Creativity Training Programs for Cognitive Components of Creativity

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Abstract: In this study, we identified the cognitive components of design creativity and proposed new training program for cognitive components of design creativity. Five cognitive components of design creativity are fluency, flexibility, originality, elaboration and problem sensitivity. The proposed training program for design creativity cognitive components was composed of five different activities such as making stories, negation, filling black box, sensitization and diverse classification. Each activity of the training program has been devised so that one or two cognitive components are strongly addressed. In this way, this program could be used in helping students considering their individual needs and contexts. Preliminary experimental results indicate that the proposed creativity training program could be useful in design creativity education.

Key words: Creativity Training Program, Design Creativity, Fluency, Flexibility, Originality, Elaboration, Problem Sensitivity.

1. Introduction

It is important to establish a concrete concept of design creativity and to find a distinct cognitive process for design problem solving in education of design creativity. We have conducted research work toward design creativity education so that various underlying cognitive elements and processes of design creativity are identified and then these design creativity elements and processes can be enhanced through training methods reflecting individual learner's cognitive personal characteristics. Visual reasoning capability has been identified as a critical element of design creativity [1], and a design reasoning model obtained from visual reasoning process were devised to investigate the cognitive interaction among elementary steps of visual reasoning [2, 3]. This design reasoning model has been used to study design creativity education and to development of its enhancement program. The study on the design activity was also conducted to identify the critical steps in the design process and to investigate the characteristic patterns of designers based on their personal characteristics [4]. In addition, the studies on design creativity modes have been conducted by investigating the relations among personal creativity modes, perceived creativity and design team interactions [5]. In this paper, the cognitive components of design creativity will be identified, and the new training programs for design creativity components will be proposed. We also developed the conceptual design task to evaluate the design creativity. In addition, the effectiveness of the proposed training program will be validated with experiments.

2. Cognitive Components of Design Creativity

Design creativity is closely related to ideas [6]. Creative products, whether tangible or intangible, can be regarded as the embodiment of 'good ideas'. Although every good idea may not be considered as 'creative', all creative outcome can be traced back to good ideas. Therefore, the design creativity has been often defined in terms of the capacity to produce new or original ideas by many pioneering researchers [7, 8, 9]. Methods with the aim of enhancing design creativity have pursued the promotion and maximization of the generation of ideas [10, 11, 12]. Brainstorming is one example of such a family of methods.

However, design creativity cannot simply be defined by only the capability to produce new or original ideas. It is necessary to further decompose the design creativity into its cognitive elements which are highly related to design thinking ability. In addition, there exists no systematic exercise program to foster design creativity by its cognitive elements. Therefore, it is important to establish a concrete component of design creativity and to find a distinct cognitive process for design problem solving in education of design creativity.

The cognitive components of design creativity have been defined based on Treffinger's creative learning model [13]. The Treffinger's creative learning model encompassed the cognitive and affective aspects. The cognitive aspects in Treffinger's creative learning model are fluency, flexibility, originality, elaboration, and cognition and memory. We replaced cognition and memory with problem sensitivity, and identified five cognitive components of design creativity such as fluency, flexibility, originality, elaboration and problem sensitivity. These five creativity components coincide with those claimed by Kraft [14], and the definitions of each cognitive components of creativity are following.

- **Fluency.** Fluency is an ability to make multiple answers to the same given information in a limited time [15] and quantity of meaningful solutions [16].
- **Flexibility**. Flexibility is an adaptability to change instructions, freedom from inertia of thought and spontaneous shift of set [15]. That is the mode changing categories [16].
- **Originality**. Originality is rarity in the population to which the individual belongs; its probability of occurrence is very low [15, 16].
- **Elaboration**. Elaboration is the realization or transformation of an idea, which may become very general or simple or in contrary very fantastic or enriched into details [16].
- **Problem Sensitivity**. Problem Sensitivity is an ability to find problems [16] and to aware needs for change or for new devices or methods [16].

3. Design Creativity Cognitive Component Training Program

The training program was developed to enhance above five components of the creativity. This program includes 'making stories', 'sensitization', 'negation', 'filling black box' and 'diverse classification'. The specific explanation with snapshots about each training program is presented in Kim et al. [17].

3.1 Making Stories

The 'making stories' asks the students to produce different stories using three different pictures by changing the order of them. Therefore, this activity aims to improve the flexibility mainly. The elaboration can also be developed through this activity by implying cause and effect of given pictures and specifying them. In addition, the originality can be enhanced through the activity to make unique and novel stories.

3.2 Negation

In the 'negation' the students are asked to compulsively and purposely negate the given objects. In this activity, the students are supposed to negate a chair and a shopping basket and make new ideas about them. As a result, the fixed views or ideas on the objects can be broken, and the students can find the different and potential aspects of the objects. In this way, this activity can help to make new objects and transform original objects. This program aims to develop flexibility and originality.

3.3 Filling Black Box

The objective of 'filling black box' is to mainly develop fluency by logically addressing the connections between the given input and output concepts as many as possible within a limited time. This activity can also develop elaboration by explaining the logical relations of input and output concepts that would be hardly associative. The originality can additionally be enhanced by discovering distinctive connections between given input and output concepts.

3.4 Sensitization

In the 'sensitization' the students are asked to express their feelings on the given physical objects and abstract concepts according to five different senses. In this activity, the problem sensitivity can mainly be developed to dig out potential characteristics of the given objects or concepts. In addition, this activity aims to develop the flexibility by describing concrete feelings on abstract concepts from the view of five senses which can hardly be expressed.

3.5 Diverse Classification

The final activity is the 'diverse classification.' In this activity, the students are asked to classify the given objects in several different ways. Therefore, the flexibility can be mainly developed by considering diverse criteria to group the given objects in a different fashion. In addition, this activity aims to develop the problem sensitivity to understand the multiple characteristics of the given objects.

4 Validation Experiments

4.1 Experimental Design

We grouped five activities of the creativity cognitive component training program into two activity sets: activity set A and activity set B. Activity set A was composed of making stories, negation, and filling black box. It is expected that the activity set A improves the participants' fluency, originality and fluency mainly. On the other hand, activity set B contained sensitization and diverse classification, and is expected to mainly enhance the participants' problem sensitivity and flexibility. Figure 1 represents the map between the creativity cognitive

components and each activity. From the map given in Figure 1, we assumed that fluency, originality or elaboration of those who attended the activity set A will be enhanced and problem sensitivity of those who attended the activity set B will be enhanced.

Activities \ Elements	Fluency	Flexibility	Originality	Elaboration	Problem Sensitivity
Making Stories		High	Low	Medium	
Negation		High	Medium		Low
Filling Black Box	High		Low	Low	
Sensitization		Medium			High
Diverse Classification		High			Medium

Figure 1. Relation map between creativity components and each training program

For the confirmation of our assumptions, the experiments were carried out according to the following steps. Firstly, we applied pre-test that could measure the abilities of five components of the creativity to 50 students of the creative engineering design course. Secondly, we classified 50 students into three identical groups. When assigning the students into three identical groups, each group was formed in order for the average scores of five creativity components of each group to be uniform based on the results of the pre-test. In addition, the distributions of gender and grade were uniform for each group. A number of each group was 17, 16, and 17, respectively. The group 1 performed activity set A, the group 2 performed activity set B, and the group 3 was considered as a control group in which none of such activity sets was applied. Thirdly, a week after each group carried out the creativity cognitive component training program; all groups had a conceptual design task as a post-test. The post-test is the design task to produce concept designs of a portable reading device. The procedure of the experiment is summarized as follows:

- Step 1. Conduct pre-test for 50 students to measure the abilities in the five elements of design creativity.
- Step 2. Classify the 50 students into three identical groups based on the results of the pre-test.
  Apply activity set A to group 1, activity set B to group 2 and no activity to group 3.
- Step 3. A week after, each group conducts post-test.

4.2 Pre Test

The pre-test was applied to identify the identical experimental and control groups. The pre-test was composed constructive perception test and mental synthesis test.

4.2.1 Constructive Perception Test

The constructive perception test was performed according to method proposed by Suwa and Tversky [18]. The students were asked to generate and write down as many as possible interpretations on the four kinds of ambiguous picture cards one by one. Four minutes were given to each ambiguous picture. In the constructive perception test, fluency and flexibility of the participating students were evaluated. The number of ideas that the students generated in the constructive perception test were counted and used to evaluate their fluency. The more the counts of ideas, the participants obtained the higher the fluency scores. In the case of flexibility, the categories generated by the students were counted and considered to be their flexibility scores. These categories could be counted by grouping several ideas on the basis of their ideational similarity. Ambiguous pictures used in the test are presented in Figure 2.

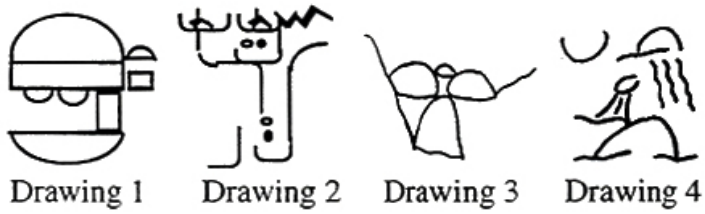

Figure 2. Ambiguous pictures used in the constructive perception test [11]

4.2.2 Mental Synthesis Test

The students were required to memorize fifteen kinds of object parts in Figure 3, and then to generate a meaningful product with three objects in a given category while closing eyes during 2 minutes [19]. Then, they were asked to sketch and describe their product invented in their mind during 6 minutes. In the first section, they should make a transportation vehicle using cylinder, half-sphere, and cross. In the second section, they should make furniture using tube, sphere, and ring for 2 minutes with closed eyes, and they were asked to sketch what they imagined for 2 minutes. And then, they have to make a reasonable explanation on it in terms of a weapon category for 4 minutes.

In mental synthesis test, originality, elaboration and problem sensitivity were evaluated by assessing the results from those two sections. The originality on the generated ideas was evaluated by mainly considering their novelty. In addition, the degree of transformation of the idea from the given object was taken into a consideration as well as the subject judgment on the goodness of the ideas. The assessment of the elaboration on ideas had two folds. In the section 1, the detail of the design thinking and its external presentation were considered as the evaluation criterion. On the other hand, in the section 2, the degrees of development of ideas and their detail as weapons were heavily weighed. In the case of problem sensitivity evaluation, the degree of the appropriateness and fidelity of the answers of each student to given questions was taken were computed by taking the averages of those for two sections.

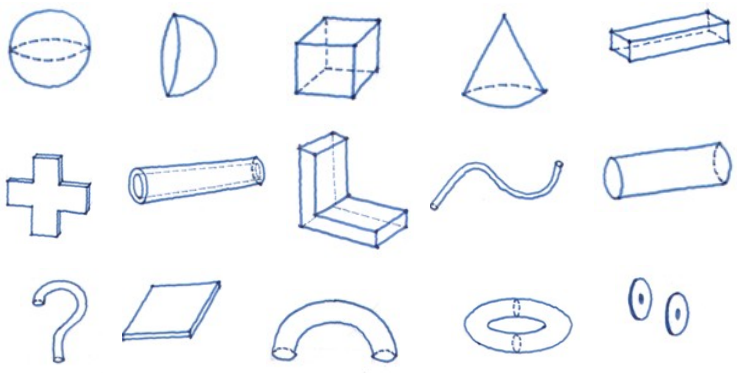

Figure 3. Set of object parts in mental synthesis test [12]

4.3 Post Test

4.3.1 Conceptual Design Task

The post-test is a conceptual design task to design the portable reading device. In assignment 1of the design task, during first 10 minutes, the students had to produce available ideas as many as possible for a portable reading device with given five clues: an accordion, a tape, a hinge, a toilet pump and a steel wire hanger. Then, in assignment 2, they should choose one of the ideas which they generated, and elaborate it with sketching and making detailed descriptions during next 20 minutes.

Similar to the case of pre-test, the evaluations on the results of post-test were conducted in terms of five creativity components. The fluency was measured by counting the number of ideas in assignment 1. In the measurement of flexibility, the categories of generated ideas were counted. In addition, the conceptual distance between the generated ideas and given clues was considered. The originality measure was done by considering the novelty of the ideas in comparison with all other generated ideas and their distinctiveness. In the elaboration measurement, the detail of the developed conceptual design given in assignment 2 was evaluated. Besides, the detail of the usage of the conceptual design that was required to be addressed in assignment 2 was heavily weighed. The problem sensitivity could be evaluated by considering how well the students reflected the issues of users or situations in which the portable reading device was used.

4.4 Results and Discussions

The evaluations on each creativity component in the case of the post-test were conducted by two evaluators. The correlations between two evaluators are good enough for evaluation results to be used for further analysis ($r=.944$, $p<.01$ in fluency; $r=.559$, $p<.01$ in flexibility; $r=.608$, $p<.01$ in originality; $r=.602$, $p<.01$ in elaboration; $r=.644$, $p<.01$ in problem sensitivity).

As results of paired t-test, the scores of fluency ($t= -.298$, $p=.050$) and originality ($t=-3.073$, $p<.01$) of post-test are significantly higher than those of pre-test in group 1. However, the differences between pre and post test were not found in group 2 and 3. Accordingly, it is believed that the increase in scores of fluency and originality can be attributed to the effectiveness of the activity set A of the creativity component training program since it aimed to enhance students' fluency, originality and elaboration. However, we could not find the statistically

significant results in the case of elaboration, although activity set A also aimed to enhance students' elaboration ability.

Activity set B was designed to improve the students' flexibility and problem sensitivity, but no such statistically significant results were found. Therefore, it is necessary to revise the activities in the activity set B. It is also possible to revise the pre test. In pre test, we used the constructive perception and mental synthesis test. However, it was not easy to measure problem sensitivity from the mental synthesis test. Therefore, it may be necessary to develop another pre test, which is similar to post test, conceptual design task, to compare the scores between pre and post tests and furthermore to improve the effectiveness of the design creativity component training program.

5. Conclusion

In this study, we identified the cognitive components of design creativity and proposed new training program for cognitive components of design creativity. This program could be used in helping students considering their individual needs and contexts. Five cognitive components of design creativity were identified, and those are fluency, flexibility, originality, elaboration and problem sensitivity. The proposed training program for design creativity cognitive components was composed of five different activities such as making stories, negation, filling black box, sensitization and diverse classification.

In making stories, the students were required to produce several different stories by changing order of three different pictures. The aim of this activity was to improve flexibility, originality and elaboration. The negation asked students to compulsively negate the given objects and contrive their alternate purpose or usage. Accordingly, the students' flexibility, originality and problem sensitivity could be enhanced. In filling black box, the students were supposed to logically connect given input and output concepts in as many possible ways within a limited time, and as a result, the fluency could be improved. The sensitization asked students to express their feelings on the given physical objects and abstract concepts according to five different senses. With this activity, the problem sensitivity could be enhanced primarily and flexibility secondarily. In diverse classification, the students were asked to classify the given objects in several different ways. Therefore, flexibility was developed and problem sensitivity developed secondarily.

We conducted the validation experiments to investigate the effectiveness of the training program for design creativity cognitive components. The results show that the proposed program was partially effective to enhance the students' design creativity cognitive components, especially fluency and originality in activity set A. More rigorous approach is desired to examine what cognitive components could be effectively addressed in each activity. These research efforts would be helpful for design creativity education by considering individual's needs and contexts.

References

[1] Kim, Y. S., Kim, M. H. and Jin, S. T. (2005) Cognitive Characteristics and Design Creativity: An Experimental Study. In *Proceedings of the ASME International Conference on Design Theory and Methodology*, Long Beach.

[2] Kim, Y. S. and Park, J. A. (2008) Visual Reasoning Model for Studying Design Creativity. In *NSF Workshop on Studying Design Creativity*, Aix-en-Provence.

[3] Park, J. A. and Kim, Y. S. (2007) Visual Reasoning and Design Processes. In *Proceedings of International Conference on Engineering Design*, Paris.

[4] Kim, Y. S., Jin, S. T. and Lee, S. W. (2006) Design Activities and Personal Creativity Characteristics: A Case Study of Dual Protocol Analysis Using Design Information and Process. In *Proceedings of the ASME International Conference on Design Theory and Methodology*, Philadelphia.

[5] Kim, M. S., Kim, Y. S. and Kim, T. H. (2007) Analysis of Team Interaction and Team Creativity of Student Design Teams Based on Personal Creativity Modes. In *Proceedings of the ASME International Conference on Design Theory and Methodology*, Las Vegas.

[6] Goldschmidt G. and Tatsa D. (2005) How Good are Good Ideas? Correlates of Design Creativity, *Design Studies*, vol. 26, no. 6, pp 593-611.

[7] Guilford J. P. (1950) Creativity, *American Psychologist*, vol. 5, pp 444-454.

[8] Vernon P. E. (1989) The Nature-Nurture Problem in Creativity. In Glover J. A., Ronning R. R. and Reynolds C. R. (eds), *Handbook of Creativity*, pp.93-100, Plenum Press, New York.

[9] Eysenck H.J. (1994) The Measurement of Creativity. In Boden M.A. (ed), *Dimensions of Creativity*, pp.199-242, MIT Press, Cambridge, MA.

[10] de Bono E. (1992) *Serious Creativity*, Harper-Collins, London.

[11] Parnes S. J. (1987) The Creative Studies Project. In Isaksen S. G. (ed), *Frontiers of Creativity Research*, pp.156-188, Bearly Ltd, Buffalo, NY.

[12] Isaksen S. G., Dorval K. B. and Treffinger D. J. (1998) *Toolbox for Creative Problem Solving*, Kendall & Hunt, Dubuque, IA.

[13] Treffinger, D. J. (1980) *Encouraging Creative Learning for the Gifted and Talented*, Ventura County Schools/LTI, Ventura, CA.

[14] Kraft, U. (2005) Unleashing Creativity, *Scientific American Mind*, vol. 16, no. 1, pp 17-23.

[15] Guilford, J. P. and Hoepfner, R. (1971) *The Analysis of Intelligence*, McGraw-Hill, New York.

[16] Urban, K. K. (1995) Creativity-A Component Approach Model. In *Proceedings of the World Conference on the Education for the Gifted and Talented*, Hong Kong.

[17] Kim, Y. S., Lee, S. W., Park, J. A. and Jeong, J. Y. (2009) Exercises for Cognitive Elements of Design Creativity, to be presented at *the International Conference on Engineering Design*, San Francisco.

[18] Suwa, M. and Tversky, B. (2001) Constructive Perception in Design. In Gero, J. S. and Maher, M. L. (eds.), *Computational and Cognitive Models of Creative Design*, University of Sydney, Sydney.

[19] Finke, R. A., Ward, T. B. and Smith, S. M. (1992) *Creative Cognition: Theory, Research, and Applications*, The MIT Press, Massachusetts.