

# The Influence of Gender, Learning Background, Participation, and Topic Limitation on the Imagination of Industrial Design Students in Taiwan

Yo Wen Liang<sup>1</sup>, An Sheng Lee<sup>2\*</sup>, Kuei Chia Liang<sup>3</sup>, Huang Ning Lee<sup>4\*</sup>

<sup>1</sup> Ming Chi University of Technology, Department of Communication Design, New Taipei City, TAIWAN

<sup>2</sup> National Chiayi University, Department of Wood-Based Materials and Design, Chiayi City, TAIWAN

<sup>3</sup> National Taiwan Normal University, Department of Design, Taipei, TAIWAN

<sup>4</sup> Toko University, Department of Restaurant Management, Chiayi, TAIWAN

Received 4 September 2017 • Revised 23 October 2017 • Accepted 16 November 2017

## ABSTRACT

In this study, five industrial senior designers are invited to observe and record a required design practice course of an industrial design department of a university for one semester, 18 weeks, each week for 5-6 hours. During the process, the imagination indicators proposed by Vygotsky is adopted in combination with a 5-point Likert scale. The sophomore class, 63 students in total, is observed. The outcome of study indicates that when the topics are with limitation, the gender factor has significant influence during design stages, and the influence of students' pre-university learning background is significant as well. When the topics are not limited, the influence of the gender factor also appears to be significant. The pre-university learning background has more influence on the performance of imagination and vocational high school graduates do better than regular high school graduates. In the meantime, students with higher level of class participation exhibit better imagination.

**Keywords:** design course, imagination, industrial design, learning background, students' learning

## INTRODUCTION

Today, in spite of the rapid advancement in technology, imagination is still the best soft power in the development of human civilization. It is also an important ability to present human intelligence. Imagination is required to stimulate innovations and breakthroughs in every field, especially the design industry where creativity and innovativeness are highly essential. At present, all advanced nations, besides emphasizing the importance of cultivation of creativity, have started to work out plans to cultivate imagination. Industrial design is a problem-solving process. Professional designers must have great imagination and creativity to solve problems (Liang, 2008; Smith et al., 1995). In Taiwan, the industrial and academic sectors highly value and are also in urgent need of product development and design personnel and design students with creativity, integrated ability and planning ability. These abilities are considered important indicators for industrial competitiveness in the future.

However, the industrial sector and the academic sector hold different views toward the factors that have influence on imagination. Some scholars suggest the length of time of design activities can have an effect on thinking and imagination (Lin et al., 2014; Wieth & Zacks, 2011). Others try to study the influence of situations on imagination (Folkmann, 2013; Smith et al., 2009). Overall, studies conducted in Taiwan on actual use of imagination still lack definition of other factors and experiments, particularly in research of design education in university (Liang et al., 2016), making it an area urgently calling for exploration. Other than that, during the process of application of design methods and design thinking, there is often the black-box phase, a part of the process that takes places in the mind of the designer. Whether verbal or nonverbal study approaches are adopted to analyze and examine it (such as thinking out loud or interview), it is impossible to establish the designer's complete thinking

---

© **Authors.** Terms and conditions of Creative Commons Attribution 4.0 International (CC BY 4.0) apply.

✉ [yowenliangphd@gmail.com](mailto:yowenliangphd@gmail.com) ✉ [sheng1887@mail.ncyu.edu.tw](mailto:sheng1887@mail.ncyu.edu.tw) [sheng1887@yahoo.com.tw](mailto:sheng1887@yahoo.com.tw) (\*Correspondence)

✉ [kcliang@ntnu.edu.tw](mailto:kcliang@ntnu.edu.tw) ✉ [hn.lee@mail.toko.edu.tw](mailto:hn.lee@mail.toko.edu.tw) (\*Correspondence)

#### **Contribution of this paper to the literature**

- This study attempts to analyze the influencing factors of black box of imagination and design thinking, furthermore, to explore the references of different scope.
- This study explored students' performance in design imagination from four different influencing factors, and the results can be the references to university teachers for their teaching strategy.
- The findings of this study can serve as references in introduction and development of further imagination stimulation courses to improve the imagination and performance design student in university in order to train more talents with innovative thinking.

process and design logic (Liang et al., 2010). Therefore, finding out how to guide or stimulate the imagination of designers or design students is a rather important issue in development of creative product design, especially cultivation of future design talents—students. In Taiwan, students of design departments in university include vocational and regular high school graduates. So far, studies on the influence of pre-university learning backgrounds on imagination have been few. If this area can be examined by including also the student gender and class participation factors, it may be possible to learn more about imagination in design.

The objective of this study is to discuss whether factors such as the pre-university learning background, gender and class participation have any effect on the use of imagination of students when they engage in product design for industrial design courses. The imagination indicators proposed by Vygotsky (2004) are adopted in this study. Design experts are invited to form a team to analyze the contents of each design stage in practice courses in Taiwan to establish data in correspondence with the said indicators and then, based on the data, the experts observe a design class for 18 weeks, record the results and complete related statistical work to study whether the pre-university learning background, gender and class participation have influence on the imagination of the students at each design stage. In Chapter 2, literature associated with design thinking and design imagination, innovative integration and design imagination, and imagination experience, logical thinking and non-logical thinking will be discussed.

## LITERATURE REVIEW

### **Design Thinking and Design Imagination**

The factors that can influence design thinking and design imagination in the design industry and business environment are not only limited to the know-how, skills and aesthetic literacy of the designer; they may also hide in the overall design process and development (Bruce & Cooper, 1997; Cross, 1994), including project experience, information changes and use, and customer relations which all can have direct or indirect effects on the development of the designer's design thinking and design imagination and even affect the final outcome and presentation of the project (Ulrichj & Eppinger, 1995). Hence, the dissimilarities in design characteristics, practices and perception and depiction of design problems between different designers can lead to different contents and directions of thinking as well as distinct results (Liang, 2008). Therefore, the importance of design thinking and design imagination goes without saying. In other words, they form the soft power of each designer and have a deep impact on the innovativeness and competitiveness of products designed.

Design thinking and cognition are a creative and innovative problem-solving process in which designers examine and determine the factors that can cause differentiation. At this point, creativity can also take place. This process is a rather important issue in research of design thinking and imagination today (Cross, 1994; Holt, 1990). When an experienced designer stresses the significance of the problem-solving process and the result can make customers satisfied and gain profit at the same time, design activities are just like a creative problem-solving process (Lawson, 2006; Pahl et al., 2007). Development of design thinking is to assure the outcome can better comply with the expectations and experiences of consumers (Chang, 2010). This kind of design mode is called consumer-oriented creative design mode which can usually lead to products that sell better and also set the guideline for the tendency of further development of the products.

A number of studies on design thinking and imagination indicate (Liang, 2008; Vygotsky, 2004; Worst, 2007) that when design thinking first begins and imagination is in a stage of "extraction, association, preparation and fermentation, the contents belong to "restoration of memory, association of memory, generalization of memory, analogy of memory and other mental activities. These are related to "extraction and rephrasing" in the process of design imagination to extract appropriate materials or elements to solve design problems and create products. Creative imagination occurs as a result of the stimuli gathered for designers to reassemble and think to come up with solutions.

## **Innovative Integration and Design Imagination**

Since the Arts and Crafts Movement, the foundation of development in the field of design and related research has been laid down in the UK. The contents of design and techniques in the UK include industrial design and engineering design. Industrial design involves product quality and attractiveness and consumer recognition, whereas engineering design focuses on technical innovations and how to turn concepts developed through industrial design into products (Liang, 2008). Product innovation used to emphasize more on functions, but now the stress is placed on taste, features and market differentiation. Steve Jobs once pointed out in an interview when he was young that functions were emphasized in the products of Microsoft but taste was lacking (Isaacson, 2011). The success of the various products of Apple since then has proven this.

Innovative integration refers to the consolidation of originality, strategy and specification during the product planning stage (conception, proposal and specification). US-based HaA Design has pointed out that "originality" is the path indicators, including the "direction" and the "blueprint," of the "map." It is a concise explanation of the aforesaid "originality" and "strategy" (HaA Design, 2016). With the emergence of the experience economy, businesses are taking the initiative to "create consumers' new feelings about their products," in other words, to interpret "originality" from a new angle (Pine & Gilmore, 1998). Many studies have also suggested (Liang, 2008); Shan et al., 2002; Yu et al., 2001) that design strategies are intended to incorporate innovativeness in products to allow users to have new experiences. Subsequently, the framework of a product is precisely established to guide designers to understand the background to find inspirations and solutions through design development and discussion. Then inspirations are transformed into applicable concepts, operating modes or interactive product simulations to bring imagination to realization. In the end, the concepts are converted into mature concrete products to be tested and marketed through trade shows and catalogs. In other words, through divergence and convergence, related knowledge is incessantly internalized and externalized to create new products. Therefore, application of the core knowledge of industrial design in the product planning stage to maximize its influence on design imagination will make significant contributions to the innovativeness and sustainable management of the design industry.

### **Imagination Experience, Logical Thinking and Non-Logical Thinking**

Imagination experience is an industrial design concept derived from application of the scenario method with the scenario design method in teaching. It is intuitive, perceivable, as well as logical and non-logical at the same time. Stimuli are needed to trigger the use of the concept. Inspirations may occur in a series and alone, depending on the growth environment and the formation of experience and cultivation of knowledge (Xu & Bien, 2002). As pointed out in *Experiences in Visual Thinking* by McKim (1980), images are to stimulate the thinking mode of "visualization, imagination and drawing." Goldschmidt (1994), on the other hand, suggests images first appear in an individual's mind and are modified to become the images the individual intends to express. Knowledge is processed professionally (for example, industrial design approaches) and developed into innovative know-how through comparison, verification, association and communication to develop core competitiveness that takes form as a result of extension and accumulation of diverse knowledge and makes it possible for an enterprise to have positive development (Wu, 2002).

Logical thinking is a guideline and mode according to which humans infer and deduce their ideas. That is to say humans can adopt various approaches to know the truth. Each way of recognizing an idea can be seen as a form of logic (Lucas et al., 2003). It is related to imagination to some extent. As indicated in studies on logical thinking (Pezzuti et al., 2014; Wang, 2003) and non-logical thinking (Hitchcock, 2009; Su, 2002), the diverse forms of thinking can be contradictory to, different from and opposite to existing logic and, because of such relations, stimulate imagination.

## **METHODOLOGY**

In this study, an industrial design department that has been around for more than 15 years is selected to examine its required practice courses and the research is conducted in three phases: analyzing the connection of the contents of different stages of the design course by using imagination indicators, observing how the courses are taught and recording the use of imagination, and analyzing the imagination of students in different stages of the design course.

### **Analysis of the Connection between the Contents of Different Stages of Design Courses with Imagination Indicators**

During this phase of study, the contents of the target course each week are analyzed to understand the framework of teaching of practice courses of industrial design or product design. Five designers each with more than ten years of design experience are invited to form the focus group and study whether the contents of the design

**Table 1.** The scale indexes of imagination: initiation, fluency, flexibility, and originality

Index of imagination	Description of content
Initiation	An individual with past achievements as a result of his or her imagination has a lot of mental images that could serve as topics. The more experience an individual accumulates, the more diverse the mental images that can be extracted will be. It is related to past experience.
Fluency	The existing cognitive schema of an individual's database can be developed into imagination with a brand-new schema through logical analogy triggered by internal or external stimulation. In other words, it is the quantity of associations of similar types generated as a result of internal or external stimulation.
Flexibility	The existing cognitive schema of an individual's database can be developed into the ability to make associations with a brand-new schema through logical analogy triggered by internal or external stimulation. Different from fluency, flexibility allows an individual to break through the current condition. At the same time, different angles are adopted to think about possibilities and directions of flexible changes, including type conversion and diversified association between dissimilar types.
Originality	Mental images created by an individual based on his or her ability to make associations are assembled, converted and twisted to become an ability through creative thinking. It is breakthrough thinking ability generated by integration of the ability to make associations and the ability to "create something out of nothing. The individual will be able to break through conventional boundaries and come up with new and unique ideas without the restraints of older systems.

courses to be taught for 18 weeks are associated with the imagination indicators proposed by Vygotsky (2004) or related to the arguments presented in the literature reviewed earlier about stimulation of students' imagination. The items to be evaluated in the imagination evaluation scale are the imagination indicators proposed by Vygotsky in his publication *Theoretical Conceptions of Imagination*: initiation, fluency, flexibility and originality, as shown in [Table 1](#).

### Observation of Design Course Teaching and Recording of Use of Imagination

The five experienced designers participating in the first experiment observe design class teaching through participant observation and record the processes of ten design class sessions for one semester, 18 weeks (the time spent on class regulation explanation, departmental evaluation, mid-term and final examinations deducted) to assess the use of students' imagination in different design stages. Low-involvement participant observation is adopted, meaning that the participation is mainly to observe. The experts observe as teaching assistants and do not disturb the class by engaging in conversations or interactions with the teacher or students. It is a sophomore class and there are 63 students in total. The class is observed five to six hours per week, depending on the class arrangement.

When observing, the five experienced designers take notes and each one uses an imagination evaluation scale to record the students' use of imagination in different design stages. There are also research assistants to take pictures of each work designed by each student and film the design processes to facilitate subsequent quantitative and qualitative analysis. A five-point Likert scale is adopted and the imagination indicators, namely initiation, fluency, flexibility and originality, proposed by Vygotsky are applied to evaluate the imagination of students as they design their works each week. Among the many studies conducted with regard to imagination, these indicators are the ones more generally accepted.

### Analysis of Students' Imagination in Different Stages of the Design Course

In this phase of study, the contents of observation and results recorded by the focus group are quantified for statistical analysis and qualitative work analysis to examine whether the use of students' imagination in different stages of the design course is affected by factors such as gender, the pre-university learning background, participation and topic limitation. Three hypotheses are also explored according to the results of statistical analysis:

- Student gender and pre-university learning background have no significant influence on students' use of imagination (1-5 points) (two-way analysis of variance).
- Student participation in discussions (1-5 points) has no relation to students' use of imagination (Pearson correlation analysis).
- Whether there is topic limitation or not has no significant influence on students' use of imagination (1-5 points) (dependent sample t-test).

In subsequence, quantitative work analysis is conducted to examine the results from the quantitative study. The photographs taken in ten class sessions and electronic files of the students' works are also referred to for the research team and focus group to undergo.

**Table 2.** Result of analysis of the connection between the contents of different stages of the design course and imagination indicators: design course topic 1

Design Course Topic 1: Design of Sound-playing Products								
Time	Week 2		Week 3		Week 4		Week 5-6	Week 7-8
Design Stage	1. First draft		2. Second draft		3. Draft Refinement		4. Model Production	5. Product Precision Mold and Presentation Board
Connection to Imagination Indicators	Initiation Index A	Fluency Index B	Initiation Index A	Fluency Index B	Initiation Index A	Fluency Index B	Flexibility Index C	Originality Index D
Course Contents	Students draw in total 30 drafts of products with sound-playing concepts in different styles.		After discussing with the teacher, each student chooses three of the concepts in the first draft and establishes two more drafts.		After discussing with the teacher, each student selects two concepts from the second drafts and draws a refined design that includes details and various aspects.		Based on the two concepts presented in the refined draft, each student produces the engineering drawing and then builds the model accordingly.	After discussing with the teacher, each student chooses one of the two concepts to produce the product precision mold and also designs the presentation board.

**Table 3.** Results of analysis of the connection between the contents of different stages of the design course and imagination indicators: design course topic 2

Design Course Topic 2: Design of Products with Light, Sound and Heat								
Time	Week 10		Week 11		Week 12		Week 13-14	Week 15-16
Design Stage	1. First draft		2. Second draft		3. Draft Refinement		4. Model Production	5. Product Precision Mold and Presentation Board
Connection to Imagination Indicators	Initiation Index A	Fluency Index B	Initiation Index A	Fluency Index B	Initiation Index A	Fluency Index B	Flexibility Index C	Originality Index D
Course Contents	Students draw in total 30 drafts of products with light, sound and heat concepts in different styles.		After discussing with the teacher, each student chooses three of the concepts in the first draft and establishes two more drafts.		After discussing with the teacher, each student selects two concepts from the second drafts and draws a refined design that includes details and various aspects.		Based on the two concepts presented in the refined draft, each student produces the engineering drawing and then builds the model accordingly.	After discussing with the teacher, each student chooses one of the two concepts to produce the product precision mold and also designs the presentation board.

## RESULTS

### Results of Analysis of the Connection between the Contents of Design Stages and Imagination Indicators

After a joint analysis conducted by the research team and the focus group, the contents of ten class sessions (the time spent on class regulations explanation, departmental evaluation, mid-term and final examinations deducted) in which design activities take place are adopted as the subject and what happen in different design stages of the courses is examined. In the end, the Vygotsky imagination indicators are applied to evaluate the results of observation and recorded use of imagination. It is concluded in this study that the stages of first draft, second draft and draft refinement have a lot to do with initiation and fluency, while the stage of model production is closely related to flexibility and the final product precision mold establishment stage is closely related to originality. The design course observation activities are divided into two parts, each a complete product design project. The first project is carried out in the first five class sessions. The topic is “design of sound-playing products” and limitation exists. The second one is conducted in the second five class sessions. The topic is “design of products with light, sound and heat.” There is no topic limitation; hence, the design topic is more open. The stages of the design course and the connection between the course contents and imagination indicators are as shown in **Tables 2** and **3**.

### Results of Observation of Design Course Teaching and Recording of Use of Imagination

The design imagination evaluation scale is established to measure the results obtained in the first half of this study. Class participation is included in the scale since one of the purposes of this study is to examine whether it will affect design imagination. The results are as shown in **Table 4**.

**Table 4.** Design of the teaching observation and design imagination evaluation scale

Student Code	Gender 1= male; 2= female	Learning background 1= High school; 2= Vocational	Evaluation of Use of Imagination in Different Design Stages (Indexes A~D) (5-point Likert Scale)								
			Week 2 First draft		Week 3 Second draft		Week 4 Draft refinement		Week 5-6 Model Production	Week 7-8 Product Precision Mold and Presentation Board	Participation
			Index A	Index B	Index A	Index B	Index A	Index B	Index C	Index D	
A01											
A02											
A03											
A61											
A62											
A63											

(Index A = Initiation; Index B = Fluency; Index C = Flexibility; Index D = Originality)



**Figure 1.** The process of observation of design course teaching and recording of use of imagination

The five experts used the design imagination evaluation scale to record the two design projects implemented by the 63 students in the class. The results are the quantified data on the use of imagination in ten class sessions. The research team also filmed the process of each of the ten sessions, including the students’ participation in discussions and the status of the works designed in each stage. The results will be analyzed in the following section. **Figure 1** shows the process of teaching observation and recording of use of imagination.

### Results of Analysis of Students’ Imagination Exhibited in Their Works for the Design Course

#### *Descriptive statistics on the overall use of students’ imagination*

As indicated in the quantitative data established in the imagination evaluation scale by the five experts observing the ten class sessions, there are 63 students. There are 26 males and 37 females when classified by gender,

**Table 5.** Descriptive statistics on the performance of students' imagination when designing products with topic limitation

Gender	Learning background	N	First Draft:		First Draft:		Second Draft:		Second Draft:		Draft Refinement:		Draft Refinement:		Model Production:		Product Precision Mold and Presentation Board: Originality		Participation	
			Initiation	Fluency	Initiation	Fluency	Initiation	Fluency	Initiation	Fluency	Initiation	Fluency	Flexibility	Flexibility	M	SD	M	SD	M	SD
			M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
male	Senior high School graduate	19	2.83	0.80	2.45	0.73	2.57	0.68	2.17	0.77	2.21	0.77	1.97	0.95	3.00	0.91	2.63	0.97	2.66	1.21
	Vocational high school graduate	7	3.00	0.48	2.54	0.77	2.75	0.41	2.43	0.53	2.29	0.37	1.93	0.53	3.46	0.80	2.89	0.66	2.89	1.04
	Total	26	2.88	0.73	2.47	0.73	2.62	0.61	2.24	0.71	2.23	0.68	1.96	0.84	3.12	0.89	2.70	0.89	2.72	1.15
female	Senior high School graduate	30	3.21	0.55	2.84	0.70	2.97	0.52	2.46	0.68	2.56	0.65	2.22	0.65	3.21	0.81	2.93	0.82	3.29	0.88
	Vocational high school graduate	7	3.64	0.38	3.18	0.51	3.46	0.47	2.93	0.57	3.14	0.48	2.60	0.38	4.07	0.43	3.64	1.05	3.89	1.44
	Total	37	3.29	0.54	2.91	0.68	3.06	0.54	2.55	0.68	2.68	0.65	2.30	0.62	3.37	0.82	3.07	0.89	3.41	1.01
Total	Senior high School graduate	49	3.06	0.68	2.69	0.73	2.81	0.61	2.35	0.72	2.43	0.71	2.12	0.78	3.13	0.85	2.82	0.88	3.05	1.05
	Vocational high school graduate	14	3.32	0.53	2.86	0.71	3.11	0.56	2.68	0.59	2.71	0.60	2.29	0.58	3.77	0.69	3.27	0.93	3.39	1.31
	Total	63	3.12	0.65	2.73	0.73	2.88	0.61	2.42	0.70	2.50	0.69	2.16	0.74	3.27	0.85	2.92	0.91	3.12	1.12

**Table 6.** Descriptive statistics on the students' use of imagination when designing products without topic limitation

Gender	Learning background	N	First Draft:		First Draft:		Second Draft:		Second Draft:		Draft Refinement:		Draft Refinement:		Model Production:		Product Precision Mold and Presentation Board: Originality		Participation	
			Initiation	Fluency	Initiation	Fluency	Initiation	Fluency	Initiation	Fluency	Initiation	Fluency	Flexibility	Flexibility	M	SD	M	SD	M	SD
			M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
male	Senior high School graduate	19	2.36	0.64	2.14	0.86	2.58	0.63	2.22	0.81	2.76	0.96	2.68	0.77	3.00	0.86	2.70	0.96	2.44	1.05
	Vocational high school graduate	7	2.64	0.89	2.68	0.86	2.43	1.07	2.21	1.18	2.25	0.95	2.38	0.90	3.32	1.15	2.75	1.09	2.54	1.33
	Total	26	2.43	0.71	2.29	0.88	2.54	0.75	2.22	0.90	2.63	0.97	2.50	0.86	3.09	0.93	2.71	0.98	2.47	1.11
female	Senior high School graduate	30	2.82	0.58	2.37	0.83	2.93	0.58	2.43	0.76	2.67	0.65	2.32	1.04	3.21	0.79	3.10	0.83	3.24	0.82
	Vocational high school graduate	7	3.61	0.69	3.21	0.92	3.60	0.64	3.18	1.12	3.32	0.49	3.11	0.61	3.46	0.85	3.89	0.79	4.11	1.00
	Total	37	2.97	0.67	2.53	0.90	3.05	0.65	2.57	0.87	2.80	0.67	2.71	0.91	3.26	0.79	3.25	0.87	3.41	0.91
Total	Senior high School graduate	49	2.64	0.64	2.28	0.84	2.79	0.62	2.35	0.79	2.71	0.78	2.59	0.85	3.13	0.81	2.94	0.90	2.93	0.99
	Vocational high school graduate	14	3.13	0.91	2.95	0.90	3.02	1.04	2.70	1.21	2.79	0.91	2.52	0.89	3.39	0.97	3.32	1.09	3.32	1.40
	Total	63	2.75	0.73	2.43	0.89	2.84	0.73	2.43	0.89	2.73	0.80	2.55	0.87	3.19	0.85	3.03	0.95	3.02	1.09

and 49 regular senior high school graduates and 14 vocational high school graduates when classified by pre-university learning background. The descriptive statistics on the performance of the students' imagination when designing according to a topic with limitation are as shown in **Table 5**.

The descriptive statistics on the students' use of imagination when designing according to a topic without limitation are as shown in **Table 6**.

**Table 7.** Statistics on the influence of student gender and pre-university learning background on imagination when designing products with topic limitation

Factors	First Draft: Initiation		First Draft: Fluency		Second Draft: Initiation		Second Draft: Fluency		Draft Refinement: Initiation		Draft Refinement: Fluency		Model Production: Flexibility		Product Precision Mold and Presentation Board: Originality		Participation		
	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	
Gender	7.373	0.009*	5.858	0.019*	10.816	0.002*	3.552	0.064	9.490	0.003*	4.727	0.034*	2.705	0.105	3.848	0.055	6.265	0.015*	
Learning background	2.587	0.113	0.985	0.325	4.344	0.051	3.036	0.087	2.630	0.110	0.749	0.390	7.166	0.010*	3.279	0.075	1.641	0.205	
Gender*																			
Learning background	0.490	0.487	0.336	0.564	0.854	0.359	0.259	0.612	1.544	0.219	1.146	0.289	0.647	0.424	0.699	0.406	0.315	0.577	

**Table 8.** Statistics on the influence of student gender and pre-university learning background on imagination when designing products without topic limitation

Factors	First Draft: Initiation		First Draft: Fluency		Second Draft: Initiation		Second Draft: Fluency		Draft Refinement: Initiation		Draft Refinement: Fluency		Model Production: Flexibility		Product Precision Mold and Presentation Board: Originality		Participation		
	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.	
Gender	13.039	0.001*	2.118	0.151	1.103	0.298	4.930	0.030*	0.623	0.434	0.492	0.486	0.444	0.508	7.981	0.006*	15.888	0.000*	
Learning background	7.456	0.008*	7.041	0.010*	6.131	0.022*	1.937	0.169	0.083	0.777	0.854	0.359	1.215	0.275	2.389	0.128	2.583	0.113	
Gender*																			
Learning background	1.622	0.208	0.363	0.549	non	non	2.037	0.159	non	non	4.392	0.040*	0.015	0.903	1.831	0.181	1.714	0.195	

**Results of statistical analysis of the influence of the students' gender and pre-university learning background on their design imagination**

The statistics on the influence of the students' gender and pre-university learning background on their use of imagination indicate that the gender factor has a larger effect on use of imagination. When this finding is combined with the descriptive statistics shown in Tables 5 and 6, it is obvious that the female students outdo the male ones in initiation and fluency in the first draft stage, in initiation in the second draft stage and in initiation and fluency in the draft refinement stage. In the meantime, the pre-university learning factor has significant influence on flexibility in model production. Vocational high school graduates outperform regular senior high school graduates. The statistics are as shown in Table 7.

The statistics on the influence of student gender and pre-university learning background on use of imagination when designing according to a topic without limitation indicate that the pre-university learning background has more influence on use of imagination in the beginning of the design work. When this outcome is combined with the aforesaid descriptive statistics, it is obvious that vocational high school graduates outperform regular senior high school graduates in initiation and fluency during the first draft stage and in initiation during the second draft stage. Meanwhile, the gender factor appears significantly different in initiation during the first draft 1 stage and in originality in the last stage of establishment of the product precision mold and presentation board. Female students outdo males ones. The statistics are as shown in Table 8.

**Statistics on the influence of student participation in discussions on design imagination**

The correlation statistics on the influence of students' participation in discussions on design imagination when they design products with topic limitation reveal all the design course contents have high positive correlations (Pearson correlation coefficient>0.7), meaning the students' performance and attitude when discussing designs with topic limitation are highly positively correlated with the performance of their imagination in each design stage. The statistics are as shown in Table 9.



**Table 9.** Correlation statistics on the influence of students' performance in discussion of products designed with topic limitation on their imagination

	First Draft: Initiation	First Draft: Fluency	Second Draft: Initiation	Second Draft: Fluency	Draft Refinement: Initiation	Draft Refinement: Fluency	Model Production: Flexibility	Product Precision Mold and Presentation Board: Originality
Pearson Correlation Coefficient	0.840*	0.803*	0.849*	0.818*	0.836*	0.780*	0.767*	0.819*
Sig. (two-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

**Table 10.** Correlation statistics on the influence of students' performance in discussion of products designed without topic limitation on their imagination

	First Draft: Initiation	First Draft: Fluency	Second Draft: Initiation	Second Draft: Fluency	Draft Refinement: Initiation	Draft Refinement: Fluency	Model Production: Flexibility	Product Precision Mold and Presentation Board: Originality
Pearson Correlation Coefficient	0.671*	0.418*	0.713*	0.549*	0.493*	0.429*	0.579*	0.845*
Sig. (two-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

**Table 11.** Statistics on the influence of topics with/without limitation on the students' imagination

	M	N	SD	t	Sig. (two-tailed)
Design topic with limitation-first draft: Initiation	3.12	63	0.65	5.074	0.000*
Design topic without limitation-first draft: Initiation	2.75	63	0.73		
Design topic with limitation-first draft: Fluency	2.73	63	0.73	2.970	0.004*
Design topic without limitation-first draft: Fluency	2.43	63	0.89		
Design topic with limitation-second draft: Initiation	2.88	63	0.61	0.506	0.615
Design topic without limitation-second draft: Initiation	2.84	63	0.73		
Design topic with limitation-second draft: Fluency	2.42	63	0.70	-0.074	0.941
Design topic without limitation-second draft: Fluency	2.43	63	0.89		
Design topic with limitation-draft refinement: Initiation	2.50	63	0.69	-2.413	0.019*
Design topic without limitation-draft refinement: Initiation	2.73	63	0.80		
Design topic with limitation-draft refinement: Fluency	2.16	63	0.74	-3.359	0.001*
Design topic without limitation-draft refinement: Fluency	2.54	63	0.86		
Design topic with limitation-model production: Flexibility	3.27	63	0.85	0.901	0.371
Design topic without limitation-model production: Flexibility	3.18	63	0.85		
Design topic with limitation-product precision mold and presentation board: Originality	2.92	63	0.91	-1.418	0.161
Design topic without limitation-product precision mold and presentation board: Originality	3.03	63	0.95		

The correlation statistics on the influence of students' participation in discussions on design imagination when they design products without topic limitation reveal most design course contents have high positive correlations (Pearson correlation coefficient > 0.7), meaning the students' performance and attitude when discussing designs without topic limitation are highly positively correlated with the performance of their imagination in each design stage. The statistics are as shown in **Table 10**.

**Statistics on the influence of topics with/without limitation on the students' imagination**

The statistics on the influence of topics with/without limitation on the students' imagination indicate that during the beginning of draft initiation and concept convergence in the draft refinement stage, the students use their imagination better, but there is no significance difference in other stages. The statistics are as shown in **Table 11**.

### ***Results of qualitative analysis of imagination exhibited in the works produced by the students for the design course***

**(1) Using "gender" as a variable in examination of design of products with/without topic limitation**

When using imagination to initiate concepts for products, the female students outperform the male ones during both the draft and draft refinement stages. They produce better combinations of straight and curved lines as well as more form variations. As a consequence, the styles of their products are more changeful and this explains why the statistics indicate female students do better than the male ones in initiation and fluency during the first draft stage, in initiation and fluency during the second draft stage and in initiation and fluency during the draft refinement stage. However, in the second half of the design process, during the model production stage and the product precision mold and presentation board product stage, the works show there is no significant difference between the female and male students. Moreover, when there is no limitation on the topic, the use of imagination of the female students is also not significantly different from that of the male ones, as indicated in the statistics.

**(2) Using "pre-university learning background" as a variable in examination of design of products with/without limitation**

During the first draft stage, the students show no significant difference in use of imagination. Nevertheless, in the second draft stage, each student with a vocational high school background can continue to produce a certain number of drafts with various concepts and again develops more related drafts based on those drafts, exhibiting decent initiation and fluency. On the contrary, students with regular senior high school education produce drafts that contain less diversity while the contents are also excessively similar to currently available products. For this reason, the experts are unable to give them high scores in initiation and fluency. In addition, during the model production stage, the vocational high school graduates are able to convert 2D designs into initial 3D models which also turn out to be more complete compared to the ones produced by those with a regular high school background. Therefore, the statistics show that the ones with a vocational high school background perform better in flexibility in the model production stage than those with a regular senior high school background. However, when the topic has no limitation, the use of imagination between these two groups of students is not significantly different. One thing certain is that the use of imagination of all the students appears to be better when the topic is limited.

**(3) Using "participation in discussions" as a variable in examination of design of products with/without limitation**

It is discovered that students with higher ratings in discussion participation ask more questions in class and they also are able to brainstorm based on the teacher's answers and suggestions to get more inspirations and implement them in the following stage of design work. Besides, students who participate more in discussions can also produce more and diverse drafts and come up with products of more changeful forms. The operating methods of their products are more innovative and their design performance in subsequent design stages is better than those with lower-level participation in discussions. In comparison, the latter type of students spends less time discussing with the teacher and asks fewer questions. Their drafts normally contain one or two product concepts and the designs are more realistic. The concepts are often similar to those in existing products and the final results are common and lack imagination. When the topic is without limitation, the discussion participation ratings are more or less the same as when the topic is limited. In every design stage, students with higher ratings in discussion participation perform better than the ones with lower ratings.

**(4) Using "with/without topic limitation" as a variable in examination of imagination performance in each stage of the design process**

When the topic is limited, all the students are able to come up with product concept drafts according to the topic given by the teacher in the first draft stage. For instance, some students adopt environmental protection and energy saving as the theme and draw out car lights, digital bus stops, sports equipment and solar street lights. The lines in the drawings are fluent and changeful and the styles are also more diverse, formed with geometric and curved lines or irregular lines. The functions are clearly defined and there are innovative ideas. On the contrary, when the topic has no limitation, there is not enough imagination in the initial drafts and repeated concepts are obvious.

When the topic has limitation, the students perform better in styling, color distribution and component arrangement in the draft refinement stage, compared to when the topic has no limitation. For example, some students draw out aromatic hydrotherapy machines in the shape of flowers and try different numbers of flower petals and color distribution and leaf form variations whereas some others incorporate necklaces, zippers and bracelets in portable emergency first-aid kits. However, when the topic has no limitation, the results of draft refinement are relatively less characteristic and the final products lack imagination and are also similar to existing products available on the market.

## CONCLUSION

The results of exploration of related issues in studies of design imagination can serve as references in introduction and development of further imagination stimulation courses to improve the imagination and performance design student in university in order to train more talents with innovative thinking. This study is intended to find out which factors have significant influence on student imagination stimulation and guidance in design education in university in Taiwan. The results of this study can serve as references for further studies on design imagination. They can also be helpful for teachers of design courses to make suitable adjustments when various factors are taken into consideration to improve design courses and students' imagination.

By studying the contents and teaching of current design courses and students' use of imagination, more factors that stimulate imagination can be identified to offer substantial suggestions for design education. Future studies can also include other teaching materials or methods that stimulate imagination. It is hoped that the findings in this study can have concrete benefits in establishment of projects to develop the theoretic foundation for research on imagination and improvement of imagination in design education to upgrade the imagination of design students in university in Taiwan to make substantial contributions to the industrial design industry.

## ACKNOWLEDGEMENTS

This study has been supported by the Design Imagination Project, funded by Ming Chi University of Technology, National Taiwan Normal University, and National Chiayi University. The authors are grateful to the five senior industrial designers and 63 students of industrial design for participating in this study as well. Also, we are very grateful for the funding from the Ministry of Science and Technology (Project MOST106-2313-B-415-004) to make this project possible.

## REFERENCES

- Bruce, M., & Cooper, R. (1997). *Marketing and design management*. London: Intl Thomson Business Press.
- Chang, W. W. (2010). Design viewpoints of creative life. *Technology Development Magazine*, 453, 20-29.
- Cross, N. (1984). *Developments in design methodology* (ed.). Chichester, U.K.: John Wiley & Sons.
- Folkman, M. N. (2013). *The aesthetics of imagination in design*. Cambridge: MIT Press.
- Goldschmidt, G. (1994). On visual design thinking: the vis kids of architecture. *Design Studies*, 15(2), 158-174. doi:10.1016/0142-694X(94)90022-1
- HaA Design (2016, August). ISO certified design and development. Retrieved from: <http://www.haapd.com/>
- Hitchcock, D. (2009). Non-logical consequence. *Studies in Logic, Grammar and Rhetoric*, 15(28), 1-22. doi:10.1007/978-3-319-53562-3\_7
- Holt, T. (1990). *Thinking historically: Narrative, imagination, and understanding*. College Entrance Examination Board.
- Isaacson, W. (2011). *Steve Jobs*. New York: Simon & Schuster.
- Lawson, B. R. (2006). *How designers think (4th Edition)*. Oxford: Architectural Press.
- Liang, K. C. (2008). *The issues of project activities influencing design development*. Taipei: WuNan.
- Liang, Y. W., Lee, A. S., & Liu, S. F. (2016). A study on design-oriented demands of VR via ZMET-QFD model for industrial design education and students' learning. *Eurasia Journal of Mathematics, Science and Technology Education*, 12(5), 1205-1219. doi:10.12973/eurasia.2016.1507a
- Liang, Y. W., Liu, S. F., & Zhou, X. B. (2010). Using metaphor elicitation technique to explore designers' demands in virtual reality. *Journal of Art and Design of Huaan University*, 6, 165-179.
- Lin, W. S., Hsu, Y. L., & Liang, C. Y. (2014). The mediator effects of conceiving imagination on academic performance of design students. *International Journal of Technology and Design Education*, 24(1), 73-89. doi:10.1007/s10798-013-9244-x
- Lucas, H. C., Tuschling, B., & Vogel, U. (2003). *Hegels enzyklopädisches System der Philosophie*. Stuttgart: Frommann-Holzboog.
- McKim, R. (1980). *Experiences in visual thinking*. New York: Brooks/Cole Pub Co. Press.
- Pahl, G., Beitz, W., Feldhusen, J., & Grote, K. H. (2007). *Engineering design: a systematic approach*. Berlin: Springer.
- Pezzuti, L., Artistic, D., Chirumbolo, A., Picone, L., & Dowd, S. M. (2014). The relevance of logical thinking and cognitive style to everyday problem solving among older adults. *Learning and Individual Differences*, 36, 218-223. doi:10.1016/j.lindif.2014.07.011
- Pine II, B. J., & Gilmore, J. H. (1998). *Welcome to the Experience Economy*. Harvard Business Review.

- Shan, C. G., He, M. Q., Bien, S. J., & Wang, H. X. (2002, May). Exploring the design policy. *2002 Proceedings of the Symposium on Design Academic Research Achievements*, Taipei.
- Smith, S. M., Kohn, N. W., & Shah, J. J. (2008). What you see is what you get: effects of provocative stimuli in creative invention. Gero, JS (ed): 2008, *The International Workshop on Studying Design Creativity*.
- Smith, S. M., Ward, T. B., & Finke, R. A. (1995). *The creative cognitive approach*. Cambridge: MIT Press.
- Su, L. Q. (2002). *The icons of non-logical objects for the visually creative expression in western painting* (Unpublished master's thesis). National Pingtung University, Pingtung, Taiwan.
- Ulrich, K. T., & Eppinger, S. D. (1995). *Product design and development*. New York: McGraw-Hill Education.
- Vygotsky, L. S. (2004). Imagination and creativity in childhood. *Journal of Russian and East European Psychology*, 42, 7-97. doi:10.2753/RPO1061-0405280184
- Wang, Z. S. (2003). *Several problems should be paid attention to in research report*. Hanzhong: Hanzhong Education Center.
- Wieth, M. B., & Zacks, R. T. (2011). Time of day effects on problem solving: when the non-optimal is optimal. *Thinking & Reasoning*, 17(4), 387-401. doi:10.1080/13546783.2011.625663
- Worst, S. J. (2007). *Vygotsky's theory of the creative imagination: a study of the influences on preservice teachers' creative thinking capacities* (Unpublished doctoral thesis). Western Michigan University, Kalamazoo, USA.
- Wu, S. H. (2002). *From manufacturing Taiwan to knowledge of Taiwan (Harvard Business Review on Innovation)*. Taipei: Global Views.
- Xu, M. W., & Bien, S. J. (2002, November). *Consumption experience mode into the design chain store space planning and application: Sakura cooking as a sample*. Proceedings of the Workshop on the Development of Human Factors in Design, Taipei.
- Yu, D. Z., Lin, W. C., & Wang, J. Q. (2001). *Scenario design: new method of product and service design in information age*. Taipei: Ten-Yuan.

**<http://www.ejmste.com>**