Personal Creativity Mode and Design Performances

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Abstract
Personal characteristics such as cognitive styles may have close relations with design creativity. Professor Wilde of Stanford University proposed eight personal creativity modes based on Jungian cognitive theory. It would be interesting to identify the relations among these creativity modes and more specific design performances. Various creativity-related tests were conducted on the students of a freshmen design course at Sungkyunkwan University, including a personal creativity mode test, Torrance test of creative thinking, a brainstorming test, and a visual reasoning test. By analyzing the correlations between these test results and various design assignment performances, the interrelations of personal characteristics and design performances could be studied. This paper will discuss the interrelations of personal characteristics and design performances based on the test results and their implications in design creativity education.

Keywords:
Creative Engineering Design, Personal Creativity Modes, Design Creativity, Team Composition

1 INTRODUCTION

The Creative Engineering Design (CED) course at Sungkyunkwan University (SKKU) is a design course for freshman engineering students. The objective of the course is to educate engineering students the basic design qualities in creative problem solving. The course provides learning opportunities in pursuing design solutions through collaborative efforts of design team work as well as innovative and effective design ideation methods and design presentation skills. The learning is done through several design projects. The curriculum starts with a project for freehand sketching in conceptual design. Next, a Quality Function Deployment (QFD) project, where customer requirements are surveyed and critical design requirements are identified as well as critical parts and part features, is conducted using simple products that are familiar to most freshman-level engineering students such as mechanical pencils. Also a conceptual design project is given where a new product is designed at conceptual level and design presentations and peer critiquing sessions are conducted. Finally, a design-build-test project is conducted where a working prototype is built and evaluated through a competition. Each student of the class will experience various different team work situations, from a single person design assignment to small group quality function deployment project and to bigger group conceptual design project and design-build-test project with all difference compositions of the team members.

In conducting these projects, students acquire learning about the design processes and skills in these processes. Also they have opportunities in learning and using various creative and rational design methods [2]. Furthermore, various tests are performed on students so that personal

characteristics and abilities are measured and utilized in forming design teams. These tests include a personal creativity mode test, learning style test, idea generation test, Torrance test of creative thinking, and visual reasoning test. The personal creativity mode test is the one developed by Professor Wilde of Stanford University based on Jungian creativity theory [17].

By analyzing the correlations between these test results and various design assignment performances, the interrelations of personal characteristics and design performances could be obtained. Furthermore, these results could be used in educating various design qualities for individual student in a more suitable manner reflecting his or her personal aspects. Also, the design tasks in the course could be organized better to make sure all aspects of design tasks closely related with various design creative modes are included. This paper will discuss the interrelations of personal characteristics and design performances based on the test results and their implications in design creativity education. This paper also discusses the team composition aspects using these personal characteristics.

2 VARIOUS CREATIVE-RELATED TESTS

A total of five different tests have been conducted in CED. The outcomes of these tests are used in identifying personal characteristics and performances.

2.1 Personal Creativity Mode Test

The personal creativity mode test is the one developed by Professor Wilde of Stanford University. This test is to be referred to as *Wilde test* in this paper. Wilde test has been used at Stanford in composing design teams in project-based design courses. Wilde test is based on Jungian creativity theory. The personal creative modes are intrinsically related with the personal cognitive preference [17]. Based on the cognitive theory of Jung, personal cognitive preferences can be identified based on four aspects, perceiving/judging preference, factual/ conceptual perception, thinking/feeling judgment, and introverted/extroverted cognitive motivation. With these cognitive preferences, eight different modes of creativity can be identified as shown in Table 1. By further partitioning each mode into two and including two central ones, a total of 18 design team roles have been determined and associated with the personal cognitive preference modes as shown in Figure 1 [16].

In Wilde test, personal preference information on four areas of Introverted/Extroverted (I/E), iNtuitive/Sensing (N/S), Feeling/Thinking (F/T), and Perceptive/Judging (P/J) is obtained. Also from the four area scores, Gough Creative Index (GCI) can be obtained. GCI is a creativity index derived from personal cognitive preference information of well known creative people [4], [15].

At Stanford, Wilde test has been used in composing design teams so that the design team roles are distributed as evenly as possible for all the teams. As a way to verify the utility of this team composition method, they used the design team performances in a typical design competition as reflected in the quantity and the quality of the awards Stanford design teams received [16], [18].

	PERCEPTUAL MODES		RESPONSIVE MODES	
	Conceptual (Intuitive)	Factual (Sensing)	Objective (Thinking)	Subjective (Feeling)
EXTRAVERTED MODES	*Synthesizing*	*Experiential*	*Organizing*	*Teamwork*
NTROVERTED MODES	*Transforming*	*Knowledge-based*	*Analyzing*	*Evaluating*

Table 1: The eight personal creative modes [17]

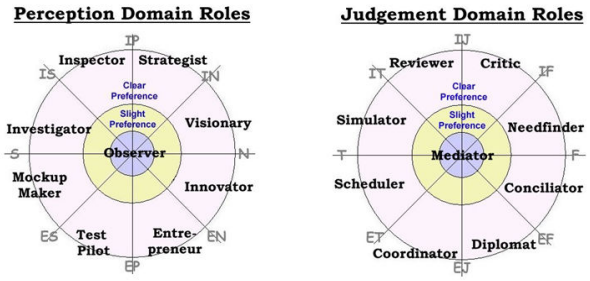

Figure 1: Team Roles [16]

2.2 Index of Learning Style

The Index of Learning Style was developed by L. Silverman and R. Felder to measure the difference of leaning styles of teacher and learner, in an attempt to propose effective learning methods. They divided the learning process into four dimensions: Perception, Input, Processing, and Understanding. 16 learning styles can be defined by combining contrasting tendencies in each dimension. That is, the perception dimensions with Sensory/iNtuitive (S/N), input dimension with Visual/Auditory (V/A), processing dimension with aCtive/Reflective (C/R), and understanding dimension with seQuential/Global (Q /G) tendencies.

2.3 Torrance Test of Creative Thinking

Torrance Test of Creative Thinking (TTCT) is a creativity test based on the divergent thinking creativity theory of Guilford [5]. TTCT tests creativity using 5 norm-referenced measures (fluency, originality, abstractness of titles, elaboration, resistance to premature closure) and checklist of 13 creative strengths, criterion-referenced measures [12], [13]. TTCT is composed of figural and verbal portions. The figural portion of TTCT has been conducted in CED.

2.4 Visual Reasoning Test

The ability of a design engineer to visualize and reason about geometric aspects of physical objects and processes is crucial to the success of their professional activities. The essential relation between design creativity and visual reasoning has been argued by many design educators [8] and creativity researchers. Udall argued that the capability to see and integrate objects in various viewpoints (the lifting operation in mathematical jargon) is a decisive factor for design creativity [14]. More recently, constructive perception, the ability to coordinate perception of subtle features and relations in the external environment and conceptual generation of ideas and interpretations, has been proposed to form the foundations for design creativity, and this ability was measured by the capability of generating many interpretations of ambiguous drawings with some missing elements [11]. We believe there are common aspects in constructive perception and visual reasoning processes.

As a way to test the student's capability in visual reasoning before they receive any form of education on the matter, we conducted a simple test composed of relating orthographic projections and pictorial projections of polyhedral solid objects. For example, so-called missing view problems have been given to the students without much explanation on how to solve the problems but with a very general introduction on perspective projection and orthographic projections. We wanted to test the student's uneducated visual reasoning capability as we tested their brain bias and personality. The missing view problem requires visually constructing a valid 3-D solid object by visually analyzing two 2-D orthographic projections, and forms the foundations of visual reasoning processes (See Figure 2. for an example of missing view problem). Though not used in CED course yet, we are developing an intelligent tutoring system for visual reasoning so that a self-paced adaptive learning of visual reasoning can be possible [7].

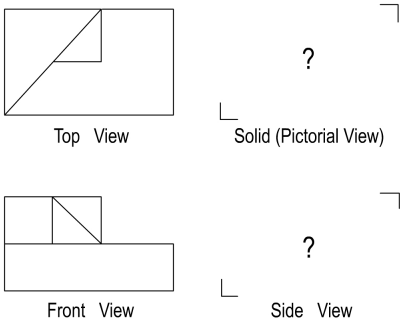

Figure 2: Example of a Missing View Problem

2.5 Idea Generation Test

The test of Idea Generation (IG) is conducted to examine associate relation between personal idea generation capability and other tests. Before the test, we provided the students with lessons on several idea generation methods.

SCAMPER

SCAMPER is a kind of check list method. Check list for idea generation is originated by Prof. Alex Osborn at California University [9]. Basic principle is making a table of checking and to inspect each other. Bob Everle advanced it and devised new idea generation method. [3] SCAMPER theory is based on the assertion that newness is from arranging and adding something to old thing.

This training is given to students for enhancing verbal idea generation technique. There are 7 keywords given for idea generation.

- S: Substitute
- C: Combine
- A: Adopt
- M: Modify-magnify-minify
- P: Put to other use
- E: Eliminate
- R: Rearrange-reverse

Mind map

The mind map originated by Tony Buzan is based on radiant thinking [1]. In spite of drawing on 2 dimensions paper, mind map actually expresses multi-dimensionality consisted of the factors, space, time and colors. In point of using both text and picture at the same time, this method contributes to activation of thinking for idea generator. The merits of this method are not only expanding of association abilities but also utilizing whole function of the cerebral cortex. Process of mind map is composed of preparation mind map, central image, main trees and sub trees. Especially, this training is given to students for helping figural idea generation. In actual test, we used the Brain Drawing substitute on mind map for efficiency of idea generation evaluation.

Figure 3: Verbal Idea Generation by SCAMPER

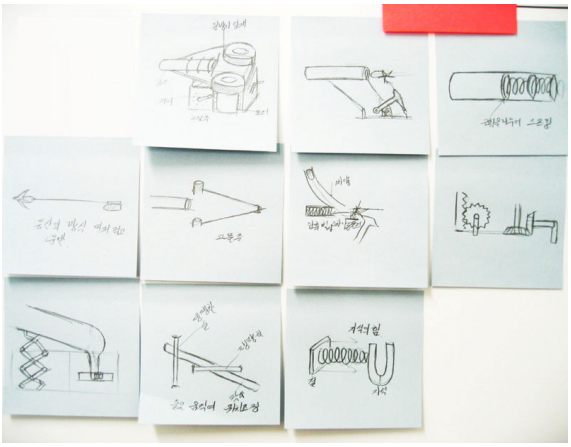

Figure 4: Figural Idea Generation by Brain Drawing

3 TEAM FORMATION METHODS

In composing the design teams in a class environment, there is a principle to be abided by, though it may present obstacles in understanding the effects of team composition methods. Pedagogical aspects have higher priority than research aspects. As all the class activities are related with their course grades, we can not intentionally control the team formation as needed to identify some findings. Thus for all deliberate team formation cases, we made our best efforts to compose the teams so that all the teams are evenly well-composed.

Among the given design-oriented assignments, QFD, Concept Design, and Design-Build-Test project were conducted as team projects. Each team was composed of four to six students, and the team formation was determined before they carry out the assignments.

QFD teams were formed in a random manner based on the seating order in the lecture room. The formation of the Concept Design teams was determined by the PCMT result. Thus, each possible leader was assigned to each team first, and then, the balanced variety of the rest members was of main concern. Teams for the Design-Build-Test project were formed based on the ILS as well as the PCMT result, so that a variety of different leaning style students can be mixed. The purpose of such team formation is to find out whether the character of the team takes effect on the quality of the assignment outcomes.

4 EXPERIMENTAL METHOD

4.1 Participants

The experiments used in this paper were conducted in the CED class of 2004 fall semester. 55 students participated in the experiments in total. Except for 3 students who failed to carry out the assignment properly, all other 52 students' data were used for the analysis. In addition, 2 students' data were excluded form the ILS-related analyses as they did not take the ILS test.

4.2 Tasks and Processes

Students went through 5 kinds of tests such as IG, PCMT, TTCT, VRT, ILS, and performed 5 design-oriented assignments such as Road Map, Concept Design, Design-Build-Test project, QFD, and 3D Puzzle. Their procedures are as follows:

Psychological Test

IG – This test was done team by team, and these teams were identical with those who had conducted the Design-Build-Test assignment. Independent test was performed both in verbal and figural areas, and 30 minutes were given for each test. The SCAMPER and Brain Drawing method were used, where students used *post-it* to draw or describe theirs ideas on it, and put it on a big foam board. Figure 3 shows a sample of performance by SCAMPER and each independent idea described in word or short sentence on tiny and colorful post-it. Also figure 4 shows a sample of performances by Brain Drawing. Square type and middle post-it are used and each idea is drawn on it with some explanatory remarks. The number of *post-its* was counted for each team as indicating the amount of ideas.

TTCT – Only the figural test was done over the verbal test, and the given test time was 30 minutes. A group test method was used, where all 55 students took the test, gathered in a single lecture room.

PCMT – Each single student took the test using the website without the time limit. The student could verify his/her PCMT result after answering 40 questions.

VRT – Each student was asked to solve 4 Missing View Problems in 20 minutes. The student was asked to draw the pictorial view and side view of each problem with pencil and paper.

ILS – Students marked on the suitable items from the given 44 questions. The test was taken in a group, and 15 to 20 minutes were given to them depending on the test speed.

Design Assignments

Concept Design – 11 teams were formed in total, and 5 to 6 students were assigned to each team. Each team chose its design theme autonomously, and developed the design concepts using IG, QFD, and etc. Four weeks were given to complete the assignment.

Design-Build-Test Project – Each team was composed of 5 to 6 students, whose task was making a mini cannon. The cannon was actually used in the shooting contest at the end of semester. Both operational mechanism and design quality were considered for the evaluation criteria.

Road Map – Each student made a road map to his/her house in this individual assignment in a half of week. The intent of the assignment is to train students in designing and using visual information as well as non-visual information.

QFD – Each team was composed of 4 to 5 students, and they were asked to complete the QFD through two phases of work. They investigated the user requirements in the first phase, the second phase was to figure out the technical aspects of them, and results from previous stages are synthesized into a final QFD in the third phase. It was a team-based project, and three weeks of completion time was allowed.

3D Puzzle – It is an assignment to design and make prototype a puzzle toy. The puzzle set should be structurally stable enough and present a suitable fun for small children. One week was given to complete the assignment.

4.3 Results

In finding interrelations of the experiments results, we used statistical methods using correlation coefficient analysis, average scores, and some specific results with distinctive characteristics.

Analysis of Individual Scores

We examined the correlations between all the psychological test results and assignment scores conducted in the CED course in order to find out the relations between psychological characteristics of the students and performances of design-oriented assignments. The correlation between IG, TTCT, PCMT, VRT, and ILS, all of which have strong relation to the psychological characteristics of individuals, and design-oriented assignments are shown in Table 2. The assignments used in the analysis are Concept Design, Design-Build-Test project, Road Map, QFD, and 3D Puzzle.

	GCI	Road Map	Con. Design	Design Build	QFD	3D puzzle	VRT	TTCT	IG (verb.)	IG (fig.)
GCI	1					**-.519**				
Road Map		1			**-.293**				**.329**	**.361**
Concept Design			1							
Design Build				1	**-.284**					**.281**
QFD					1					
3D Puzzle						1		**-.281**		
VRT							1			
TTCT								1		**.280**
IG(verbal)									1	**.282**
IG(figural)										1

Table 2: Correlations between psychological test scores and design-oriented assignment scores

The highest correlations were found between Road Map assignment and IG (verbal) and between Road Map assignment and IG (figural). Their scores are .329 and .361 each.

Creative and unique ideas were counted important in the evaluation for the Road Map assignment. Thus, the result shows that those who generate more ideas are likely to come up with unique ideas in most cases.

The correlation between Design-Build-Test assignment and IG (figural) was relatively high with the score of .281. This result supports the general assumption that the figural idea generation is important element to successfully perform the Design-Build-Test assignment. Note that the IG (figural) was done for the Design-Build-Test project.

In addition, the result showed that there are correlation between total Creativity Index (TTCT) and IG (figural) (.280), and also between IG (figural) and IG (verbal) with the score of .283. The correlation result between TTCT and IG (figural) can be natural considering the fact that only the figural part of the TTCT was conducted in this research.

Negative correlations were also found in some parts in addition to the positive ones. Highly negative correlation between GCI and 3D Puzzle (-.519), and also negative correlation between TTCT and 3D Puzzle (-.281) are among those. This result explains that the higher the GCI and TTCT scores are, the worse the students perform in the 3D Puzzle assignment, and vice versa. In fall 2004, the grade of 3D Puzzle was done in a manner where those conform to some design constraints got better scores. Moreover, inverse correlation was found between Design-Build-Test project and QFD assignment (-.284). The essence of the QFD assignment is to find out associated design requirements based on thorough investigation of user requirements, to perform relative analysis on related products, and to examine the characteristics of their parts. Therefore, it is an analytical phase design assignment which requires knowledge-based creativity and analyzing creativity. On the contrary, the Design-Build-Test project requires experiential creativity which is more related to the actual production and operation. Accordingly, it may require for a single person to have two distinct abilities in order to be able to conduct both assignments with ease. In reality, however, most of people tend to have only one side over the other. This may be the reason for the inverse correlation to appear between Design-Build-Test project and QFD assignment.

As described in previous investigations on the correlations between personal styles and design oriented assignments, those design abilities such as QFD, 3D Puzzle, and VRT which are closely related to the design creativity, were turned out to have no correlations with general creativity indices such as GCI and TTCT, or even to have inverse correlations. This result proves that general creativity indices such as GCI and TTCT may not indicate the level of design creativity. Therefore, design

creativity requires more variety of abilities than general research assumptions which limit the elements of creativity to the richness of imaginations or divergent thinking ability.

Analysis of Group Scores

We conducted an analysis to find out which style group performs better in which assignment after grouping the students based on PCMT and ILS test.

First, groups were formed according to the similarity of PCMT types, and we analyzed the relations between types and assignment performance. Table 3 shows each PCMT type and average assignment scores for each type. The line graphs of Figure 5, 6, 7 give a better understanding of this comparison. As shown in Table 1, there are 8 types of PCMT. Only 6 types of students were found in this research, however, as shown in Table 3.

In PCMT types, synthesizing type gained the highest GCI score, and the knowledge-based type did the lowest. This result seems to be natural considering the fact that innovator has something to do with the synthesizing type, while the Investigator belongs to the Knowledge-based type.

On the other hand, knowledge-based type and analyzing type gained the highest VRT scores. This result explains that the VRT requires logical thinking and analytic ability. Knowledge-based type got the lowest score in the Design-Build-Test project, but did the average score in Concept Design. This reflects that the Concept Design requires more investigator ability than the Design-Build-Test project. The fact that the synthesizing-type and analyzing-type got high points in Concept Design assignment explains that the Concept Design assignments require ability to devise something new as well as ability.

In addition, the major mode and minor mode of individual student in PCMT were investigated to identify relations of personality mode and assignment ability of individuals. The distribution of personality modes of all students, that participated in this experiment showed; that there was more introvert mode than extrovert mode(70% .vs. 30%), more intuitive mode than sensing mode (74% .vs. 26%), and more feeling mode than thinking mode(82% .vs.18%). The analysis was done with students, whose marks were within the top 10% in all assignments, and it was identified whether there were specific personality mode patterns in them or not. But there were not any specific personality mode patterns. That is, regardless of assignments, most of students had intuition mode and feeling mode, and only a few students had sensing mode and thinking mode.

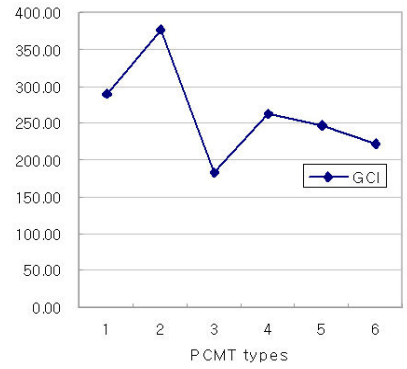

Figure 5: Comparison of GCI scores for PCMT types

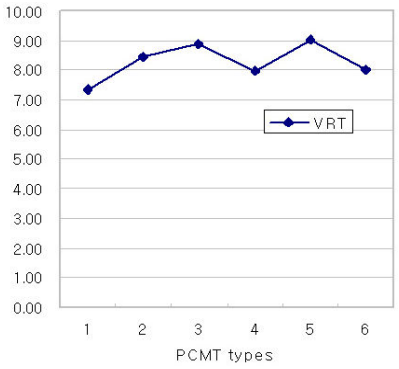

Figure 6: Comparison of VRT scores for PCMT types

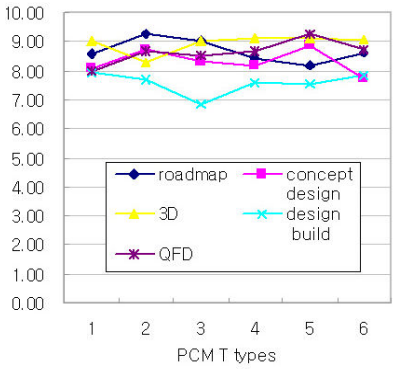

Figure 7: Comparisons of Design assignment scores based on PCMT types

	PCMT type	N	GCI	Road map	Concept Design	Design Build	QFD	3D	VRT	IG (verbal)	IG (figural)	TTCT	fluency	Originality	Abstractedness of title	Elaboration	Resistance to premature closure
1	TRANSFORMING	7	290.00	8.57	8.10	7.93	7.97	9.00	7.36	19.29	9.00	58.43	59.71	69.43	38.71	79.86	17.43
2	SYNTHESIZING	8	377.38	9.25	8.71	7.70	8.66	8.27	8.44	18.88	9.00	67.38	52.00	61.38	45.00	82.13	21.00
3	KNOWLEDGE	3	182.33	9.00	8.33	6.83	8.50	9.00	8.88	18.00	7.00	66.00	58.00	35.33	34.00	99.00	23.33
4	EVALUATING	24	262.54	8.42	8.17	7.59	8.66	9.09	7.96	18.42	7.33	52.54	53.21	59.29	25.29	82.75	16.29
5	ANALYZING	5	247.20	8.20	8.85	7.56	9.24	9.12	9.04	17.60	9.60	56.40	59.60	55.80	35.40	83.60	18.00
6	TEAMWORK	5	221.20	8.60	7.75	7.84	8.74	9.04	8.00	22.00	8.60	61.40	71.00	61.40	34.80	86.20	11.20

Table 3: Assignment Scores for different PCMT types

However, there were also meaningful results. Among students that had introvert mode and thinking mode (GCI<200), 8 people carried out 3D (3 people) and VRT (5 people) well, on the other side only 2 people did concept design (1 people) and QFD (1 people) well. On the contrary, among students had extrovert mode and feeling mode (GCI>350), 7 people carried out concept design (3 people) and QFD (4 people) well, on the other side only 2 people did 3D (none) and VRT (2 people) well. I think that this result is not concrete enough to explain the relations between PCMT modes and assignment abilities. Through further researches more data will be gathered, we would be able to clarify which PCMT modes are suitable for which specific design assignments.

Table 4 shows the comparative analysis of ILS styles and scores for each style. Comparison between different perception styles shows that the iNtuitive group got higher scores than Sensory group as shown in Figure 8. This result shows that intuition people usually has higher creativity index than those who use sensory in term of obtaining information. This kind of pattern appears also in the relations to the Creativity Index as illustrated in Figure 9.

	type	N	GCI	Road map	concept Design	Design Build	QFD	3D	VRT	TTCT
S-N comparison	S	33	251.52	8.58	8.30	7.73	8.55	9.01	8.31	55.91
	N	17	314.53	8.71	8.39	7.50	8.87	8.81	7.76	58.18
G-Q comparison	G	31	279.65	8.68	8.36	7.65	8.56	9.06	8.23	58.32
	Q	19	272.94	8.62	8.33	7.65	8.66	8.74	8.12	56.68
average		50	272.94	8.62	8.33	7.65	8.66	8.94	8.12	56.68

Table 4: Comparison between S-N & G-Q scores From ILS types

The comparison in terms of information understanding dimension shows that Global style learners who prefer global and multiple learning style got highest GCI and TTCT scores than seQuential style learners who prefer successive and step by step learning style. Thus, it can be said that the Global style learner has higher general creativity. There were no significant differences of the performance score of design assignments in terms of leaning style as shown in Table 4.

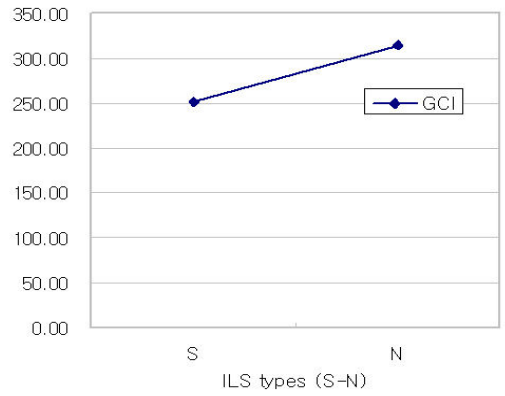

Figure 8: Comparison of GCI scores for the ILS(S-N) type

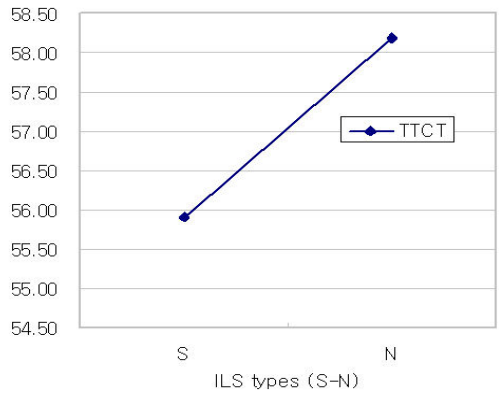

Figure 9: Comparison of TTCT scores for ILS(S-N) type

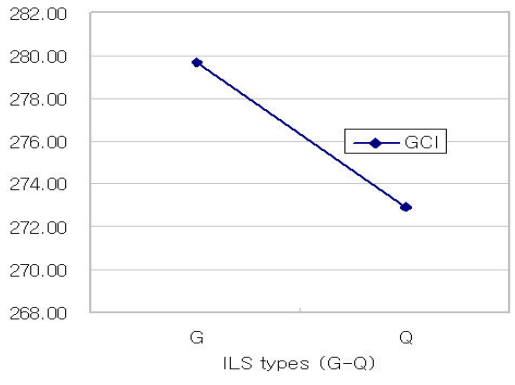

Figure 10: Comparison of GCI scores for the ILS(G-Q) type

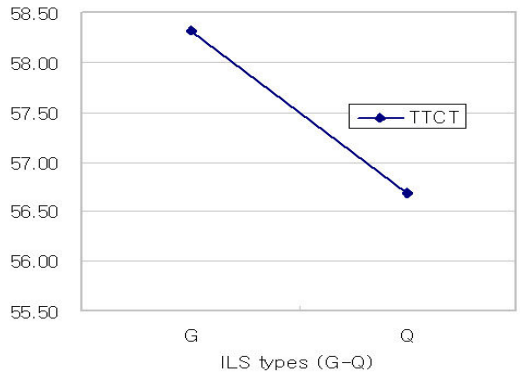

Figure 11: Comparison of TTCT scores for the ILS(G-Q) type

5 TEAM COMPOSITION AND DESIGN PERFORMANCE

By using the performance results of the QFD project for which teams were composed in a random manner, the utility of the team composition methods using PCMT can be justified. Note that random team composition is the typical method used in most other design courses. The missing design roles of the QFD teams of the CED course are shown in Figure 12 for only the teams with high or low performance scores. That is teams that cover the 4 or 5 roles out of 16 roles got high scores from QFD assignment, while teams that cover only 3 roles got low score.

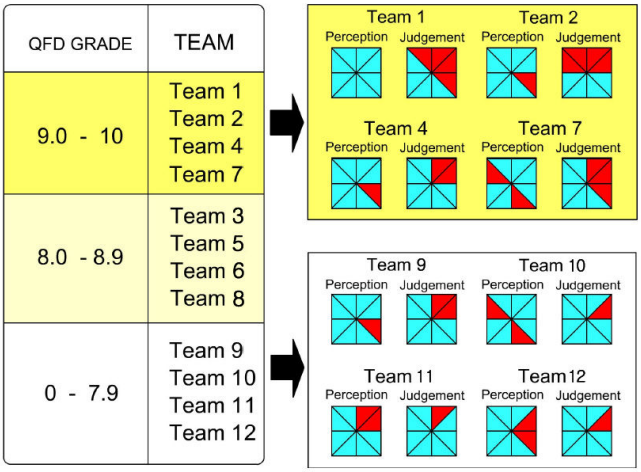

Figure 12: Result of QFD

Following is the analysis to figure out the relations between team roles and the performance scores of Concept Design and Design-Build-Test assignments. Both are team-based assignments, where each team is formed based on PCMT result so that the number of roles in a team should be well balanced. Interesting findings could be obtained from the team scores: the more the number of roles is, the higher the score is. This tendency can be found in both assignments. Note that the slight differences between the teams are due to the effort to form the teams as evenly as possible.

Concept Design Grade	Team	Number of Roles	Average
9-10	Team1	5	
	Team8	5	
	Team9	5	5.00
8-8.9	Team2	5	
	Team4	4	
	Team10	5	4.66
7-7.9	Team3	4	
	Team5	4	
	Team7	5	
	Team11	5	4.50
6-6.9			
0-5.9	Team6	4	4.00

Table 5: Relation between the grade of Concept Design and the number of roles

Design-Build-Test Grade	Team	Number of Roles	Average
8-8.9	Team3	4	
	Team5	4	
	Team6	4	
	Team7	4	
	Team9	3	3.80
7-7.9	Team2	3	
	Team4	3	
	Team8	3	
	Team11	4	3.25
6-6.9	Team13	4	3.50

Table 6: Relation between the grade of Design-Build-Test project and the number of roles

6 SUMMARY AND CONCLUSIONS

We have described the findings on various personal characteristics test results and design performances of a freshman level design course as well as our experiences in composing teams using personal characteristics. The analysis results have implication on desired personal characteristics and creativity modes for some specific design tasks. For the tasks that require careful explanation, the elaboration aspect of TTCT is related. In producing a large quantity of ideas in a limited time frame while following given rules, those with high Design-Build-Test project grade or those with high TTCT creativity index perform better. In addition, it is noticeable that highly negative correlations exist between GCI and 3D Puzzle, and between TTCT and 3D Puzzle. This result implies that only the general creativity index is not enough to explain design creativity. That is, the design creativity consists of logical and analytic thinking as well as spatial perception ability in addition to general creativity which is usually represented by divergent and unique thinking.

We have confirmed that team composition methods using personal creativity modes are useful and the design roles associated with the personal creativity modes are justifiable at least for some subset of the design roles. These results could form a foundation to develop design education strategies and methods. We envision that methods to enhance specific design creativity modes suitable for specific design tasks could be devised based on further findings of the relations between design performances and personal characteristics.

In sum:

1. The ability of idea generation is related with the Design-Build-Test project grade or those with high TTCT creativity index.
2. Highly negative correlations exist between GCI and 3D Puzzle, and between TTCT and 3D Puzzle.
3. Some PCMT modes are suitable for some design assignments. For example, knowledge mode and analyzing mode are suitable for VRT.
4. Team composition methods using personal creativity modes are useful. The design roles associated with the personal creativity modes are justifiable at least for some subset of the design roles.

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