The Effects of Imagination on Engineering Design Performance

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INTRODUCTION

The purpose of this study is to verify the imagination effect toward design performance, as well as whether imagination can increase the explanatory power in regard to design performance. Could imagination like creativity be a predictor to design performance? Some reports already showed the importance of design industry value added, like “Get Creative” published on Business Week in 2005 reminded American businesses to pay attention to add the value of traditional commodities, services, and customers ’experience. Through improving, expanding consumer’s experiences of design industry, the British government in 1998 also raised the concept of Creative Economy, and formulated several industrial policies to lead businesses upgrading products and services [1]. In Taiwan, the scale, exports, international competitions, and educations of design industry have contributed and ranked in front of the world. Based on the survey by Taiwanese Ministry of Finance toward design industry, the number of business has increased from 1624 to 2362 for last five years; volume of business also from NTD.2,200 to7,710 and the export volume of business also have increased from 29% to 56%. They all show that the design industry of Taiwan has played an important role in domestic and foreign markets [2].The leading index of international design industry performance: iF, RedDot, IDEA, G-Mark, the total scores also ranked in the top three of Asia, and the top ten of the world from 2005 to 2010. It shows the capability and achievement are affirmed in the design industry of the world. Besides, the numbers of schools, departments in Taiwan also have increased for nearly ten years. In summary, Taiwanese design industry has got attention no matter in schools, government, and in the foreign markets.

Compared to the need of design in practices from the universities, industries, governmental policies, the academic show more interests in the factor of design performance. The design performance comes from the implementation effectiveness of creative process, and design is a creative process as well as a problem solving process [3]. Many studies advocate that design activities via creative process could solve problems and affect the final design performance [4][5]. And confirm that individual creativity can find the problems, develop choices, and solve the problems, thereby achieving the individual’s and organization’s performance requirements [6][7][8].Therefore, design activities rely on creativity to solve problems and improve design performance [9]. In fact, creativity can be viewed as the cognitive activities in the problem-solving process. This cognitive activity includes the process of discovering and identifying problems, and developing solutions [10][11].They especially focus on the early stage of creativity; they found that the early stage of creativity mostly comes from the

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contents structure of the memory, restructuring and conceiving new theories of imagination [12][13][14]. They define imagination as employing the interconnectedness of different concepts and their relationships to achieve creative thinking [8]. In short, creativity and imagination could affect the creative process of design activities. The imagination can explain the creative production processes, and creativity can handle the creative problem-solving activities. However, most research on the imagination focuses on the development of concept-based theories [14][15]. This study takes the perspective of the imagination's combination of concepts in the production of creative activities [15] to clearly define this perspective via the theoretical development of the imagination, and verifies how the imagination can impact engineering design performance. Therefore, based on the above research background and motivation, the purpose of this study is to investigate whether imagination can affect engineering design performance, and increase the explain effect of it.

1. LITERATURE REVIEW

1.1 Creativity and imagination

As previously mentioned, design activity is a process of solving problems. And creativity and imagination could affect design performance. Creativity is a personal exploration process; as a problem-solving process, it involves discovering problems, exercising thinking, finding the answers, and producing finished output. Besides, creativity also involves some outstanding individuals who possess special features and capabilities [10] which enable these individual to produce novel ideas [8].Most of important, it is a personal exploration process [9]; as a problem-solving process, it involves discovering problems, exercising thinking, finding the answers, and producing finished output. In this creativity process, people will use a diffusion mode of thinking to gather useful information, in order to compile and produce new results[10][11].In other words diffusion mode of thinking often apply the behavioural angle employs the diffusion thinking ability to define creativity [9][10].However, Wallas argues that the problem-solving is the latter two stages in creative processes, consists of the stage during which the solution to the problem suddenly appeared to the individual's mind, and others the final stage during which the individual would carry out all the required tests to see if the idea could work. Thus, Wang &Horng argue that problem-solving, creativity is just part of creative process. And it is necessary to look further into the former of creative process [12].Scholars stress that imagination specializes in the cognitive process of creative production [14][15]. And imagination is bound to cognition, which precedes creativity; creativity will result from the process of re-configuring or re-combining concepts [22] with the aim of designing new products or finding solutions to problems. This study addresses the view that the most important and key differences between imagination and creativity are that imagination is limited to the incubation of ideas in the human brain, while creativity not only breeds new ideas in an individual's brain but also entails carrying out all of the activities related to these new ideas, since creativity must has concrete or specific measurements of real outputs. However, creativity is a lengthy and complicated process; for the purpose of obtaining a more sufficient and precise understanding of design performances, it is necessary to separate all of the sub-details for a detailed discussion. Thus, the purpose of this study is to separate imagination, as a concept independent from creativity, and to explore and verify the impact of the imagination's cognitive mechanisms in order to further understand the sub-cognitive processes behind the details of creativity in science and engineering [19][20][21].

1.2 Imagination and engineering design performance

Although imagination and creativity are different in the creative process, how imagination do affect than creativity? The psychological process of imagination involves the expression of combined concepts, i.e., two or more concepts are linked to form a new concept through permutations and combinations from past experiences or images [22][24]. And imagination is the creative ability to combine different concepts, especially in the cognitive process can produce new or creative ideas in science and engineering fields [11]. Linking concepts to produce new concepts explains the creative phenomenon. During the process of concept combination, the individual organizes the original cognitive concept to distinguish these concept's characteristics according to similarity, difference, or overlapping. Concept combination means that the output or interpretation process of creating new concepts is derived via two or more combined known concepts, for example, "jotter" and "computer" will form notebook, and "blind" and "dog" will link to generate guide dogs; so lots of new words or concepts are formed by combining different concepts [20]. In the field of design, if the practitioners or designers can use more creative thinking via conceptual combinations, then they can more easily

break through the factors limiting the scope of innovation [13] and generating new concepts which lead to better performance.

Besides, Campbell argues that imagination contributes to solving problems and is a cognitive process of innovation for handling and adapting to environmental changes [17]. Imagination thus is more than creative thinking skills; it also includes a positive effect on performance results [11][15][21]. Design performance is an output or result of the creative process, and it is also in engineering field[15]. Engineering design performance is the concrete expression in the design activities with imagination in the creative process of product design. The results of the design are also better when imagination thus has the impact of improving design performance [15]. This study verifies the imagination impact on design performance, and stress imagination than creativity effect in the creative process of design performance. After all, the imagination, according to the theory of concept combination, can affect creative design activities and improve design performance [20][21]; the imagination's use of concept combination can break through past creativity limits on design performance [12]. Therefore, this study verifies that imagination can affect the design performance in engineering.

2. METHODS

In the paper, our main purpose is to find out whether imagination has its own effect on designing performance. We measured imagination by a task development following concept combination theory, gathered two-man team data from an creativity competitions and analysis whether imagination cause the difference of design performance.

2.1 Subjects

The subjects were undergraduate students who joined an creativity competitions held by Chung Hsing University in Taiwan, 2013.There are 45 teams got into the semi-finals, which are the subject pool.

2.2 Procedure

The creativity competition is a three stage competition (table 1). We held a workshop for those teams entering the semi-finals. We applied Wang & Horng's [25] imagination test of concept combination (ITCC) to measure imagination of these teams before the workshop. We ask competitors hand over their project plan in two weeks.

Table 1. Work flow of the competition

Stage	Data	Treatments
Preliminary Contest	March 1st to April 20th	Students find out their teammate themselves. Every team is constituted by two students. Every team had to write down a creativity blueprint associated with all three topics, which are cool, playing, and saw. The blueprint was limited to 100 words or an A4-size picture.
Semi-final	April 27th to May 11th	Teams entered the semi-final should participate in a one-day-long workshop. We measure imagination in the workshop. The workshop has four talks about creativity and imagination, design, saws, and cases. After the workshop, competitors had to create a concrete plan with the same topic as preliminary contest.
Final	May 25th	We selected the best 15 teams of those who entered the semi-final. The 15 teams had to present their plan within 15 minute.

2.3 Variables

2.3.1 Imagination

We adopted Wang & Horng's [25] imagination test of concept combination (ITCC) that asks contestants to imaginatively combine two concepts to produce new concepts and record the associative reasons.The scale has 18 questions. Every question has two nouns. The subject has to

create a new concept by the two nouns. Because of time constraint, we occupied 9 items of the scale. In the past research, the task is reliable with 9 items. We average the scores of the teammates as imagination of a team.

2.3.2 Design Performance

The Designing Performance is scoring by three scholars and two design experts. The evaluation indicator constitutes of three aspects: innovation (60%), subject conceptualization and content clarity (clarity, 20%), strategy for competition and creative marketing (competition, 20%). We average the scores of five judges as the design performance of a team. The total scores among five judges showed highly significant positive correlation (table 2). The total scores from five judges showed high consistency.

Table 2. Correlations among five judges

	1.	2.	3.	4.
1. judge 1				
2. judge 2	0.906***			
3. judge 3	0.976***	0.903***		
4. judge 4	0.992***	0.948***	0.983***	
5. judge 5	0.950***	0.992***	0.951***	0.980***

Note: + p < 0.1; * p< 0.05; ** p < 0.01; *** p < 0.001

3. RESULTS

3.1 Correlation analysis

The study used the design score of contestants to verify the relationship of imagination on design performance. This study used Pearson correlation analysis in order to determine whether there was correlation between study variables (table 3). The analysis showed no significant correlation between imagination and design performance (r=0.05，p>0.1), but imagination and the innovation indicator of design performance have a positive significant correlation (r = 0.32, p <0.05).The result presents that contestants have higher imagination, also leading to higher design performance results.

Furthermore, the three valuation indicators (innovation, clarity, competition) of design performance underwent further correlation analysis; we found that innovation (0.71***, p<0.001), clarity(0.86***, p<0.001) and competition (r =0.9***, p<0.001) showed highly significant positive correlation with design performance, and the scores between the three indicators and design performance all show high consistency. Therefore, the three indicators are all relevant in evaluating design performance.

Table 3. Descriptive statistics and correlations among variables

	Mean	S.D.	1	2	3	4	5
1. Imagination	7.38	2.16					
2.Rank grade	0.76	1.18	0.28+				
3.Design performance	73.59	4.30	0.05	0.62***			
4.Innovation	74.07	4.78	0.32*	0.79***	0.71***		
5.Clarity	77.87	3.62	0.17	0.65***	0.86***	0.77***	
6.Competition	69.69	6.41	-0.11	0.37**	0.90***	0.37**	0.59***

Note: 1. + p < 0.1; * p< 0.05; ** p < 0.01; *** p < 0.001

2. Innovation, clarity, competition are the three evaluation indicators of design performance by judges

3.2 Regression analysis

The study adopted regression analysis (table 4) to explore the influence effect of imagination on design performance, and to verify whether or not imagination have prediction and explanatory ability in relation to design performance. Model 1 presents that imagination has no a significant interpretative effect in regard to design performance ($F = 0.233$, $p > 0.1$). Because design performances from total judges have no significant difference, the results are not conforming to expectations. We use the score of the innovation indicators and rank grades as dependent variable to retest the relationship between imagination and design performance.

The model 2 presents that imagination has a significant interpretative effect in regard to innovation score ($F = 5.053$, $p < 0.05$); the adjusted cumulative variance was .084, showing that imagination initially has explanatory power related to design performance. Furthermore, imagination has a significant positive prediction relationship with design performance ($\beta = 0.324$, $p < 0.05$). The model 3 presents that imagination has a significant interpretative effect in regard to rank grades ($F = 4.115$, $p < 0.05$); the adjusted cumulative variance was .069, showing that creativity has explanatory power related to design performance. Furthermore, imagination has a significant positive prediction relationship with design performance ($\beta = 0.302$, $p < 0.05$).Therefore, model 2 and model 3 total shows that higher imagination always leads to better design performance.

Table 4. Regression results

	Model 1	Model 2	Model 3
	β	β	β
Imagination	0.075	0.324*	0.302*
R^2	0.006	0.105	0.091
Adj R^2	-0.019	0.084	0.069
F	0.233	5.053*	4.115*

Note:1. + p < 0.1; * p< 0.05; ** p < 0.01; *** p < 0.001
2. Dependent variable is design performance in model1; Dependent variable is score of the innovation indicators in model 2; Dependent variable is rank grade in model 3

3.3 Logistic regression analysis

The study divided 45 teams into final-team and non final-team, and used T-test to examine whether there is a significant difference between the two groups. The results present that two groups has significant difference in imagination（t=-3.051，p<0.01），the imagination of the final-team（M=8.875）is significant higher than the non final-team（M=6.83）.

The study adopted logistic regression analysis (table 5) to explore the influence effect of imagination on design performance, and to verify whether or not imagination have prediction and explanatory ability in relation to design performance. The results present that the final-team has high performance and the non final-team has low performance. In the overall model fit , $X^2$is significant (X^2=8.079,p<0.01） and Hosmer-Lemeshow is not significant (Hosmer-Lemeshow=4.663,p>0.05). These results presents that the overall model fit is good. In addition, the Wald of imagination is 6.467（p<0.01）,presenting that there is significant association between imagination and design performance . These teams of high imagination have higher design performance and are accepted into the final certainly.

Table 5. Logistic Regression results

Variables	β	S.E.	Wald	Df	Strength of association
Imagination	0.478	0.188	6.467**	1	Cox-Snell R^2=0.164 Negelkerke R^2=0.239
Constant term	-4.733	1.561	9.186**	1	
overall model fit	X^2=8.079** Hosmer-Lemeshow=4.663 n.s.				

Note:1. + p < 0.1; * p< 0.05; ** p < 0.01; *** p < 0.001; n.s. p>0.1

2. Groups accepted into final are high performance groups; other groups are low performance groups

4. DISCUSSION AND CONCLUSION

This study defines imagination in terms of the ability for conceptual combination, and examines the effect of imagination on engineering design performance through a creativity competition. The results show that teams with rich imagination usually achieve better design performance tendency, and the 15 teams that went into the final competition showed higher imagination. This result verifies most scholars' belief that imagination belongs more to the front-end thinking mechanism of creativity, and has a potentially influential effect on creative thinking and activities development [26][27]. Therefore, people with a rich imagination in the creative cogitating stage can also easily associate various special or unique concepts and freely imagine, link and combine concepts to produce new ideas or innovation. Empirically, imagination influences design performance; this result can attest to past non-empirical arguments of imagination theory [28] [29], that imagination does not only exist in cognitive processes [26] [30], and could practically influence tangible outputs or real results. Furthermore, via the results of this study, we can further clarify that the imagination of concept combination can practically impact the results of design performance.

In short, this research contributes to the relational studies in creativity. It identifies a new central role whereby imagination can strengthen traditional creativity research deficiencies in the stage of idea generation and creative incubation, and examine the imagination explanatory power in regard to design performance. However, despite its strengths, this study has some limitations. First, it relies on data from student samples. The results may not be validly extended to other practical field applications. Second, the indicators of design performance following the design contest may exhibit some weakness in relation to objective and practical appraisal. Therefore, results of the study should be retested in other large design or other practical activities. In accordance with the study, engineering design education should emphasize the training on creativity and imagination and include them in professional classes.

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