students in terms of inculcating creativity. Educators should develop and adjust teaching methods based on the current state of creativity and course characteristics of undergraduates to enhance creativity among students majoring in product design.

5.5 Summary

This chapter summarizes the results of an empirical study of the "PIEPR" teaching method designed in the present study. We implemented the "PIEPR" teaching method of project-based learning in our teaching experiment and compared the experimental and control groups after the experiment. A statistical analysis of the TTCT results and a study of the teaching effects validated that the "PIEPR" teaching method teaching method designed in this study can enhance the creativity of product design students.

CHAPTER 6 Conclusion

In this chapter…

- Conclusion of all the Findings from Studies 1-3
- Contribution to knowledge science
- Limitations and recommendations for future research

Chapter 6 Conclusion

This chapter contains conclusions, contributions to scientific knowledge, and recommendations for future research. First, we summarized the findings from studies 1 to 3 (Chapters 3 and 5) and presented our insight into the research results. Second, we discussed the contribution of our research to scientific knowledge, academically and practically, and the significance of this research for future product design education. Finally, this chapter provided limitations and recommendations for further research and future instructional design.

6.1 Conclusion of all the Findings from Studies 1-3

All findings of our study are summarized.

The first study (Chapter 3) was focused on exploring the level of personal creativity and its influencing factors among college students majoring in product design through a questionnaire survey. We explored the students' creativity and product design capabilities, their cognition of creative thinking methods, and the perceptions and demands of teaching methods and course forms. Based on the results, students' creativity level was, in general, poor. Our study also examined the reasons for the low level of creativity among students. Low creativity in students was primarily the result of poor teaching methods by educators. The lack of creativity among students was also due to a lack of understanding of creative thinking methods, disinterest in homework propositions, and a rigid teaching environment. Moreover, we suggested the following recommendations based on the questionnaire results. 1) Fully integrating creativity education into the curriculum and instruction, such that teachers should provide students with basic product design knowledge and develop unique teaching strategies that enhance their creativity. 2) Educators should teach creative thinking methods more effectively. Educators should adopt traditional teaching methods to emphasize using different types of creative thinking methods during product design to help students develop their flexibility in applying them. 3)Students must be provided with rich creative thinking methods. The cultivation of creativity in students should not be limited to the common creative thinking methods. Providing students with various creative thinking methods at different phases of the design process is essential. 4) Adjusting the course form to include practical projects. We recommend that educators develop practical learning projects as part of their courses to motivate students to engage in the learning process. Furthermore, the homework propositions should be related to subjects the students are interested in to encourage creativity. We conducted a teaching method design to enhance students' creativity based on the findings by addressing the above influencing factors. This section of the results addressed SRO1 and SRO2.

Study 2 (in Chapter 5) presented an overview of the applications and teaching effectiveness of several different creative thinking methods used by the interviewed educators.

First, according to the respondents, the teaching effect provided by analogy and association was general. The analogy and association method could be applied to product appearance design, cultural and creative product design, and product modeling design. However, the use of this method would depend on each student's knowledge and personal vision levels, and particularly, students’ caliber will influence their creative outcome. In addition, this method is not suitable for products with a high degree of industrialization. Eight respondents listed different application scenarios of the biomimicry method, including daily necessities design, houseware design, product appearance design, and vehicle design. Biomimicry is an ideal method for designing the product's appearance and the product form. The Biomimicry method includes conducting time-consuming in-depth research, which is a disadvantage. Since the biomimicry method is often adapted from the appearance of animals or plants, the works produced by the method tend to be less innovative. Most of the eight respondents agreed that the brainstorming method helps students conduct idea generation during the teaching process. The brainstorming method has a better effect on teaching. However, half of the respondents realized that not all ideas are helpful. The respondents were familiar with the attribute listing method, but they occasionally used it. Respondents said that listing the attributes of a product could sometimes limit their thinking. However, brainstorming is a valuable technique for testing the dimensions of creative ideas. Respondents commonly used mind mapping at the idea generation stage. Mind mapping allowed creators to organize ideas and discover connections between objects.

Nevertheless, users could confuse mind mapping with brainstorming, and sometimes the generated ideas were not accurate. Most of the respondents were not aware of the TRIZ. All the respondents believed that the method was unsuitable for students' current professional competence. All respondents considered SCAMPER a more effective teaching method than other creative thinking methods. The method is commonly used in product improvement designs since it can enable creators to change the product. However, SCAMPER is used to make partial adjustments based on the original product, and it could sometimes result in a lack of innovation in design work. Five of the eight respondents indicated they would apply the 5W2H method when teaching to assist students in generating solutions and product positioning. Respondents considered the 5W2H method useful for validating student ideas. However, the 5W2H method was ineffective if students were not aware of the answers to most questions. Thus, we employed the feedback mentioned above from interviewees to combine the benefits of creative thinking methods in the teaching experiments in the following chapters, also avoiding the disadvantages mentioned by the interviewees. Our goal was to bring better results for our later teaching experiments.

Second, the educators interviewed offered their insights into the factors that lead to low student creativity. We summarized the specific reasons as follows:

- Due to a lack of life experience, students will face challenges identifying the problems in their daily lives.
- Lack of observational skills among students.
- Independent thinking ability must be developed among students.
- The curriculums are poorly designed.
- Students have poor time management and self-management skills.
- The teaching environment and the classroom layout setting are unreasonable.
- The course assignments lack novelty and attractiveness.

- Lack of innovation in teaching methods and teaching content.

Therefore, we considered the above influences when designing the “PIEPR” teaching methods to avoid adverse effects on students' creativity.

Third, the respondents suggested five methods to stimulate students' creativity in Question4 (Q4) of the interview, including sharing excellent design cases with students, recommending SWOT analysis, working and discussing in groups, random stimulation, and role-playing. We employed these methods as scaffolds for students in the instruction design.

Fourth, respondents made suggestions for generating creative ideas for different stages of product design. The responses are summarized in Figure 4.3. Students were provided scaffolding using these data in the teaching experiments.

Finally, eight educators with rich teaching experience offered suggestions for teaching methods regarding assignment proposition, teaching methods, teaching activities, students' learning behaviors, and teaching content. For instance, incorporating project-based learning into our curriculum improves students' creativity. Setting real-world questions and selecting current social issues or topics in which students were interested were used to inspire students’ enthusiasm for learning. Providing students with scenarios, such as photos, videos, and news, stimulate their observation of the problem. Setting appropriate milestones to help students develop time management and self-management skills is also required. Lastly, the classroom layout can be changed to improve the teaching environment. The results from this section addressed the SRQ3.

In Study 3 (Chapter 5), we conducted pre-and post-tests of the teaching experiment to determine students’ creative thinking levels by using the Torrance Test of Creative Thinking-Figural (TTCT-Figural). Furthermore, we investigated the teaching effect following the experiment to determine the effects of the teaching method on students’ creative thinking levels. We combined the findings of Study1 and Study2 with project-based learning to develop our instructional design. We drew our conclusions after analyzing the interview data and the pre-and post-test results of experimental and control groups and reflecting on how the course was conducted. According to the interview data and the pre-test and post-test results of the experimental and control groups, and our observation of the course process, both experimental and control groups exhibited improvement in all four criteria of creative thinking abilities. A comparative analysis of the creative thinking level of students in the experimental group in pre-test and post-test revealed that the experimental group students significantly improved their flexibility, fluency, originality, and elaboration with our “PIEPR” teaching methods experimental activities. However, the flexibility, originality, and elaboration levels of the students in the control group increased slightly, and the improvement effect was not statistically significant. Hence, we indicated that the improvements in the experimental group students' creative thinking skills in each evaluation criterion were more effective than those in the control group students. It demonstrated that the “PIEPR” teaching method, designed based on the golden standard, is implementable and valuable in cultivating creative thinking skills among product design students. SRQ4 was addressed in this part of the results.

6.2 Contribution to knowledge science

The field of knowledge science is problem-oriented and interdisciplinary, which means knowledge synthesis is essential to solving complex real-life problems. Knowledge science aims to organize and process objective and subjective information to create novel knowledge and new value.

We designed an innovative teaching method as the "PIEPR" based on project-based learning. The "PIEPR" teaching method is named after the initials of each of our teaching processes. We designed our educational experiments in strict compliance with 7 project-based teaching practices of the Gold Standard PBL. We also incorporated the four stages of the creative process defined by Kneller, namely preparation, incubation, inspiration, and validation (KNELLER, 1978). Furthermore, we improved the original PBL teaching practice framework with particular approaches that may enhance students' creativity for the design process and product design methodologies to supplement the existing teaching practice standards. Our invention focused on improving the composition of the scaffolding process for students. We aimed to enhance students' creativity by providing rich scaffolding and creative thinking methods. We aimed to achieve educational innovation by implementing a complete project-based learning process. Moreover, this research had academic and practical contributions, as illustrated in the following sections.

6.2.1 Academic contribution

The level of creativity is an essential indicator of talent quality in contemporary society. It is increasingly critical for educators to help students become creative individuals and enable creative thinking in their future careers, lives, and society. Design education plays a unique role in preparing for the innovations, creators, and thinkers of the 21st century. An important issue of product design education has been cultivating students' creativity in design education. Universities have the vital responsibility of developing inventive talent. It is necessary for educators to impart basic knowledge about design theory to students and cultivate their creativity and problem-solving abilities through reasonable and effective teaching methods to meet the need of society. The main contribution of this study is designing the "PIEPR", an innovative teaching method based on project-based learning that can enhance the creativity of product design students. In this study, we proposed specific creative teaching methods and teaching processes: preparation, impaction, exploration and implementation, presentation and evaluation, and reflection and improvement to foster students' creativity. We followed the four stages of the creative process in our teaching process and adhered to the 7 project-based teaching practices of Gold Standard PBL.

The innovation of the "PIEPR" teaching methods is mainly reflected in providing rich scaffolding, project management tools, and evaluation methods for product design students in the learning process. This study aimed to provide theoretical support for creativity cultivation in product design education in colleges and universities. Various methods, including empirical research, questionnaires, and interviews, have been employed to demonstrate the effectiveness of our innovative teaching methodology. It is verified that the "PIEPR" teaching method we designed according to the gold standard of project-based learning was feasible and valuable in cultivating the creativity of students majoring in product design. In conclusion, this study provided appropriate and effective teaching strategies for fostering creativity in product design education.

6.2.2 Practical contribution

Traditional product design education in China has excessively emphasized fundamental theory and skill training. Educators' methods in design curricula seem inadequate to help students improve their design creativity. Individual creative talents and the development of distinctive ways of thinking have been severely ignored, resulting in a shortage of student innovation. Hence, teaching methods for creativity in product design education have grown important.

This study aimed to examine the theory and practice of product design teaching methods that promote students' creative development, with a further emphasis on combining project-based learning and creative thinking methods in the teaching process. In our research, we took the core course for students majoring in product design as an example. Based on the Gold Standard PBL models, we redesigned the project design elements and teaching practices and implemented them in the experimental group using the "PIEPR" teaching methods. In this research, we organized experimental and control groups to evaluate the effectiveness and practicability of the "PIEPR".

Exploring teaching methods and evaluation methods to improve students' creativity in product design education can provide support and guidance for more researchers. This research effectively referenced future product design education by designing the "PIEPR" teaching method. We hope the "PIEPR" teaching method we developed could be popularized and utilized in more future product design education courses.

6.2.3 Originality of this research

1) An innovative teaching method as the "PIEPR" based on project-based learning was designed (see Figure 6.1). The educational experiments in this research were in strict compliance with 7 project-based teaching practices of the Gold Standard PBL. The teaching method also incorporated the four stages of the creative process defined by Kneller, namely preparation, incubation, inspiration, and validation (KNELLER, 1978). Furthermore, the original PBL teaching practice framework was improved, which required teachers with particular approaches that may enhance students' creativity for the design process and product design methodologies to supplement the existing teaching practice standards. "Closing Reflections" was added the original PBL teaching practice framework, which requires the teacher and students to reflect on the lesson by writing a reflective journal after the next teaching session (see Appendix13 and 14). On one hand, it helps teachers to adjust their teaching strategies to produce better effect in the next lesson. On the other hand, it also helps students to review what they have learned through the course and fill in the gaps in knowledge. Meanwhile, it also allows teachers to be better informed about students' expectations for future courses.

2) The invention of this research focused on improving the composition of the scaffolding process for students. We aimed to enhance students' creativity by providing rich scaffolding and creative thinking methods. The innovation of the "PIEPR" teaching methods is mainly reflected in providing rich scaffolding. For instance, various scaffolds for each step of the product design process were provided to assist students in solving problems at different design stages.

Different methods of creative thinking were taught in different stages of product design to stimulate students' creativity and ideas. Furthermore, students are required to complete project milestones, project calendar, and group diary to manage the progress of the project completion.

3) Diversified novel course evaluation criteria and evaluation methods are proposed. An evaluation criteria was designed specifically for the course (see Appendix 8) for the evaluation of student work by teachers and external experts. More importantly, the course is no longer evaluated by a single teacher, but included student self-evaluation, student mutual-evaluation, and teacher evaluation (see Appendix 9-12). Hence, students were able to receive more objective scores and valuable revision comments.

4) Mixed research methods including empirical research, questionnaires, and interviews, have been employed to demonstrate the effectiveness of the innovative teaching method. It is verified that the "PIEPR" teaching method we designed according to the gold standard of project-based learning was feasible and valuable in cultivating the creativity of students majoring in product design. Behavioral observations were also utilized in Chapter 5 to investigate the effect of the teaching method on students' learning statements during the teaching experiment. The use of mixed research methods helps ensure the accuracy of the research results and provides more educators with viable teaching strategies.

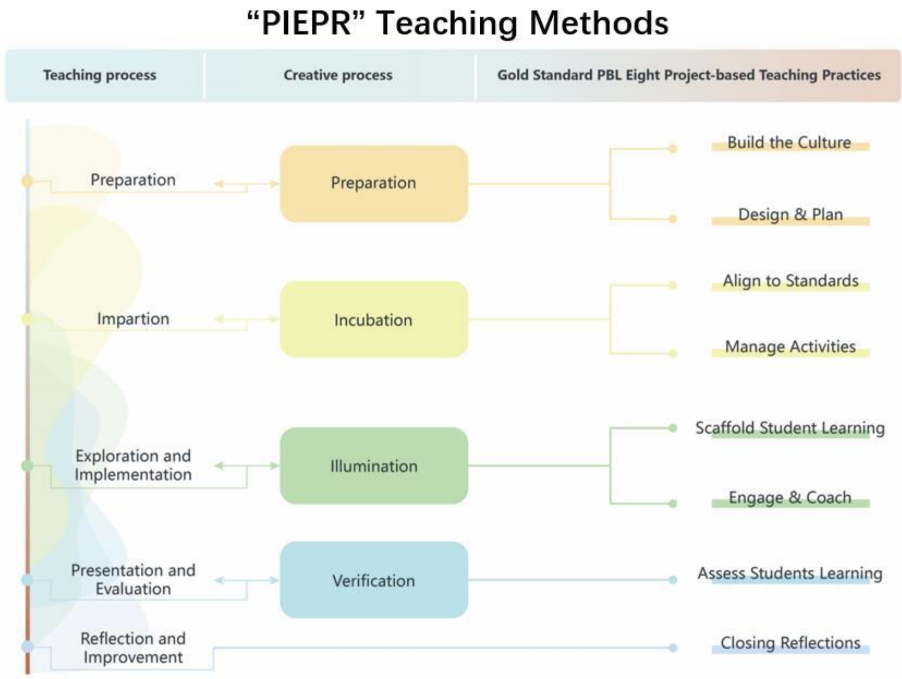

Figure 6. 1 The Innovative composition of teaching methods "PIEPR"

6.3 Limitations and recommendations for future research

A summary of the study limitations and recommendations for future research are presented.

(1) The data for the study were selected from a limited sample. This study was only conducted at one university in China. The Data were collected and analyzed from an 8-week

teaching experiment with product design students. The study has not yet been generalized due to limitations in the number of product design students eligible for the study. As creativity promotion is a long-term process, many factors can influence it. Therefore, further implementation, investigation, evidence collection, and analysis in additional universities and student samples are necessary to determine whether the innovative teaching methods we designed in this study can be replicated and practiced on a larger scale.

(2) The creative thinking methods contain a huge and complex knowledge system. A limited number of creative thinking methods were selected in this study based on the current level of creativity of product design students and the suggestions of eight educators. Thus, we suggested that future research explore more effective creative thinking methods to constantly improve the scaffolding content in the "PIEPR" teaching method.

(3) The sample of interviewees selected for this study was small, and all of the interviewees were from Asia. Future research should try to select outstanding educators in other countries worldwide to conduct in-depth interviews to examine more effective teaching strategies. And also make research contribution in the international context.

(4) This study was only conducted the teaching experiment with product design students in one product design course. A future study should also test its effectiveness in other courses in the product design program.

(5) This study was an educational innovation study built only around the project-based learning model. Future research should attempt to explore the integration of other effective teaching methods with the "PIEPR" teaching methods to enhance the creativity of product design students better.

(6) Lack of life experience was mentioned by several educators in Study 2 as a reason for students' lack of creativity. Therefore, future research could try to explore and list solutions to students' lack of life experiences.

(7) It is important to emphasize educational innovation in the post-epidemic era, especially in the era when online education is prevalent. Hence, future research should explore and validate how to break out of the students' number limitations, and how to conduct Project-based learning online.

(8) We design the “PIEPR” teaching method only integrated project-based learning with the processes and methods of product design. Due to the limited duration of the course, the final product designed by the students and more consumer preferences could not be examined and analyzed. Therefore, educators in future education are encouraged to design a showcase platform for students to display their designs so that more users or consumers can understand and comment on their designs.

(9) Although "Closing reflection" has been added to the PIEPR teaching method, the effectiveness of this instructional step has not been detailed described. Future research could explore deeper into the effects of "Closing reflection" on teachers and students.

(10) Since the characteristics of each course and the teaching style of each teacher are different, the PIEPR teaching methods described in this dissertation may not be applicable to

every educator. Therefore, future research can explore the implementation cost to continuously improve this teaching method. Or highlight the most effective parts of this teaching method to support educators in developing their own PBL approach to teaching.

(11) The contribution of this study is to provide rich scaffolding in the teaching process and to add the step of closing reflection to the PBL gold standard. Hence, future research can explore which is more important in Project-based learning between scaffold students learning and closing reflection to provide educators with more intuitive suggestions.

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Research Accomplishment

◎for oral presentation and □for poster presentation at the international conference

Publications / Submission in Scholarly Journals

- **Paper Title:** Improving Student Creativity Through Project-Based Learning- A Case Study of Integrating Innovation and Entrepreneurship Education with Product Design Courses
  Name of Journal: Journal of Positive School Psychology
  Authors: Xiaolei Sun and Eunyoung Kim
  Issue: Vol.5 No.4 (2022)

Award

- Best presentation award

41st Annual Conference of Japan Creativity Society: New Horizon of Creativity and Innovation - 2019.9.28

Conference Presentation and Proceedings

1. X. Sun, E. Kim, "Research on the Construction of Women's Cosmetic Brands in the Age of Social Network", in Proceedings of Sydney International Business Research Conference 2019(SIBRC), pp. 61. 2019.

   ◎oral presentation

2. X. Sun, E. Kim, "A Study on the Design of Intelligent Crutch for the elders", in Proceedings of 2019 Southern Oregon University Creativity Conference, 2019.

   □poster presentation ◎oral presentation

3. X. Sun, E. Kim, Y. Takaya, L. Wang, "A Proposal of Creativity Teaching in Product Design Education", in Proceedings of 41st Annual Conference of Japan Creativity Society: New Horizon of Creativity and Innovation, pp. 11-16, 2019.

   ◎oral presentation.

Appendix 1

An investigation of the situation of personal creativity and influencing factors of college students in product design

产品设计专业大学生个人创造力情况和影响因素的研究

Dear students:

This investigation aims to identify the current creativity and creative thinking ability level among students who majored in product design. Your feedback will be utilized to analyze the current mastery, application, and learning needs of product design students concerning creativity. We aim to use the research data to provide suggestions for teaching creativity in product design majors in the future. We randomly selected a few student representatives from our college to conduct the survey, and you are one of them. Your participation is crucial to our research. There is no need to fill out your name in this survey, and there are no right or wrong answers also. I would appreciate it if you would provide us with real information based on your actual situation, and we will strictly keep your information confidential.

Thank you for your cooperation!

Investigator: Sun Xiaolei
September 11, 2021

各位同学：

你们好！本次调查的目的是为了了解产品设计专业学生对于创造力和创新思维的教育现状。我们想通过您的反馈来了解目前产品设计专业学生对于创造力和创新思维的掌握情况、应用情况和未来的学习需求。我的目的是通过调研数据为未来产品设计专业的创造力教学提供依据。我们从我院随机抽取了一部分大学生代表进行调查，您是其中的一位。您的参与对本次调查十分重要。本调查不用填写姓名，答案没有对错之分，希望您根据自身的实际情况反馈真实信息，您提供的情况我们将严格保密。

谢谢您的合作！

调查人：孙晓磊
2021 年 9 月 11 日

1. What is your gender ( ) ? [Single choice] * 您的性别是 （ ）？ [单选题] *

○ Male 男性

○ Female 女性

2. Do you have any experience in art training before learning the professional course of product design ( ) ? [Single choice] * 您在学习产品设计专业课程之前是否有过艺术培训的经历（ ）? [单选题] *

○ Yes, I have 有

○ Not yet 没有

3. Have you received creativity training before taking the professional course in product design ( ) ? [Single choice] * 您在学习产品设计专业课程之前是否接受过创造力的训练（ ）？ [单选题]*

○ Yes, I have 有

○ Not yet 没有

4. How many years have you been trained in design creativity ( ) ? [Single choice] * 你接受设计创造力的训练有几年了( ) ？ [单选题] *

○ Less than one year 少于一年

○ One year 一年

○ Two years 两年

○ Three years 三年

○ More than three years 三年以上

5. What do you think of your current creativity ( ) ? [Single choice] * 你认为目前自己的创造力如何 ( ) ？ [单选题] *

非常差	○1	○2	○3	○4	○5	非常好
Very poor						Very good

6. How do you think you have performed in the process of designing the product in terms of fluency ( ) ? [Single choice] * 你认为自己在设计产品过程中整体的流畅性表现如何（ ）？ [单选题] *

非常差	○1	○2	○3	○4	○5	非常好
Very poor						Very good

7. How do you think you have performed in the process of designing the product in terms of flexibility ( ) ? [Single choice] * 你认为自己在设计产品过程中的变通性表现如何（ ）？ [单

选题] *

非常差 ○1 ○2 ○3 ○4 ○5 非常好

Very poor Very good

8. How do you think you have performed in the process of designing the product in terms of originality ( ) ? [Single choice] * 你认为自己在设计产品过程中整体的原创性表现如何（ ）？[单选题] *

非常差 ○1 ○2 ○3 ○4 ○5 非常好

Very poor Very good

9. How do you think you have performed in the process of designing the product in terms of elaboration ( ) ? [Single choice] * 你认为自己设在设计产品过程中整体的精致性表现如何（ ）? [单选题] *

非常差 ○1 ○2 ○3 ○4 ○5 非常好

Very poor Very good

10. How is your ability to identify problems independently in the early stages of product design ( ) ? [Single choice] * 在产品设计前期，你独立发现问题的能力如何（ ）？ [单选题] *

非常差 ○1 ○2 ○3 ○4 ○5 非常好

Very poor Very good

11. How is your ability to solve problems independently in the early stages of product design ( ) ? [Single choice] * 在产品设计前期，你独立解决问题的能力如何（ ）？ [单选题] *

非常差 ○1 ○2 ○3 ○4 ○5 非常好

Very poor Very good

12. How well do you understand the product design process by studying the product design course ( ) ? [Single choice] * 通过产品设计专业课程的学习，你对产品设计流程的了解程度如何（ ）？[单选题] *

非常不了解 ○1 ○2 ○3 ○4 ○5 非常了解

Know it very little Know it very well

13. How is your capability of product appearance design by studying the product design course ( ) ? [Single choice] * 通过产品设计专业课程的学习，你目前对产品的外观设计能力如何（ ）？[单选题] *

非常差 ○1 ○2 ○3 ○4 ○5 非常好

Very poor Very good

14. How is your material application ability of products by studying the product design course ( ) ?

[Single choice] * 通过产品设计专业课程的学习，你目前对产品的材料应用能力如何（ ）？ [单选题] *

非常差 ○1 ○2 ○3 ○4 ○5 非常好

Very poor Very good

15. How is your product structure design capability by studying the product design course ( ) ? [Single choice] * 通过产品设计专业课程的学习，你目前对产品的结构设计能力如何（ ）？ [单选题] *

非常差 ○1 ○2 ○3 ○4 ○5 非常好

Very poor Very good

16. How is your hand drawing expression ability of product modeling design by studying the product design course ( ) ? [Single choice] * 通过产品设计专业课程的学习，你目前对产品造型设计的手绘表达能力如何（ ）？ [单选题] *

非常差 ○1 ○2 ○3 ○4 ○5 非常好

Very poor Very good

17. How well do you currently prototype with the computer for product design by studying the product design course ( ) ? [Single choice] * 通过对产品设计专业课程的学习，你目前用计算机进行产品的原型设计的情况能力（ ）？ [单选题] *

非常差 ○1 ○2 ○3 ○4 ○5 非常好

Very poor Very good

18. How is your current ability to identify problems that existed in product design by studying the product design course ( ) ? [Single choice] * 通过学习产品设计课程，您目前识别产品设计中存在的问题的能力如何（ ）？ [单选题] *

非常差 ○1 ○2 ○3 ○4 ○5 非常好

Very poor Very good

19. What do you think of your ability to complete product design independently by studying the product design course( ) ? [Single choice] * 通过产品设计专业课程的学习，你认为自己独立完成产品设计的能力如何（ ）？ [单选题] *

非常差 ○1 ○2 ○3 ○4 ○5 非常好

Very poor Very good

20. How is your current ability to participate in team cooperation by studying the product design course ( ) ? [Single choice] * 通过产品设计专业课程的学习，你参与团队合作进行产品设计的能力如何（ ）？ [单选题] *

非常差 ○1 ○2 ○3 ○4 ○5 非常好

Very poor Very good

21. Do you know about the creative thinking methods ( ) ? [Single choice] * 您了解创新思维方法吗（ ）？ [单选题] *

非常不了解	○1	○2	○3	○4	○5	非常了解

Know it very little Know it very well

22. How often do you use creative thinking methods ( ) ? [Single choice] * 您经常使用创新思维方法吗（ ）？ [单选题] *

○ Never use 从不使用

○ Use occasionally 偶尔使用

○ Often used 经常使用

23. Do you think using creative thinking methods has helped you complete your product design works ( ) ? [Single choice] * 您认为应用创新思维方法对您完成产品设计作品有帮助吗（ ）？ [单选题] *

○ It didn't help at all 完全没帮助

○ It helps, but it doesn't help much 有帮助但帮助不大

○ General 有帮助但帮助较大

○ Very helpful 非常有帮助

○ Uncertain 不确定

24. How do you think of your learning effect after applying creative thinking methods in product design ( ) ? [Single choice] * 您认为将创新思维方法应用于产品设计课程后课堂氛围效果如何（ ）？ [单选题] *

○ Not effective at all 完全没效果

○ Minor effective 效果较小

○ Great effective 效果不错

○ General 一般

○ Uncertain 不确定

25. Have you ever used creative thinking methods to assist you with your design work during a product design course ( ) ? [Single choice] * 您在产品设计专业课程中使用过创新思维方法辅助完成设计作品吗（ ）？ [单选题] *

○ Never use 从不使用

○ Use occasionally 偶尔使用

○ Often used 经常使用

26. Which of the following creative thinking methods have you used in your product design courses ( ) ? [Multiple choice] * 您在产品设计专业课程中使用过下面哪些创新思维方法（ ）？ [多选题] *

□ Brainstorming 头脑风暴法

□ Mind mapping 思维导图

□ 5W2H method 5W2H 法

□ Attribute listing method 属性列表法

□ Biomimicry method 仿生法

□ SCAMPER 奔驰法

□ Association method 联想法

□ Analogy method 类比法

27. Can you apply the brainstorming method skillfully ( ) ? [Single choice] * 您能熟练应用头脑风暴法吗（ ）？ [单选题] *

非常不熟练	○1	○2	○3	○4	○5	非常熟练
Extremely unskilled						Extremely skilled

28. Can you apply mind mapping skillfully ( ) ? [Single choice] * 您能熟练应用思维导图法吗（ ）？ [单选题] *

非常不熟练	○1	○2	○3	○4	○5	非常熟练
Extremely unskilled						Extremely skilled

29. Can you skillfully apply the 5W2H method ( ) ? [Single choice] * 您能熟练应用 5W2H 法吗（ ）？ [单选题] *

非常不熟练	○1	○2	○3	○4	○5	非常熟练
Extremely unskilled						Extremely skilled

30. Can you skillfully use the attribute listing method ( ) ? [Single choice] * 您能熟练应用属性列表法吗（ ）？ [单选题] *

非常不熟练	○1	○2	○3	○4	○5	非常熟练
Extremely unskilled						Extremely skilled

31. Can you apply the biomimicry method skillfully ( ) ? [Single choice] * 您能熟练应用仿生法吗（ ）？ [单选题] *

非常不熟练	○1	○2	○3	○4	○5	非常熟练
Extremely unskilled						Extremely skilled

32. Can you skillfully apply the SCAMPER method ( ) ? [Single choice] * 您能熟练应用SCAMPER 法吗（ ）？ [单选题] *

非常不熟练	○1	○2	○3	○4	○5	非常熟练
Extremely unskilled						Extremely skilled

33. Can you use the association method skillfully ( ) ? [Single choice] * 您能熟练应用联想法吗（ ）？ [单选题] *

非常不熟练	○1	○2	○3	○4	○5	非常熟练
Extremely unskilled						Extremely skilled

34. Would you like teachers to guide creative thinking methods in product design courses at this stage ( ) ? [Single choice] * 现阶段，你在产品设计专业课程中希望老师指导使用创新思维方法吗（ ）？ [单选题] *

不希望	○1	○2	○3	○4	○5	非常希望
No						essential

35. What is the main method of assignment proposition for product design courses you have taken at this stage ( ) ? [Multiple choice] * 现阶段您参加的产品设计专业课程的作业命题方式是（ ）？ [多选题] *

□ Virtual project proposition 以虚拟课题为主

□ Real-world project proposition 以实际课题项目为主

□ Assignment based on competition 以竞赛题目为主

□ Other 其他

36. What factors affect your creativity ( ) ? [Multiple choice] * 您认为影响您创造力的原因有哪些（ ）？ [多选题] *

□ Lack of understanding of creative thinking methods 对创新思维方法不了解

□ Rigid teaching environment 教学环境死板

□ Teachers' teaching methods 教师授课方式

□ Not interested in homework proposition 对作业命题不感兴趣

□ Other 其他

37. Do you think completing homework tasks independently will affect your creativity （ ）? [Single choice] * 你认为独立完成作业任务会影响你的创造力吗（ ）？ [单选题] *

非常不同意	○1	○2	○3	○4	○5	非常同意

Strongly Disagree　　Strongly agree

38. Do you think working in groups will affect creativity （ ）? [Single choice] * 你认为对以小组合作的形式会影响创造力吗（ ）？ [单选题] *

非常不同意	○1	○2	○3	○4	○5	非常同意

Strongly Disagree　　Strongly agree

39. Do you think the understanding of creative thinking methods will affect creativity（ ）? [Single choice] * 你认为对创新思维方法的了解会影响创造力吗（ ）？ [单选题] *

非常不同意	○1	○2	○3	○4	○5	非常同意

Strongly Disagree　　Strongly agree

40. Do you think the teaching environment will affect your creativity （ ）? [Single choice] * 你认为教学环境会影响你的创造力吗（ ）？ [单选题] *

非常不同意	○1	○2	○3	○4	○5	非常同意

Strongly Disagree　　Strongly agree

41. Do you think teachers' teaching methods will affect your creativity （ ）? [Single choice] * 你认为教师的教学方法会影响你的创造力吗（ ）？ [单选题] *

非常不同意	○1	○2	○3	○4	○5	非常同意

Strongly Disagree　　Strongly agree

42. Do you think the content of assignments in the course will affect your creativity （ ）? [Single choice] * 你认为课程的作业命题内容会影响你的创造力吗（ ）？ [单选题] *

非常不同意	○1	○2	○3	○4	○5	非常同意

Strongly Disagree　　Strongly agree

43. Do you think the competition-based assignments will affect your creativity （ ）? [Single

choice] * 你认为以比赛命题的作业任务会影响你的创造力吗（ ）？ [单选题] *

非常不同意	○1	○2	○3	○4	○5	非常同意
Strongly Disagree						Strongly agree

44. Do you think homework tasks based on practical projects will affect your creativity （ ）？ [Single choice] * 你认为以实践类项目命题的作业任务会影响你的创造力吗（ ）？ [单选题] *

非常不同意	○1	○2	○3	○4	○5	非常同意
Strongly Disagree						Strongly agree

45. Do you think the assignment of a virtual project proposition will affect your creativity （ ）？ [Single choice] * 你认为虚拟项目命题的作业任务会影响你的创造力吗（ ）？ [单选题] *

非常不同意	○1	○2	○3	○4	○5	非常同意
Strongly Disagree						Strongly agree

46. Do you think the design-studio teaching method will affect your creativity （ ）？ [Single choice] * 你认为工作室教学法会影响你的创造力吗（ ）？ [单选题] *

非常不同意	○1	○2	○3	○4	○5	非常同意
Strongly Disagree						Strongly agree

47. Do you think project-based learning will affect your creativity （ ）？ [Single choice] * 你认为项目学习法会影响你的创造力吗（ ）？ [单选题] *

非常不同意	○1	○2	○3	○4	○5	非常同意
Strongly Disagree						Strongly agree

Appendix 2

Structure of questions asked in exploratory interview study on methods that may stimulate creativity in product design education

关于产品设计教育中可能激发学生创造力的方法的探索性访谈研究的问题结构

Q1. Obtain basic information about the interviewee. (Ex: Name, graduate school, education background, working institution, position, professional title, how long did he/she study product design, how many years has he/she been a product design teacher?)
了解被访者的基本信息。(例如：姓名，毕业院校，学历，工作地点，职务，职称，他/她学习产品设计专业时长，从事产品设计教师的时长)

Q2. Are you familiar with the following creative thinking methods? How often do you use them? When do you typically use these tools during product design? Can you describe the strengths and limitations of these tools? How effective are these tools for teaching?
您了解下列选项中的哪些创新思维方法并应用于您的设计课程中？(您了解吗？使用频率是怎样？应用于什么课程，产品设计的什么阶段呢？这些方法分别的优点、局限性和教学结果是怎样呢，您满意吗，非常满意？一般？不满意

A. The association of uncommon ideas and concepts from different domains to create new, innovative solutions 将来自其他领域的不同寻常的想法和概念结合起来，以产生新的创新解决方案。

Ex: Analogy and Association　例如：类比法和联想法


B. Searching for natural models with similar problems, which are able to inspire or imitate solutions.寻找在问题定义上相似并且可能被模仿或可能激发解决方案的自然模型。

Ex: Biomimicry　例如：仿生学




C. Spontaneous generate a large number of ideas and/or possible solutions to a problem, with the choice of the best solution coming at the end of the process. 自发产生大量想法和/或问题的可能解决方案，仅在过程结束时选择最佳解决方案。

Ex: Brainstorming　　例如：头脑风暴

D. Problems are decomposed into attributes or key factors that can be changed, improved, or replaced. 将问题分解为可以改进、改变或替代的属性或关键因素。

Ex: Attribute Listing　　例如：属性列表


Attribute Listing Technique

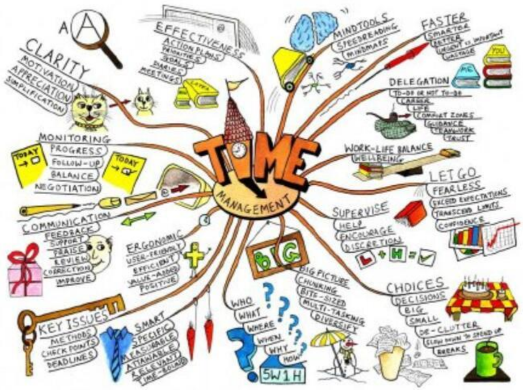
Features	Material used	Lead material	Colour	Shape	Special features
Attributes	Wood	Grey	Brown	Cylindrical	Eraser on top
Alternatives	Plastic	Luminous	Multicolour with company logo	Oval	Hook to clip onto clipboards

There are two steps in the attribute listing technique. The first is to list all of the various characteristics of the study object. The second is to deliberately change or modify these characteristics.

By means of this technique, it is possible to bring together new combinations of characteristics or attributes that will better fulfill some existing need.

E. Diagrams of items arranged around a central concept, connected and branching out on a theme or proposition 围绕一个中心概念组织的项目图，并在主题或命题上具有联系和分支。

Ex: Mind Mapping　　例如：思维导图

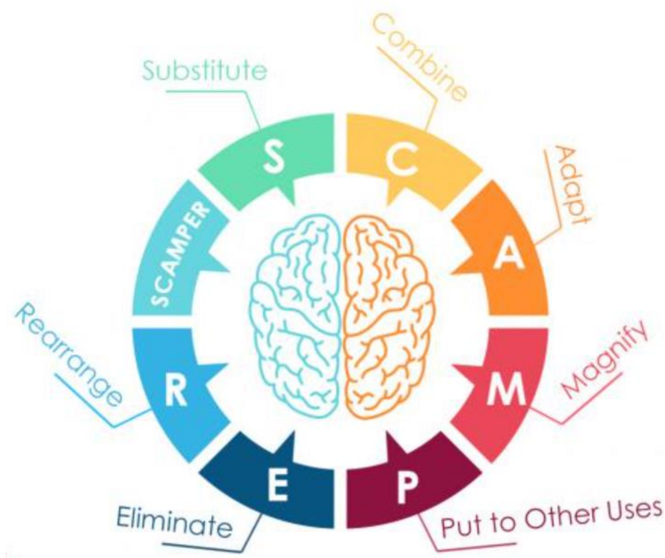


F. Structure a problem into its generic domain, then search for the solution using a matrix of 40 principles from patents. 将问题构建到其通用域中，并通过专利中发现的 40 条原则矩阵来搜索解决方案。

Ex: TRIZ, "Theory of inventive problem solving" 例如：TRIZ，"创造性问题解决理论"

G. Explore new design outcomes by substituting, combining, adapting, modifying, putting to other uses, eliminating, reducing, and rearranging. 通过替换、合并、调整、修改、减少或作为他用、消除和重新安排的方法探索新的设计结果。

Ex: SCAMPER 例如：奔驰法



H. Find answers to your questions by considering multiple perspectives. 从多角度提出问题并寻找答案。

Ex: 5W2H method 例如：5W2H 法

Q3. What do you think is the reason for the low level of creativity among students? 您认为导致学生创造力水平低的原因是什么？

Q4. What other methods do you use to stimulate creativity? Which one?
您是否使用其他类型的方法来激发创造力？哪一个？

Q5. In your opinion, what innovative thinking methods will help you generate creative ideas in the following product design process? 在您看来，在以下产品设计过程中，哪些创新思维方法会有助于您产生创意想法？

( ) Problem definition 问题定义
( ) Product research 产品调研
( ) User research 用户研究
( ) Idea generation 创意产生
( ) Idea selection 创意选择
( ) Idea verification 想法验证

Q6. What kind of teaching model（methods）do you think will improve students' creativity?
您认为什么样的教学模式(方法)会提高学生的创造力？

Appendix 3

A Test for the Creative Thinking Test for Product Design Students

产品设计专业学生创新思维测验问卷

Dear students:

What you see now is a quiz to help you measure your level of creative thinking. This test is very important. It is extremely important that you complete this test on your own according to the requirements of the questions. Please read the requirements of the following questions carefully before answering the questions. Additionally, please cooperate with the tester's command during the answering process, and respond to the questions carefully within the specified timeframe.

Thank you very much for your participation, thank you!

Investigator: Sun Xiaolei
September 11, 2021

同学您好！

您现在看到的是一份帮助您了解自己创新思维水平的测验问卷。此次测验十分重要，请务必严格按照题目要求独自完成，请您在答题前认真阅读下列题目的答题要求，另外，请您在答题过程中全力配合测试人员的口令指挥，并在规定的时间范围内认真答题。

非常感谢您的参与，谢谢！

调查人：孙晓磊
2021 年 9 月 11 日

Requirements for answering questions:

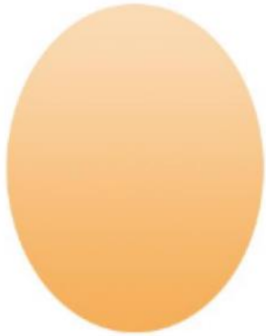
* Try to come up with as many ideas as you can.
* Please provide as much detail as possible to make your idea complete.
*You can add details to your answer if you have completed it within the allotted time, or you can sit quietly.
*Please do not answer the next question without permission.

答题要求：

*努力想出尽可能多的点子。
*为您的想法提供尽可能多的细节，让其完整。
*如果您在规定时间内已经作答完毕，您可以继续为您的想法添加细节，或安静地坐着。
*未经允许不要做下一道题目。

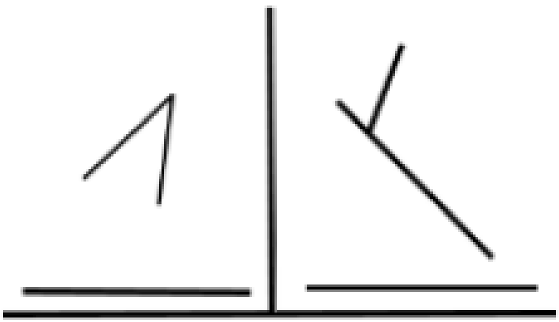
1.请以图片中的彩色蛋形为基础，构造一幅富于想象的图画。（完成时间：十分钟）

1. Please construct an imaginative picture based on the colored egg in the picture. (Completion time: ten minutes)



2.请将下面的图画添加完整，并用您完成的图画讲述一个完整的故事，故事写在图片右侧，最后请给你的图画起名，并写在该图画的下方。（完成时间：十分钟）

2. Please complete the picture below and tell a complete story with your finished picture. You can write your story to the right of the picture. Finally, please name your picture and write it below the picture. (Completion time: ten minutes)



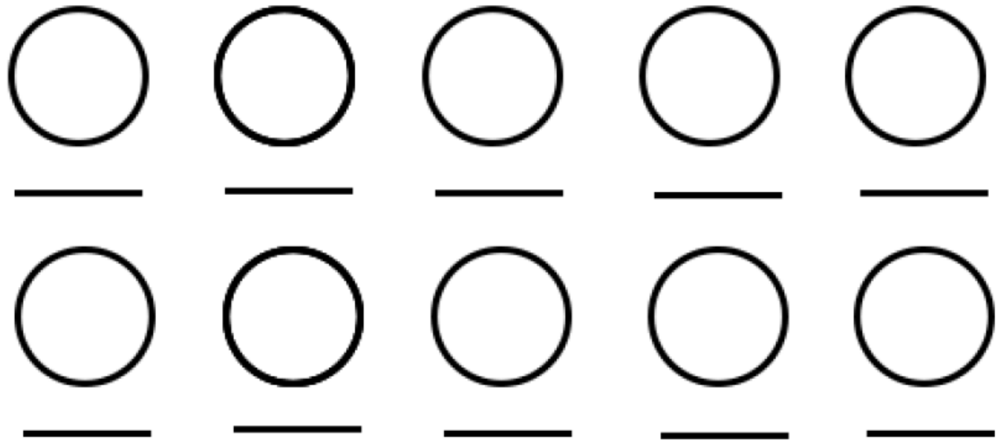
3.请根据下面所提供的形状，对形状进行补充并完成一家餐饮品牌的 logo，并在 logo 下方简述设计说明。（完成时间：十分钟）

Using the shapes provided below, please complete the logo for a restaurant brand. And describe the design briefly below the logo. (Completion time: ten minutes)

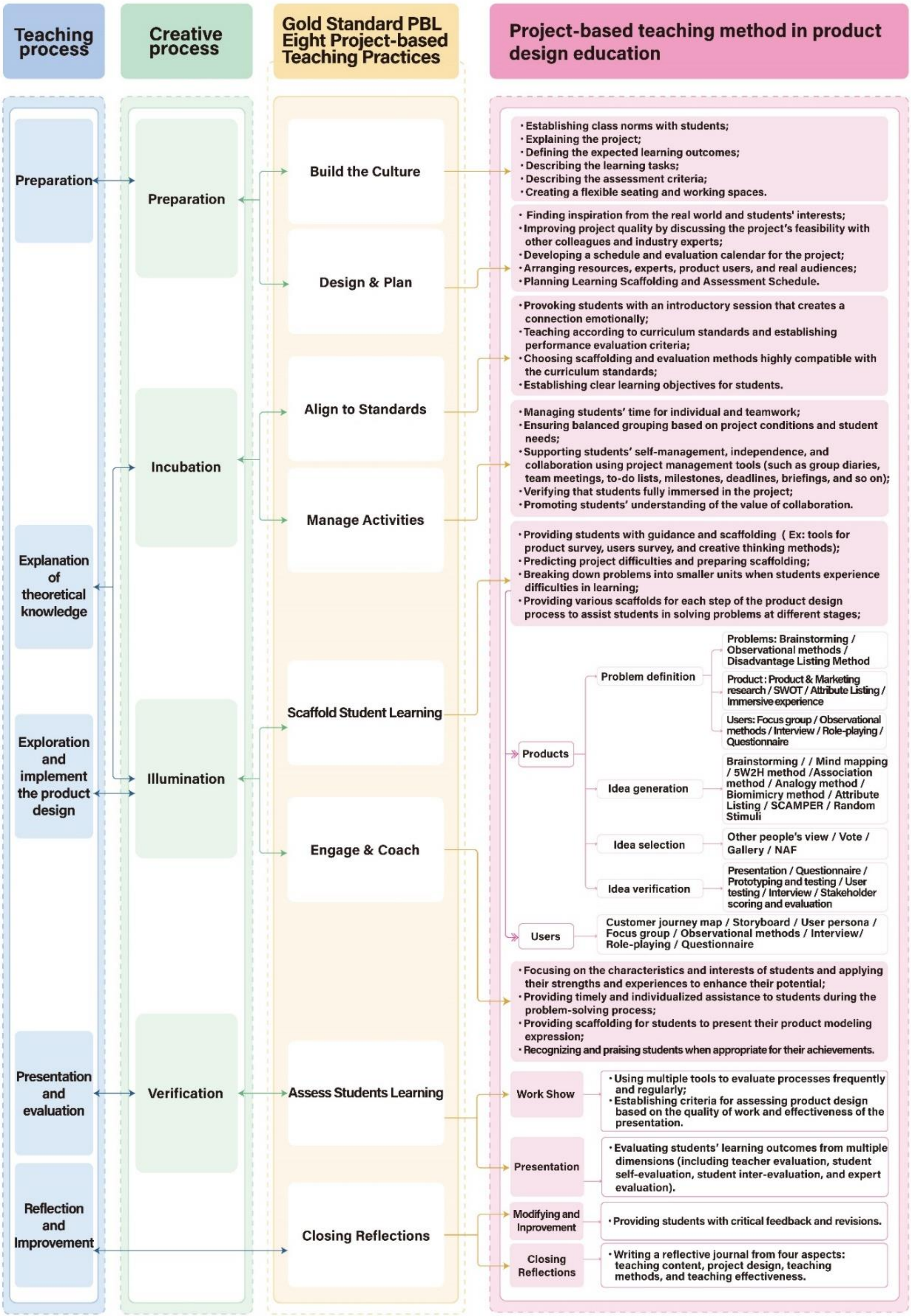
4.请尽可能多地对下面圆圈添加细节，以画出互不相同的图画，请确保最终构成完整图画。请努力画出别人未曾画出的图画，并在横线处简述你所绘制的图画的含义。（完成时间：十分钟）

4. Please add as many details as possible to the circle below to create different pictures from each other. A complete picture should be the end result. Please try to draw a picture that no one else has

drawn before, and briefly describe the meaning of the picture you have drawn in the horizontal line. (Completion time: ten minutes)



Appendix 4



Teaching process
Creative process
Gold Standard PBL Eight Project-based Teaching Practices
Project-based teaching method in product design education
Preparation
Preparation
Build the Culture
·Establishing class norms with students;
·Explaining the project;
·Defining the expected learning outcomes;
·Describing the learning tasks;
·Describing the assessment criteria;
·Creating a flexible seating and working spaces.
Design & Plan
· Finding inspiration from the real world and students' interests;
·Improving project quality by discussing the project's feasibility with other colleagues and industry experts;
·Developing a schedule and evaluation calendar for the project;
·Arranging resources, experts, product users, and real audiences;
·Planning Learning Scaffolding and Assessment Schedule.
Align to Standards
·Provoking students with an introductory session that creates a connection emotionally;
·Teaching according to curriculum standards and establishing performance evaluation criteria;
·Choosing scaffolding and evaluation methods highly compatible with the curriculum standards;
·Establishing clear learning objectives for students.
Incubation
Manage Activities
·Managing students' time for individual and teamwork;
·Ensuring balanced grouping based on project conditions and student needs;
·Supporting students' self-management, independence, and collaboration using project management tools (such as group diaries, team meetings, to-do lists, milestones, deadlines, briefings, and so on);
·Verifying that students fully immersed in the project;
·Promoting students' understanding of the value of collaboration.
Explanation of theoretical knowledge
·Providing students with guidance and scaffolding (Ex: tools for product survey, users survey, and creative thinking methods);
·Predicting project difficulties and preparing scaffolding;
·Breaking down problems into smaller units when students experience difficulties in learning;
·Providing various scaffolds for each step of the product design process to assist students in solving problems at different stages;
Scaffold Student Learning
Products
Problem definition
Problems: Brainstorming / Observational methods / Disadvantage Listing Method
Product : Product & Marketing research / SWOT / Attribute Listing / Immersive experience
Users: Focus group / Observational methods / Interview / Role-playing / Questionnaire
Idea generation
Brainstorming / / Mind mapping / 5W2H method /Association method / Analogy method / Biomimicry method / Attribute Listing / SCAMPER / Random Stimuli
Idea selection
Other people's view / Vote / Gallery / NAF
Idea verification
Presentation / Questionnaire / Prototyping and testing / User testing / Interview / Stakeholder scoring and evaluation
Users
Customer journey map / Storyboard / User persona / Focus group / Observational methods / Interview/ Role-playing / Questionnaire
Exploration and implement the product design
Illumination
Engage & Coach
·Focusing on the characteristics and interests of students and applying their strengths and experiences to enhance their potential;
·Providing timely and individualized assistance to students during the problem-solving process;
·Providing scaffolding for students to present their product modeling expression;
·Recognizing and praising students when appropriate for their achievements.
Presentation and evaluation
Verification
Assess Students Learning
Work Show
·Using multiple tools to evaluate processes frequently and regularly;
·Establishing criteria for assessing product design based on the quality of work and effectiveness of the presentation.
Presentation
·Evaluating students' learning outcomes from multiple dimensions (including teacher evaluation, student self-evaluation, student inter-evaluation, and expert evaluation).
Reflection and Improvement
Closing Reflections
Modifying and Inprovement
·Providing students with critical feedback and revisions.
Closing Reflections
·Writing a reflective journal from four aspects: teaching content, project design, teaching methods, and teaching effectiveness.

Appendix 5

Project Milestones

Directions: Use this section to create a high-level overview of your project. Think of this as the broad outline of the story of your project, with the milestones representing the significant 'moments' or 'stages' within the story. As you develop these, consider how the inquiry process is unfolding and what learning will take place. The Project Calendar will allow you to build out the milestones in greater detail.

Milestone #1 Entry Event	**Milestone #2**	**Milestone #3**	**Milestone #4**	**Milestone #5**	**Milestone #6** Public Product
Key Student Question	**Key Student Question**	**Key Student Question**	**Key Student Question**	**Key Student Question**	**Key Student Question**
Formative Assessment(s)	**Formative Assessment(s)**	**Formative Assessment(s)**	**Formative Assessment(s)**	**Formative Assessment(s)**	**Formative Assessment(s)**

Appendix 6

Project Calendar

<table>
<tr><td colspan="5">Driving Question:</td></tr>
<tr><td>Week:</td><td colspan="4">Project Milestone:</td></tr>
<tr><td colspan="5">Key Student Question(s):</td></tr>
<tr><td>Day1:</td><td>Day2:</td><td>Day3:</td><td>Day4:</td><td>Day5:</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Notes:</td></tr>
</table>

Appendix 7

Group Diary

No: Record	Date:
Work progress this week	
Difficulties we encountered	
Comments of teacher	
No: Record	**Date:**
Work progress this week	
Difficulties we encountered	
Comments of teacher	

Appendix 8

The evaluation criteria of < Product Innovation Design >
(For teachers and external experts)

Student's Name:		**Name of Evaluator:**	
Number	**Scoring Rubric**	**Marks**	**Score**
1 Innovation (10 points)	The product with originality and innovation	5	
	The elaboration of the product is good and can reflect the details of the product	5	
2 Data Analysis (10 points)	The design research is targeted, the user analysis is informative, and the data is detailed	5	
	The design positioning is accurate, and the product has good market feasibility	5	
3 Design Process (10 points)	The sketch is innovative, feasible, and forward-looking	5	
	Computer renderings are realistic and can effectively express the overall design and details of the design	5	
4 Design Elements (30 points)	Functional design is well-positioned and feasible	5	
	The structure is well designed to guarantee the realization of the function	5	
	The appearance design and technical means have innovation, in accord with product aesthetics	5	
	The application of materials and technology is feasible and meets the requirements of product function and structure	5	
	The product is ergonomic and conforms to the setting of the product function	5	
	Product color is appropriately used to meet the psychological	5	

	needs of users and convey the meaning of products		
5 Exhibition board/Product report booklet (20 points)	The exhibition board is rich in content, clear in structure and exquisite in layout design	5	
	The content of the exhibition board can fully reflect the characteristics of the work and clearly explain the ideas	5	
	The product model has a detailed representation	5	
	The text of the product report booklet is smoothly expressed, professional, and clearly elaborated.	5	
6 Defense/Presentation (20 points)	Product design with aesthetics and completeness	5	
	Able to describe the product positioning and design concept clearly and logically	5	
	The respondent's opinion is accurately stated, and with good presentation skills	5	
	The grooming of the presenter is dignified and generous. Clear thinking and good expression in the live presentation	5	
Total Point		100	
Comments:			

Appendix 9

Student self-evaluation, student mutual-evaluation, teacher evaluation

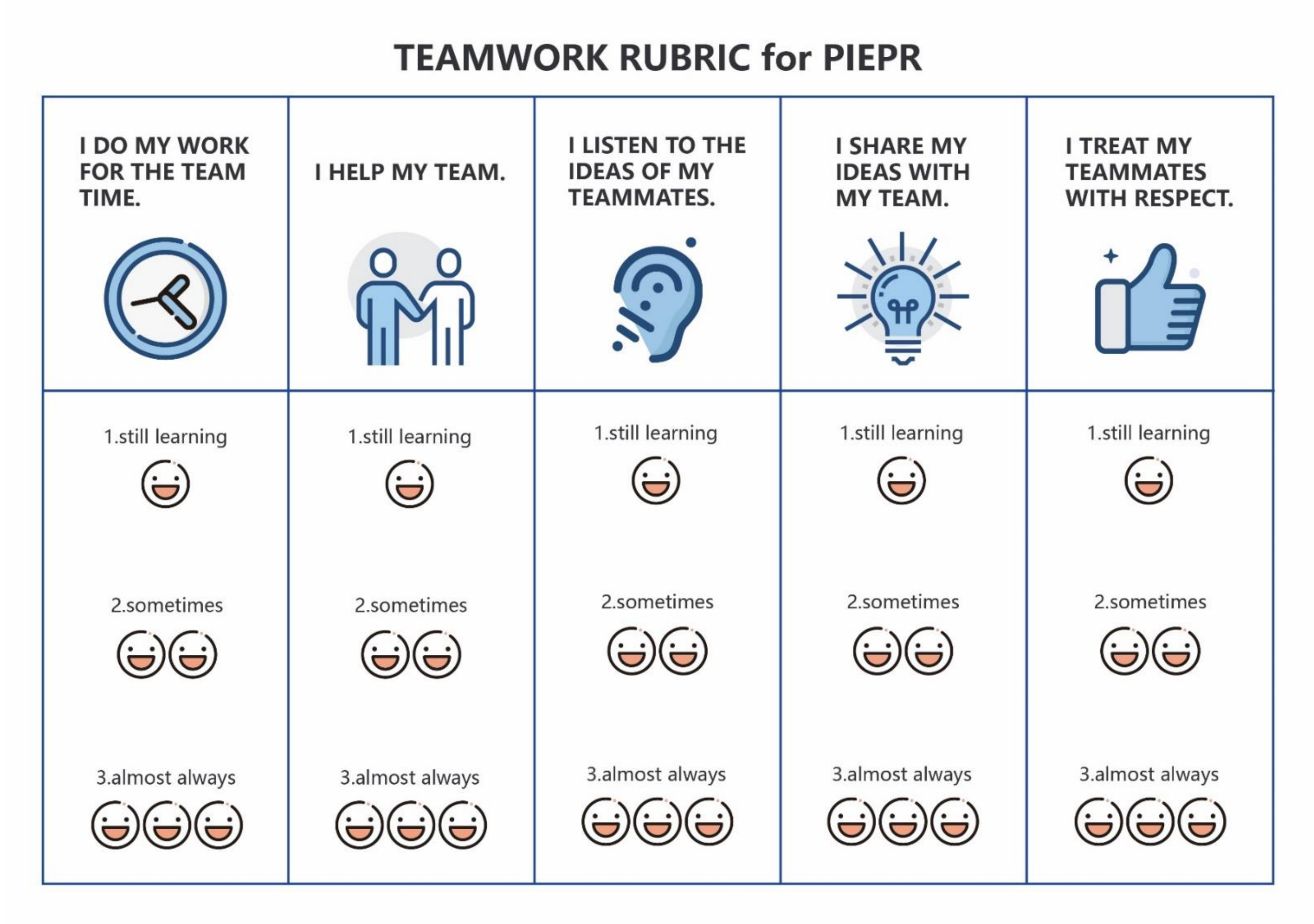
Evaluation Content	Self rated star	Mutual rated star	Teacher rated star
1.I actively participate in the formulation of the project plan	☆☆☆	☆☆☆	☆☆☆
2.I can generate ideas in various ways with other group members	☆☆☆	☆☆☆	☆☆☆
3.I actively participate in group discussion and share the harvest	☆☆☆	☆☆☆	☆☆☆
4.In the discussion, we can not only express our own opinions, but also accept and integrate the opinions of team members to form decisions	☆☆☆	☆☆☆	☆☆☆
5.I organized and summarized all the information reasonably	☆☆☆	☆☆☆	☆☆☆
6.I can actively participate in the presentation of group results	☆☆☆	☆☆☆	☆☆☆
Note: three stars in excellent grade, two stars in good grade, and one star that needs more effort			

Appendix 10

CREATIVITY & INNOVATION RUBRIC for PIEPR

I CAN EXPLAIN WHY WE ARE DOING THE PROJECT.	I CAN THINK OF IDEAS FOR WHAT TO MAKE OR DO IN THE PROJECT.	I CAN HELP PICK THE BEST IDEA.	I CAN HELP IMPROVE OUR IDEA.	I CAN HELP MAKE SOME-THING UNIQUE AND USEFUL .
1.still learning	1.still learning	1.still learning	1.still learning	1.still learning
2.sometimes	2.sometimes	2.sometimes	2.sometimes	2.sometimes
3.almost always	3.almost always	3.almost always	3.almost always	3.almost always

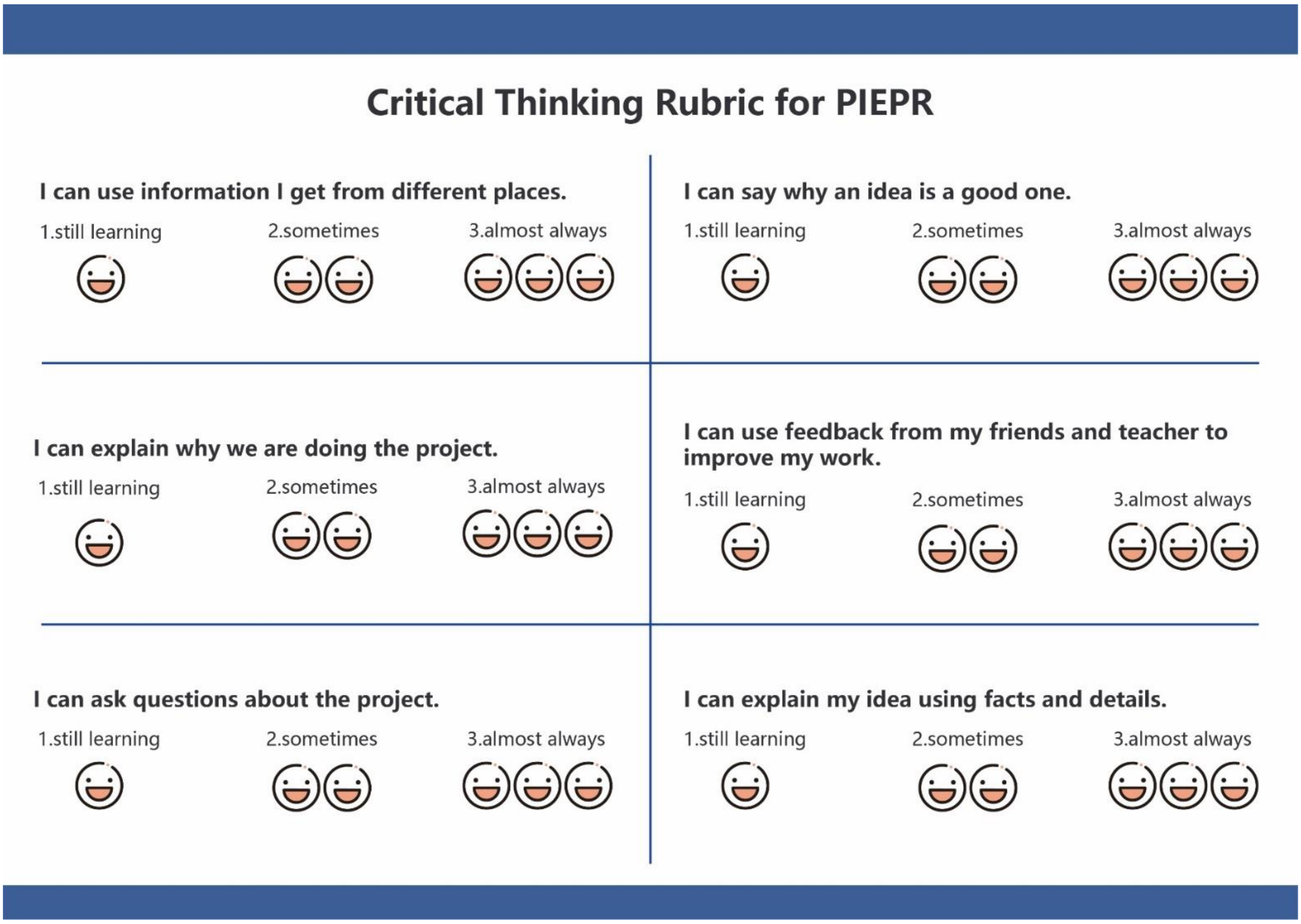
Appendix 11



TEAMWORK RUBRIC for PIEPR

I DO MY WORK FOR THE TEAM TIME.	I HELP MY TEAM.	I LISTEN TO THE IDEAS OF MY TEAMMATES.	I SHARE MY IDEAS WITH MY TEAM.	I TREAT MY TEAMMATES WITH RESPECT.
1.still learning	1.still learning	1.still learning	1.still learning	1.still learning
2.sometimes	2.sometimes	2.sometimes	2.sometimes	2.sometimes
3.almost always	3.almost always	3.almost always	3.almost always	3.almost always

Appendix 12


Critical Thinking Rubric for PIEPR
I can use information I get from different places.
1.still learning
2.sometimes
3.almost always
I can say why an idea is a good one.
1.still learning
2.sometimes
3.almost always
I can explain why we are doing the project.
1.still learning
2.sometimes
3.almost always
I can use feedback from my friends and teacher to improve my work.
1.still learning
2.sometimes
3.almost always
I can ask questions about the project.
1.still learning
2.sometimes
3.almost always
I can explain my idea using facts and details.
1.still learning
2.sometimes
3.almost always

Appendix 13

Reflective Journal for students

Name:	**Student Number:**
What I learned in this course	
What have I found out about my shortcomings through participating in the course?	
What are your expectations for your future professional studies?	

Appendix 14

Reflective Journal for teacher

Course Name:	Teacher Name:
Is the content of this course reasonable and what improvements are needed?	
Is the project design of this course reasonable and what improvements are needed?	
Are the teaching methods in this course effective and what improvements are needed?	
How effective was the course's teaching?	