An Empirical Study of the Creativity, Imagination, and Design Thinking of Taiwanese Design Undergraduates

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Abstract
Design thinking has been valued in business and education field. Design thinking uses creative approaches to problem solving, organizational development, and learning. For designers, the ultimate goal is to produce user-friendly and economic products that meet people’s needs and desires. In order to achieve that goal, creativity, imagination, and design thinking have become necessary capacities for designers to transform abstract ideas into useful products and services successfully. The purpose of the current study was to examine the relationship among creativity, imagination, and design thinking of Chinese design undergraduates. Two research questions are asked: What is the relationship among creativity, imagination, and design thinking of our participants? Do gender and age affect these relationships? Based on structural equation modeling, we found that the relationships among creativity, imagination, and design thinking were strong and positive. Additionally, age and gender did not affect in these relationships. Although some limitations were discussed in the current study, the results provide unique value for future research.

Keywords: Challenge creativity, imagination, design thinking, structural equation modeling, Taiwanese undergraduates

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1. Introduction

Creativity, imagination, and design thinking are viewed as important ingredients of design education (Owen, 2006). For designers, the ultimate goal is to produce user-friendly and economic products that meet people’s needs and desires (Brown, 2008). In order to achieve that goal, creativity, imagination, and design thinking have become necessary capacities for designers to transform abstract ideas into useful products and services successfully (Yang & Hsu, 2020). As a result, from the design education perspective, how to unleash the potential of young designers has become an important agenda in the design curriculum.

In the design field, success in producing visual and material artifacts is important. Learning through designing has the advantage of facilitating students’ cognitive, spatial, motor, social, and aesthetic skills (Kangas, Seitamaa-Hakkarainen, & Hakkarainen, 2013). Therefore, bringing design thinking into the curriculum could be an important step to help students develop constructive learning (Scheer, Noweski, & Meinel, 2012). Owen (2006) argues that design thinking is holistic and creativity is essential for design thinking, as creative thinking is a path toward invention. Furthermore, designers tend to visualize their ideas in a range of media. Through imagination, they exercise their concepts and transform them into concrete products. In short, design thinking, creativity, and imagination are valuable assets for design education. At the same time, these three variables are also promising research directions for design literature.

2. Creativity

Students of creativity have argued that creativity is multifaceted and complex (Hennessey & Amabile, 2010) and is the key driving force of human society (Florida, 2002). Two major features are important to define creativity: novelty and appropriateness (Runco & Jaeger, 2012). Although originality or novelty is treated as a criterion of creativity, it is important to recognize that creative ideas or products are not independent of its context; namely, the usefulness of the creative manifestation should be taken into consideration in order to justify the true value of creativity. Some scholars believe that creativity does not come cheap; rather, it requires at least ten years of deliberate practice and commitment (Csikszentmihalyi & Nakamura, 2006; Sternberg & O’Hara, 2000).

A large number of efforts have used different approaches to study the characteristics of creativity, and among them, cognitive-based research has dominated the creativity literature (Sternberg, 1999). More specifically, the processes of divergent thinking, ideas generation, and creative problem solving have been the major focus (Runco, 2004). Several variables have been identified as important catalysts of these process: disposition, knowledge, memory, intuition, and environment (Simonton, 2012). The trend of the cognitive approach is probably related to Guilford’s (1950) seminal systematic study of creativity. Following this path, Torrance (1974) developed the world’s most popular creativity test, the Torrance Tests of Creative Thinking (TTCT) and because of his contribution, Torrance is known as the “Father of Creativity” (Kaufman & Baer,
Imagination and creativity are highly correlated. It is believed that engaging imagination can foster creativity 
performance (Tsai, 2012). Therefore, many scholars have underlined the need to develop students’ imagination 
and creativity in order to equip them to face dynamic challenges, thereby maintaining a sustainable global 
society (Morosini, 2010). A number of studies have examined human imagination from different perspectives, 
such as visual imagery (Richardson, 1969), philosophical inquiry (Warnock, 1976), spatial conceptualization 
(Thurstone & Thurstone, 1965), mental imagery (Marks, 1995), and imagery companions (Taylor, 1999).

Psychologists have believed imagination serving one of the higher mental functions that synthetically 
combines memories and experiences into a mental construction (Morosini, 2010). Lin, Hsu, and Liang (2014) 
categorized imagination as initiating imagination, conceiving imagination, and transforming imagination. 
Initiating imagination refers to exploring novel ideas, conceiving imagination is using personal intuition and 
sensibility to generate and concentrate on possible ideas, and transforming imagination refers to developing 
abstract ideas and reconstructing knowledge across different domains.

Gaut (2003) argued that creative people have an intendency to imagine different propositions, which affect 
the following developments that can generate appropriate solutions. Similarly, designers also need imagination 
in the process of developing prototypes. In order to create elegant products or action plans that meet users’ needs, 
imagination can be considered as an important ingredient for exercising design thinking. Imagination could yield 
possibility thinking that can help designers generate products with appropriate functionality and economic use.

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4. Design Thinking
Design thinking is treated as a complex thinking process where designers utilize mental strategies to conceive 
new realities, which contributes to the transformation and innovation of forming new activities (Tschimmel, 
2012). Several important features of design thinking have been identified: (a) abductive thinking, thinking in 
new and different views related to future possibilities; (b) perceptive cognition, creating conscious and directed 
perception; (c) sketching, an extension of mental imagery; (d) prototyping, visualizing and testing new solutions; 
and (e) the human-centered approach, a joint method of working and co-creation (Tschimmel, 2012).

A number of design thinking models have been proposed over the past decades. The first, the IDEO 3I 
model (Brown, 2008), was developed by IDEO and the 3I is inspiration, ideation, and implementation. 
Innovation includes several activities, which are the identification of the design problem, elaboration of the 
design brief, and observation of the behavior of the target group. The next phase is ideation, with an emphasis on 
the synthesis from an interdisciplinary team leading to new solutions. The last phase is implementation where the 
best ideas are turned into products or an action plan. Another design thinking model proposed by the Stanford d- 
school (Yang, 2018) includes five steps: (a) empathize, using interviews to seek an understanding of human 
needs; (b) define, clarifying key people, objectives, and decisions, (c) ideate, prioritizing different ideas, (d) 
prototype, using mockups to quickly iterate proposed solutions; and (e) test, understanding the feasibility of the 
solutions. The last model is the Double Diamond proposed by the Design Council (Tschimmel, 2012), which is 
based on divergent and convergent phases of the design process. It consists of four phases: Discover, Define, 
Develop, and Deliver. In the discovery phase, the designer is looking for new opportunities and insights. The 
second stage is the definition stage, which serves as a filter for the selection of the first insights. The third stage is 
the development and prototyping of the project, and finally, the designers deliver the products and launch them 
in the market.

Design thinking pedagogy has been implemented in the design classroom. Several important educational 
values of design thinking have been discussed, including developing students’ capacities to answer real-life, ill-
defined problems, using sketching and modeling to develop nonverbal thoughts and communication, and 
cultivating hands-on design learning experiences (Renard, 2014). The benefits of design thinking for learners 
includes developing “creative thinking, critical thinking, problem-solving, meaningful learning, and 
metacognitive skills...[and progressing] affective skills such as empathy, creative self-confidence, risk-taking, 
assertiveness, self-sufficiency of knowledge generation, curiosity, being human-oriented and setting a career
goal.” (Avcu & Er, 2020, p. 5). Noel and Liu (2016) argue that the teaching and learning process in art and design education is a two-way dialog, with the focus on a student-centered approach. They believe that with the use of design thinking, students will have more opportunities to develop curiosity and empathy and with the use of research, experimentation, and critical thinking, students can explore human and environmental needs, which in turn leads to learning success and satisfaction. Gattia (2017) suggests that by using design thinking methodologies, students can find and expedient the path to the right solution more easily. Especially with design teams, design thinking is a powerful tool to eradicate the complexity and disorder, allowing them to focus on the essence of the needs and problems and finally produce workable solutions. In short, design thinking has become a necessity in the tool-box for cultivating designer training.

5. Purpose of Study
The purpose of this study is to examine the connection among creativity, imagination, and design thinking of Chinese design undergraduates. We ask two research questions: What is the relationship among creativity, imagination, and design thinking of our participants? Do gender and age affect in these relationships? It is believed that design thinking highly correlated with creativity and imagination, but this hypothesis has not been verified by empirical data. Therefore, this study attempts to examine the hypothesis and acquire a better understanding and attitudes of design thinking among our students.

6. Method
6.1 Participants
Convenience sampling was used to enlist 88 first-year Chinese fashion design college students in Taiwan. Of these, 8 (9.1%) were male and 80 (90.9%) were female, and the average age was 18.08 (SD = .27).

6.2 Measures
6.2.1 Design Thinking
The Tsai Design Thinking Scale (TDTS; Tsai, 2018) was employed to examine the design thinking profiles of our participants. The TDTS includes 16 items with five Likert-scale ranging from 1 (strongly disagree) to 5 (strongly agree). The TDTS focuses on four components of design thinking: reasoning and reflection, ideation, collaboration, and execution. Tsai (2018) reported high internal consistency and a robust four-dimensional factor solution of the TDTS through confirmatory factor analysis. In addition, in Tsai’s (2019) study, the TDTS shows an appropriate tool for capturing design thinking of college students. In other words, the measurement of the TDTS displays its acceptable validity and reliability.

6.2.2 Creativity
The Cognitive Processes Associated with Creativity (CPAC; Miller, 2009) scale was used to investigate the creative potential of our participants. The CPAC scale includes 28 items and measures six dimensions of creativity: idea manipulation, idea generation, flow, imagery/sensory perception, incubation, and metaphorical/analogical thinking. Miller (2009) reported that the internal consistency of the total scale was acceptable (α = .852) and its factor structure supported the six components of creativity. The concurrent validity of the CPAC scale was established by using the Abbreviated Torrance Test for Adults (ATTA; Goff & Torrance, 2002), the Consensual Assessment Technique (CAT; Amabile, 1982) short story task, and the Creativity Styles Questionnaire-Revised (Kumar & Holman, 1997).

6.2.3 Imagination
To measure imaginative capability, we used a 29-item Imaginative Capability Scale (ICS; Lin et al., 2014). The ICS includes three dimensions: initiating imagination, conceiving imagination, and transforming imagination. The ICS uses a 6-point scale ranging from 1 (strongly disagree) to 6 (strongly agree). Hsu, Peng, Wang, and Liang (2014) reported acceptable reliability and construct validity of the ICS.

7. Results
7.1 Correlational Analysis
Table 1 shows the means, standard deviations, and intercorrelations among the six variables (idea manipulation, image/sensory perception, flow, metaphorical/analogical thinking, idea generation, and incubation) of creativity, the three variables (initiating imagination, conceiving imagination, and transforming imagination) of imagination, and the four variables (reasoning/reflection, ideation, collaboration, and execution) of design thinking. The relationship among the 13 variables was investigated using the Pearson product-moment correlation coefficient. Almost all of the coefficients were positive and significant (p < .05), with strengths from medium (r = .26) to high (r = .76). Incubation had no significant relationship to transforming imagination (r = .21), reasoning/reflection (r = .16), collaboration (r = .05), and execution (r = -.16). Collaboration and ideation had no significant relationship (r = .20) and execution only had a significant relationship with two variables: reasoning/reflection (r = .33) and collaboration (r = .40).
7.2 Group Differences
In our study, we used an independent-sample t-test to compare the mean scores of the 13 measures of our groups. Table 2 shows that there were no significant differences between males and females.

Multivariate analysis of variance (MANOVA) was employed for our study and the 13 measures of creativity, imagination, and design thinking were viewed as the dependent variables, and gender and age were treated as the independent variables. Because of conducting a series of analyses, we ran the risk of an inflated Type 1 error. In order to minimize for the Type 1 error across the multiple tests, we used a Bonferroni adjustment by dividing .05 by 13 (which equals .004 after rounding) as our cut-off. Table 3 shows that there was no statistically significant difference between males and females for the combined dependent variables, $F(13, 72) = .94, p = .981$, Wilks’s Lambda = .94, partial eta squared = .059. When the results for the dependent variables were considered separately, there was no difference in statistical significance via the Bonferroni adjusted alpha level of .005. In terms of age, there was no statistically significant difference among the different ages for the combined dependent variables, $F(13, 72) = .94, p = .981$, Wilks’s Lambda = .94, partial eta squared = .059. When the results for the dependent variables were considered separately, there was no difference in statistical significance via the Bonferroni adjusted alpha level of .005. With regard to the interaction between gender and age, again, there was no statistically significant difference for the combined dependent variables, $F(13, 72) = .94, p = .981$, Wilks’s Lambda = .94, partial eta squared = .059. In addition, when the results for the dependent variables were considered separately, there was no difference in statistical significance via the Bonferroni adjusted alpha level of .005.

7.3 Structural Equation Modeling
Structural equation modeling with a maximum likelihood estimation was performed using IBM AMOS to examine the model structure. We used the indicators recommended by Hair et al. (2010, pp. 746-753) to assess goodness of model fit: Goodness-of-Fit Index (GFI; greater than .90 is typically considered good), Comparative Fit Index (CFI; above .90 usually indicates a good fit), Incremental Fit Index (IFI; above .90 usually indicates a good fit), Root Mean Square Error of Approximation (RMSEA; lower than .08 indicates an acceptable fit), and Standardized Root Mean Residual (SRMR; lower than .1 suggests a good fit). The results demonstrate that the model yielded an acceptable model fit: $X^2 = 87.18, df = 57, p = .006, GFI = .877, CFI = .955, IFI = .957, RMSEA = .078, SRMR = .052$. Figure 1 illustrates the factor loadings results from .17 to .90 and correlations among the three latent variables, ranges from .85 to .96; all coefficients were significant at $p < .001$, except for execution with $p = .12$.

8. Discussion
The main objective of this study was to examine the relationship among creativity, imagination, and design thinking of Chinese design college students in Taiwan. According to zero-order correlation, we found that the relationships among creativity, imagination, and design thinking were strong and positive, from $r = .855$ to $r = .956$. It seems that this robust result extends the existing literature, sheds lights on future studies, and provides some practical implications. Most importantly, the current study supports the empirical evidence of the relationship between design thinking and creativity and imagination.
9. Limitations
Before concluding our remarks, some salient limitations should be considered. First, the cross-sectional design of the current study may not provide the explanation of causal relations among creativity, imagination, and design thinking. Longitudinal or experimental designs could be used to further consolidate these findings. Second, although the results show that the model is acceptable, high correlations between some of the variables were found that might affect predictive validity. A third limitation is the use of self-reported measures and it is suggested that further studies could use real-life performance of individuals' creativity, imagination, and design thinking. Finally, homogeneous sample was used in the current study and further researcher could conduct cross-cultural studies to validate our findings.

10. Implications
The current study provides some significant insights to design education professionals. Educators should not only consider how to include creativity and imagination into their design thinking curricula, but also how to cultivate these important attributes among their design students.

In our study, we found the empirical evidence of a highly correlated relationship between design thinking and creativity and imagination. It suggests that when teachers use real-life design projects to facilitate the design thinking of their students, they should also provide proper stimuli to develop the creativity and imagination of their students. By doing so, they can help students generate better design solutions. This training process may be time consuming, but this practice is promising.

11. Conclusions
The major goal of this study was to inspect the relationship among creativity, imagination, and design thinking of design undergraduates in Taiwan. Two major findings were found. Creativity, imagination, and design thinking were positively correlated among our Chinese undergraduates, and these correlations were strong. Further, age and gender did not play a role in these relationships. Some salient limitations were discussed in this study, but the results provide its significant value in the literature. It is believed that this line of research is promising. Additionally, design thinking, creativity, and imagination of design students should be encouraged and facilitated through proper training and practice in the classroom. The possible future research could be stressed on design thinking in K-12 education. Educational practice as well as assessment and policies of supportive design thinking at schools that facilitate the adoption of design thinking in K-12 educational institutions are both important to activate design thinking practice in K-12 education.

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### Table 1. Zero-order correlations, means, and standard deviations for the study variables

| Variable | C1   | C2  | C3  | C4  | C5  | C6  | I1  | I2  | I3  | D1  | D2  | D3  | D4  |
|----------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| C1       | 0    |     |     |     |     |     |     |     |     |     |     |     |     |
| C2       | .67* |     |     |     |     |     |     |     |     |     |     |     |     |
| C3       | .62* | .73*** |     |     |     |     |     |     |     |     |     |     |     |
| C4       | .73** | .61** | .51** |     |     |     |     |     |     |     |     |     |     |
| C5       | .72** | .71** | .60** | .65** |     |     |     |     |     |     |     |     |     |
| C6       | .39** | .32** | .33** | .26* | .41** |     |     |     |     |     |     |     |     |
| I1       | .70** | .76** | .63** | .57** | .67** | .36** |     |     |     |     |     |     |     |
| I2       | .75** | .65** | .61** | .59** | .61** | .34** | .75** |     |     |     |     |     |     |
| I3       | .62** | .60** | .50** | .57** | .62** | .21  | .73** | .71** |     |     |     |     |     |
| D1       | .60** | .46** | .41** | .43** | .49** | .16  | .50** | .63** | .48** |     |     |     |     |
| D2       | .44** | .47** | .44** | .31** | .44** | .28** | .68** | .50** | .48** | .45** |     |     |     |
| D3       | .30** | .31** | .38** | .31** | .32** | .05  | .27*  | .22*  | .32** | .33** | .20  |     |     |
| D4       | .13   | .20   | .07   | .11   | .16   | -.16 | .07   | .15   | .13   | .33** | .17  | .40** |     |
| M        | 3.60  | 3.59  | 4.13  | 3.57  | 3.59  | 2.85 | 3.75  | 3.59  | 3.84  | 3.95  | 3.75 | 3.82 | 3.52 |
| SD       | .59   | .53   | .59   | .68   | .51   | .68  | .57   | .57   | .61   | .53   | .66  | .61  | .60  |

*Note.* C1 = idea manipulation; C2 = image/sensory; C3 = flow; C4 = metaphorical/analogical thinking; C5 = idea generation; C6 = incubation; I1 = initiating imagination; I2 = conceiving imagination; I3 = transforming imagination; D1 = reasoning/reflection; D2 = ideation; D3 = collaboration; D4 = execution.

* p < .05.

** p < .01.

### Table 2. Gender differences for study variables

| Variable                                | Male M | Male SD | Female M | Female SD | t(86) | p   |
|-----------------------------------------|--------|---------|----------|-----------|-------|-----|
| Idea manipulation                       | 3.53   | .38     | 3.61     | .61       | -.37  | .709|
| Image/sensory                          | 3.69   | .48     | 3.58     | .54       | .55   | .589|
| Flow                                    | 4.22   | .54     | 4.12     | .59       | .44   | .658|
| Metaphorical/analogical thinking       | 3.47   | .36     | 3.58     | .70       | -.46  | .649|
| Idea generation                        | 3.56   | .56     | 3.59     | .50       | -.16  | .877|
| Incubation                             | 3.00   | .73     | 2.83     | .68       | .66   | .514|
| Initiating imagination                 | 4.06   | .60     | 3.72     | .57       | 1.60  | .114|
| Conceiving imagination                 | 3.60   | .41     | 3.59     | .58       | .06   | .953|
| Variable                        | Male | Female |
|--------------------------------|------|--------|
| | $M$ | $SD$ | $M$ | $SD$ | $t(86)$ | $p$ |
| Transforming imagination       | 3.88 | .50  | 3.83 | .62  | .19  | .852 |
| Reasoning/reflection           | 3.88 | .51  | 3.96 | .54  | -.44 | .661 |
| Ideation                       | 3.92 | .35  | 3.73 | .68  | .75  | .454 |
| Collaboration                  | 3.78 | .47  | 3.82 | .62  | -.19 | .847 |
| Execution                      | 3.38 | .65  | 3.53 | .59  | -.69 | .490 |

Table 3. Multivariate and univariate analyses of variance for the study variables

| Variable | MANOVA $F(13, 72)$ | $C1$ | $C2$ | $C3$ | $C4$ | $C5$ | $C6$ | $I1$ | $I2$ | $I3$ | $D1$ | $D2$ | $D3$ | $D4$ |
|----------|---------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Gender (G) | .94                  | 3.26 | .64  | .10  | .42  | .63  | .57  | .12  | 1.08 | .07  | 1.09 | .19  | .06  | .28  |
| Age (A)   | .35                  | .25  | .23  | .61  | .25  | .40  | 1.08 | .01  | .03  | .10  | .03  | .34  | .06  | .00  |
| G x A     | .76                  | 3.92 | 2.17 | .62  | .17  | .82  | .78  | .73  | 1.84 | .25  | .88  | 1.39 | .22  | .01  |

Note. Multivariate $F$ rations are Wilks’s Lambda statistic. All $F$ rations were not significant. $C1$ = idea manipulation; $C2$ = image/sensory; $C3$ = flow; $C4$ = metaphorical/analogical thinking; $C5$ = idea generation; $C6$ = incubation; $I1$ = initiating imagination; $I2$ = conceiving imagination; $I3$ = transforming imagination; $D1$ = reasoning/reflection; $D2$ = ideation; $D3$ = collaboration; $D4$ = execution.

Figure 1. Proposed Model of Creativity, Imagination, and Design Thinking.