EMOTIONAL ORIENTATION AND CONTEXT ANALYSIS FOR DESIGN CREATIVITY EXERCISE TEST

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ABSTRACT

An exercise program addressing cognitive elements of creativity was devised so that personalized needs in specific elements could be addressed. The exercise program provides users with an opportunity to enhance the creativity in a personalized adaptive manner with regard to five cognitive elements: fluency, flexibility, originality, elaboration and problem sensitivity. Dynamically changing affective states are considered related to contexts in the program and an affective modeling was presented in this regard. The effectiveness of the exercise program was evaluated by using conceptual design tasks, in the form of pre-test and post-test. It was reported, 70% of students achieved enhance in design creativity. Further mining on the log data indicate the enhanced design creativity is reversely associated with negative affective states. In addition, a framework of processing natural language was introduced for estimating emotional orientation from text. It was observed that emotional orientations tend to be context-dependent and the positive emotional orientation appears when users achieve enhance in design creativity. The framework promises its application to affective modeling.

Keywords: Design Creativity, Cognitive Elements of Design Creativity, Conceptual Design Task, Data Mining, Emotional Orientation, Natural Language Processing

1 INTRODUCTION

Human creativity involves diverse aspects. Creator's personal characteristics could be one aspect, which can then be further decomposed into cognitive and affective parts. In adition, processes of creation activity could be another aspect. While creativity is a comprehensive notion in general, creative design processes could be discussed and studied with a little more specific viewpoints.

As in general creative activities, design process involves both divergent and convergent thinking processes. Promotion and maximization of the generation of ideas were pursued for enhancing the design creativity [1, 4]. While both vertical and lateral thinking approaches have been identified as used by designers [2], a recent research showed the importance of the limited commitment mode control strategy in creative designing capabilities [5].

Design creativity cannot simply be defined by only the capability to produce novel and useful ideas. Therefore, it is important to establish concrete components of design creativity and to find distinct cognitive processes for design problem solving so that education of design creativity could be attempted based on these. It is meaningful to further decompose the design creativity into its cognitive elements that are highly related to design thinking ability. Furthermore, it would be desirable if there exists a systematic exercise program to foster design creativity addressing those cognitive elements.

In addition, it is important to devise a mechanism of handling human affective states that are involved in creative design processes. Affective parts of creator's personal characteristics are dynamic in a sense that the affective states change according to various contexts. The experiences of emotion become affective states and the experiences are encoded in human behaviors, such as human speech and writings. The emotion encoded in human wording would be reflected in the words that contains meaning and semantics with regard to contexts. In the design community, the linguistic construal of emotions and attitudinal positions was computed from natural language design text. And, overall semantic orientation was presented in the study [8]. Indeed, extraction of emotions from short texts became possible by using publically opened databases, such as WordNet [15, 16]. Also, statistical natural language processing addresses ambiguity of human languages based on probabilistic and stochastic methods.

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. In our previous work, we investigated the characteristic patterns of designers based on their personal characteristics called the personal creativity modes [6]. Furthermore, we propose a framework of estimating emotional orientation using SentiWordNet [15] which was built based on WordNet [14]. With the framework, emotional orientations of texts are estimated and analyzed against contexts.

The rest of the paper is organized as follows: The cognitive elements of design creativity are presented in Section 2. The creativity exercise program and an affective modeling are described in Section 3. A framework of estimating emotional orientation is introduced in Section 4. The design creativity evaluation method is presented in Section 5. Results and discussion, and concluding remarks are in Section 6 and Section 7 respectively.

2 COGNITIVE ELEMENTS OF DESIGN CREATIVITY

In the study, the fundemantal cognitive elements of design creativity were devised and were used throughout the designed exercise test, and pre-/post-test experiment. The cognitive elements of design creativity have been defined based on Treffinger's creative learning model [9]. 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 elements of design creativity such as fluency, flexibility, originality, elaboration and problem sensitivity. The definitions of the cognitive element of creativity are the following:

- **Fluency** is an ability to make multiple answers to the same given information in a limited time [3] and quantity of meaningful solutions [10].
- **Flexibility** is an adaptability to change instructions, freedom from inertia of thought and [10].
- **Originality** is rarity in the population to which the individual belongs; its probability of occurrence is very low[3, 10].
- **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 [10].
- **Problem Sensitivity** is an ability to find problems [10] and to aware needs for change or for new devices or methods [3].

Table 1. Relation map between creativity elements and creativity exercise test

	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

3 CREATIVITY EXERCISE TEST AND AFFECTIVE MODELING

3.1 Five Tasks of Creativity Exercise Test

We devised a creativity exercise test, which fosters the enhancement of cognitive aspects of the design creativity, grounded on the definition of cognitive elements of design creativity in Section 2. The creativity exercise test consists of 5 tasks, as shown in Figure 1, that differ in the level (high, medium, and low) of addressed cognitive elements, as presented in Table 1.

Figure 1. Five online tasks of the cognitive elements exercise test: Making Stories (a), Sensitization (b), Negation(c), Filling Black Box(d), and Diverse Classification(e)

We hypothesized that the enhancement of underying cognitive aspects of design creativity can be achieved by the creativity exercise test which consists of 5 tasks with the addressed cognitive elements. The details of the 5 tasks of the creativity exercise test are as follows:

(1) Making stories: The 'making stories' exercise 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 cognitive element. The elaboration element 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.

(2) Negation: In the 'negation' exercise, 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) 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 times as possible within a limited time. This activity can also develop elaboration by explaining the logical relations of input and output concepts. The originality can additionally be enhanced by discovering distinctive connections between given input and output concepts.

(4) Sensitization: In the 'sensitization' exercise, 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.

(5) Diverse classification: The final activity is the 'diverse classification' exercise. 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 given objects.

3.2 Affective Modeling

In order to measure dynamic characteristics of learners, and to investigate its relationships with the 5 cognitive elements, we incorporated affective modeling in the creativity exercise test.

Figure 2. Affective modeling with eight emotion elements

In the context of computer-assisted learning context of creative design capabilities, affective modeling of learners is being done using self-reporting format. Affective elements composed of joy, acceptance, joy, acceptance, apprehension, distraction, sadness, boredom, annoyance, and anticipation were identified based on the basic emotion categories proposed by Plutchik [11], which were used in the affective modeling of the study. The online form of dialog representing all the affective elements was devised and presented to learners so that the participants can select one or more affective states during the experiment. Note that the affection capture diagram uses identical icons so that other influences than affective state selection could be isolated in the interaction of the diagram and the users as the diagram pops up and prompts affective state selection.
We conducted the online creativity exercise test with the affective model that is displayed to learners for selections. While students conduct the exercise test, they are asked to self-report their affective states using an affective model diagram as shown in Figure 2. The affective self-reporting was displayed to users at three checking points: (1) after the learning objectives were given, (2) after the specific problem statements were given and (3) after the student problem sessions were done. This is to reflect the changes of user affective state in our data collection once users are done with tasks. Domain experts were involved in the decision of the data collection points.

4 A FRAMEWORK OF ESTIMATING EMOTIONAL ORIENTATION

The log collected from Creativity Exercise Test contains various user activity data. User text input in Korean sentences/phrase contains explicit/implicit information about not only answers to questions in the test but affective states throughout the test. As in [8, 16], computation of emotions and semantics is applicable to various cases and provides fairly high accuracy in its meaning. Emotional orientation in the user input sentence would embrace an overall collection of affective states, indicating a representative orientation of emotion.

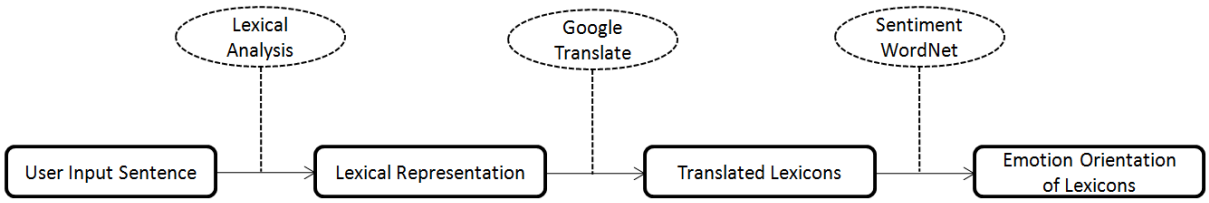


Figure 3. A framework of estimating emotional orientation of user text input

In the study, we transformed the Korean user input sentences/phrases into a set of English lexicons for the analysis of emotional orientation. Total 340 user input sentences/phrases by 25 participants were used in this regard. In the analysis phase, 25 participants were selected because they completed and filled out all the necessary tasks for text input activities while conducting Creativity Exercise Test.
Figure 3 depicts a sequential framework, presenting the analysis procedure of handling user text inputs for estimating the emotional orientation. Each step of the procedure is an independent task and eventually all the sequential steps were automated throughout the procedure. The steps are organized in the following:
(1) Acquisition of user input sentences: Creativity Exercise Test is a web-based program and consists of five main tasks and an affective modeling pop-up. In each task, the participants type in answers to questions in Korean. All the user input sentences used in the analysis were from the data collected during the five tasks. With the affective modeling pop-up, the participants select one of suggested emotions from a set of radio buttons.
(2) Lexical analysis on user text input: For the lexical representation of user input sentence, we utilized a Korean lexical analyzer and databases constructed by the institution of Bank of Resource for Language and Annotation (BORA) [12]. BORA is supported by Korea Science and Engineering Foundation (KOSEF) and Korea Ministry of Science & Technology. The lexical analyzer is capable of handling the units of a Korean language based on both lexicology and morphology, such as words, morphemes, and affixes. The units are generated by applying pre-processing, morphological analysis, and post-processing. In the study, only adjectives and nouns from the lexical representation were used for the analysis purpose, and the duplicated words were eliminated in the process. Table 2 presents a

lexical representation of a sample user text input, and the extracted lexicons (adjectives and nouns) for the presentation purpose.

(3) Translation of lexicons: We extracted only adjectives and nouns from lexical representations of the 25 participants' data. And, the extracted adjectives and nouns were translated by the Google Translate service [13]. The Google Translate API was called for translation of each word, and a post-processing method was done manually for filtering out unwanted words, such as function words, articles. In addition, we manually transformed the plural form into the singular form for better translation before performing the translation service.

(4) Estimation of emotional orientation: 'Wordnet 3.0' is a latest lexical database of English developed Princeton University [14]. It contains unique strings of noun (117798), verb (11529), adjective (21479), and adverb (4481) in the WordNet 3.0 database. In the study, we utilized a modified version of WordNet3.0 for estimating emotional orientations. The modified version of WordNet is called 'SentiWordNet' developed for sentiment analysis and opinion mining [15]. Another study using the SentiWordNet reported that there was accuracy of 60.6% for predicting positive emotion and 72.8% negative emotion respectively, when applied to MySpace comments [16]. We applied the database of SentiWordNet to estimate positive and negative emotions of words (adjectives and nouns); the used words had been generated in the translation phase of the previous step. For the application of sentiment database to the collected lexicons, we selected the first one of the sentiment scores of each adjective/noun. By doing this we simplify the whole procedure and expect to reduce error rates as we process more data.

Table 2. An excerpt of emotional orientation estimated from a sample user text input

User Text Input	**Lexical Analysis on User Text Input**	**Extracted Lexicons**	**Translated Lexicons**	**Emotional orientations (P: Positive, N:Negative)**
기쁜 감정을 주체하지 못한 나는 창밖으로 기쁨을 온 몸으로 표현하였다	기쁘/paa+은/etm ,감정/ncn+을/jco 주체/ncpa+하/xsva+지/ecs 못하/px+은/etm 나/ncn+는/jxc, 창/ncn, 밖/ncn+으로/jca 기쁨/ncn+을/jco, 온/mma, 몸/ncn+으로/jca 표현/ncpa+하/xsva+였/ep+다/ef	기쁜, 감정 주체, 나, 창, 밖, 몸, 표현	Joy, Emotion, Subject, I Window, Outside, Body, Expression	Joy (P:0.5,N:0.25), Emotion (P:0.6,N:0.0), Subject (P:0.0,N:0.1), I (P:0.0,N:0.0), Window (P:0.0,N:0.0), Outside (P:0.0,N:0.0), Body (P:0.0, N:0.0), Expression (P:0.0,N:0.0)

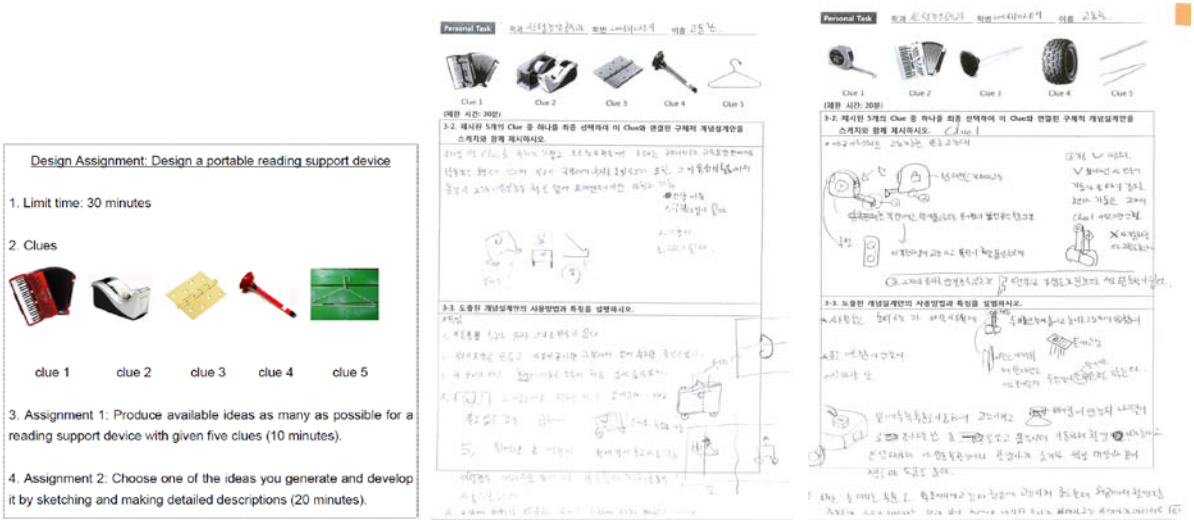
Table 2 presents an excerpt of estimating emotional orientations with the collected user text inputs. Note that only adjectives and nouns were selected for the estimation and analysis and many objective words with zero score of positive or negative were ignored in the study.

5.1 Conceptual Design Task

The pre-test and post-test are conceptual design task to design the portable reading device. In the design task, during the first 10 minutes, the students had to produce as many ideas 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. And, they should choose one of the ideas which they generated, and elaborate it with sketching and making detailed descriptions during next 20 minutes. Figure 4 presents the form of conceptual design task, and two sample data of pre-test and post-test, collected from a student who achieved enhance in cognitive elements of design creativity.

5 EVALUATION OF DESIGN CREATIVITY TEST EXPERIMENT

We conducted two assessments using conceptual design tasks to identify if there was any enhancement of design creativity in the ability of the 5 cognitive elements. Pre-test and post-test were conducted in this regard, pre-test before the creativity exercise test, post-test after the creativity exercise test. The conceptual design results were evaluated based on the five cognitive elements of design creativity by 4 domain experts with given evaluation guidelines. The calibration session was given to the 4 domain experts, and the inter-rater agreement of the Kappa value is presented in the result section, indicating



a. Conceptual design task b. Sample of pre-test c. Sample of post-test

Figure 4. A conceptual design task and two samples of pre-test and post-test acquired from a student. Conceptual design task is used for pre-test and post-test. Note that both samples of pre-test and post-test were evaluated by human experts

"moderate agreement."

5.2 Evaluation Guideline

The results of pre-test and post-test, conceptual design task were evaluated based on the evaluation guidelines as presented in Table 3. A score between 1 and 5 (inclusive) is assigned to each creativity element. Fluency was evaluated by counting the number of ideas with which the students came up. In the case of the measurement of flexibility, the categories of generated ideas were counted. The originality measure was done by considering the novelty of the ideas in comparison with all other generated ideas and their distinctiveness. In the case of the elaboration measurement, the detailedness of the developed conceptual design was evaluated. Besides, the detailedness of the usage of the conceptual design that was required to be addressed. 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. If they identified the critical issues of the given design problem, their problem sensitivity scores could be high.

Table 3. A guideline for evaluating the five design creativity elements of pre-/post-test

Creativity Elements	Evaluation Guideline
Fluency	Count the number of ideas generated. The more the ideas, the higher the fluency scores.
Flexibility	Count the category of ideas generated. The more the categories, the higher the flexibility score. Categories can be counted by grouping several ideas based on their similarity.
Originality	Evaluate the novelty of ideas generated. The rarer the ideas, the higher the originality score.
Elaboration	Evaluate the detailedness and degree of development of ideas. Consider the detailedness and completeness of developed ideas with sketches and descriptions.
Problem Sensitivity	Evaluate the appropriateness and fidelity of ideas to given problem Consider how well the students reflect the intention of given problem in their ideas.

6 RESULTS AND DISCUSSION

Forty four senior or first-year graduate students from the Interdisciplinary Design course at the Sungkyunkwan University participated in the exepriment. Figure 4 shows examples of pre-test (b) and post-test (c) performed by a student. This example shows one sample case of enhance in design creativity: The average score over the 5 cognitive elements of the post-test was increased by 1.05 from that of the pre-test. The assigned score range is between 1 and 5 (inclusive).

Four domain experts evaluated the conceptual design results. The Cohen's Kappa value was computed from the assigned scores for inter-rater reliability. The overall Kappa value was 0.44 over the five cognitive elements and the significance of the acquired Kappa value is "moderate agreement." The individual Kappa values were 0.35, 0.66, 0.34, 0.47, and 0.39 for flexibility, fluency, originality, elaboration, and problem sensitivity respectively. Fluency is considered as reliable relatively more, compared to other cognitive elements.

Table 4. Paired t-test results with p-values between pre-test and post-test

	T	**p-value**
Fluency	-4.103	0.000
Flexibility	-3.197	0.003
Originality	-5.367	0.000
Elaboration	-0.604	0.549
Problem Sensitivity	-0.623	0.537

6.1 Design Creativity Evaluation

As a result, 33 students out of 44 students showed enhance in design creativity with regard to the 5 cognitive elements (70% increases), possibly indicating the effectiveness of the creativity exercise test. The overall difference between pre-test and post-test are +0.86, +0.32, +0.65, +0.06 and +0.06 for fluency, flexibility, originality, elaboration and problem sensitivity respectively.

Further investigation with the t-test results provided that there were 3 cognitive elements (fluency, flexibility and originality) which are significantly different between pre-test and post-test, indicating the enhancements in the abilities of fluency, flexibility and originality are statistically significant enough (Table 4). On the other hand, elaboration ($t=-0.604$, $p<0.549$) and problem sensitivity ($t=-0.623$, $p<0.537$) scores are not significantly different between pre-test and post-test.

Table 5. Learned association rules between the cognitive elements and affective states

Premises	**Conclusion**	**Support**	**Confidence**
Distract = false, POST TEST > PRE TEST	Apprehend = false	0.62	0.92
Distract = false, POSE TEST > PRE TEST	Sadness = false, Apprehend = false	0.62	0.92
Sadness = false, Distract = false, POST TEST > PRE TEST	Apprehend = fasle	0.62	0.92
POST TEST > PRE TEST	Apprehend = false	0.66	0.90
POST TEST > PRE TEST	Sadness = false, Apprehend = false	0.66	0.90

6.2 Associated Emotion to Enhance in Design Creativity

The collected affective states were used for the investigation of relationships with the 5 cognitive elements of design creativity. A machine learning technique, Association Rules learning was used for this purpose. Table 5 shows enhance in design creativity and its relationships with affective states. For example, if there is enhanced design creativity (post test > pre test) then students did not select the affective states of "Sadness" and "Apprehend" (Support: 0.66 with Confidence: 0.9). Generally speaking, the enhanced design creativity is reversely associated with negative affective states; students did not select negative affective states when there was enhancement in design creativity in the post-test. Rapidminer 5.0 was used in the study for running machine learning techniques, such as Association Rules.

6.3 Analysis of Emotional Orientation

Total 925 user text inputs of 25 experiment participants were lexically analyzed in the study. The user text inputs include sentences, phrases, and words and are transformed in lexical representations. The number of unique words (adjectives and nouns) extracted from the lexical representations is 1904 in total.

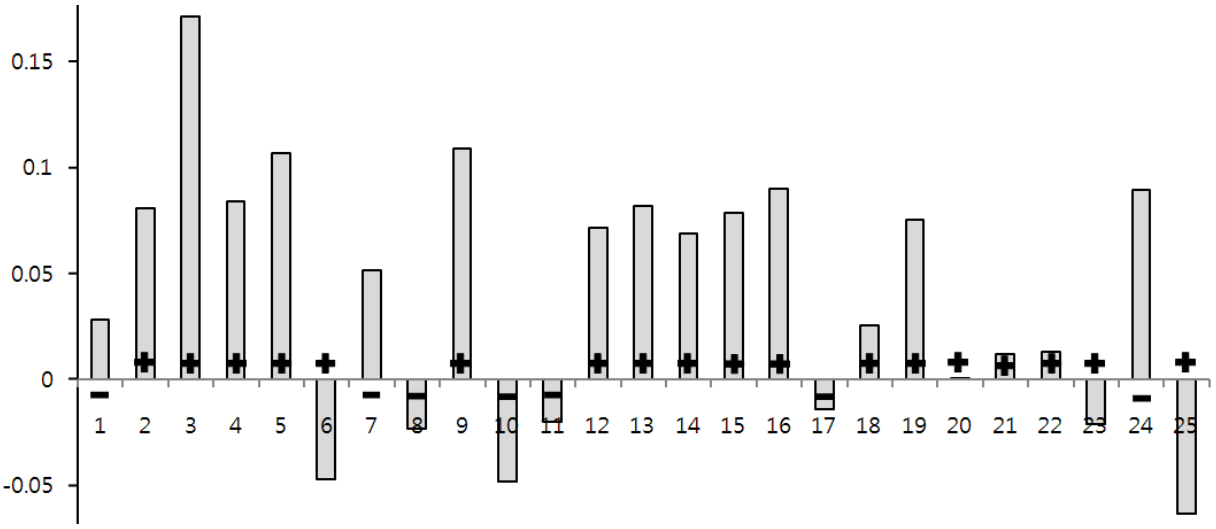


Figure 5. Average scores of emotional orientation of 25 users (bar graph), who participated in Design Creativity Test. Plus or minus under each user number represents if a user achieved enhanced (+) creativity or not (-) according to the evaluation on pre-test and post-test.

The averaged emotional orientation scores for 25 students are presented in Figure 5. Plus/minus indicates if each user achieved enhance in design creativity after participating in Design Creativity Test: plus means enhanced design creativity, minus meaning not enhanced. Among 18 participants with enhanced design creativity, 15 participants were identified as the positive emotional orientation and 4 out of 7 participants, who did not get enhanced in design creativity, were identified as the negative emotional orientation. Overall, the result shows 72% matching between emotional orientation in designers' text and whether the design creativity is enhanced. This implies a close relationship between positive wording of user text input and enhance in creativity of designers who participate in Design Creativity Test.

Further investigation on the text inputs of a user presents a trend of context dependent emotional orientations (Figure 6); positive or negative emotional orientation could appear in certain tasks, as the positive emotional orientation appears in the Negation task. Note that emotional orientation scores are produced by the framework as introduced in Section 4. The framework provides a big potential for measuring emotional orientations in sequential order over the 5 tasks as exemplified in Figure 6. In this regard, as future work, it would be interesting to investigate emotional orientations and its relationships with affective states that are introduced in Section 3.

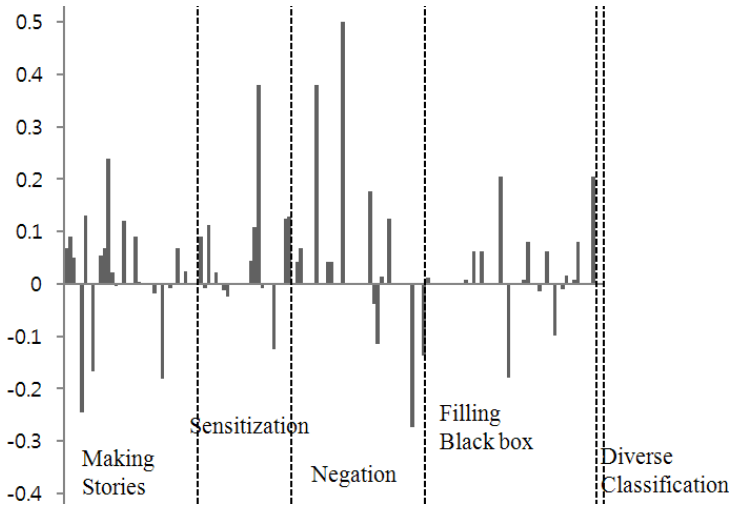


Figure 6. Emotional orientations in the input texts of a user, over the five tasks of Design Creativity Test. Note that x-axis is the extracted words from the user text inputs and y-axis its corresponding emotional orientation scores. Duplicated words were eliminated in the framework (Section 4).

7 CONCLUDING REMARKS

In the study, we presented Design Creativity Test which can be used to help students with their individual needs and contexts, and ultimately to enhance design creativity. Design Creativity Test consists of 5 tasks. Each task emphasizes a unique combination of the 5 cognitive components: fluency, flexibiltity, originality, elaboration and problem sensitivity.

In making stories, the students were required to produce several different stories by changing order of three different pictures. The aim of this task 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 task, 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 an experiment to investigate the effectiveness of the presented test, and undergraduate / graduate students participated in the experiment. Note that the study prioritized the investigation of enhance in creativity, and its relation to emotional orientation. Therefore, the study does not include the effect of demographic profiles, such as gender or class standing of students. In the analysis results there were three main findings reported; firstly, 70% of the participants of Creativity Design Test achieved enhance in design creativity with regard to the 5 cognitive elements; secondly, we found out the enhanced design creativity is reversely associated with negative affective states, such as sadness, apprehend, distract. This means designers with negative emotions would have less opportunity to enhance their design creativity when participating in Design Creativity Test. Lastly we looked into participants' text inputs to estimate emotional orientations using 'SentiWordNet' and in addition, proposed a framework for estimating emotional orientations from user text inputs. Overall, 72% matching was reported between whether there was enhance in design creativity and the estimated emotional orientations of 25 students; positive when there was enhance in design creativity and negative when not. This indicates more positive wording in user text input leads to the enhancement of design creativity. Further investigation on one user's data reveals a trend of context dependent emotional orientation and a possible application for affective modeling, in which emotional orientations appear in sequential order over the tasks and affective modeling can be tested with emotional orientations.

In addition, the proposed framework for estimating emotional orientations can provide real time scores of emotional orientation by user text inputs. The design, implementation of the system is the future work, in which personalized and context dependent services are expected to be addressed.
More rigorous approaches are desired to examine a couple of issues arisen in the study: (1) what cognitive elements could be effectively addressed in each task of Creativity Exercise Test. This is a challenging research because of uncertain factors and qualitative measurement of the cognitive elements; (2) how to improve the inter-rater reliability when evaluate the pre-test and post-test. Providing more controls would be necessary in the guidelines for multiple raters; (3) how to extract context dependent semantics information from user text inputs using WordNet and how to utilize the semantics when analyzing the log data collected from the participants for Design Creativity Test. (4) how to update conceptual design task (pre-test and post-test) for the better measurement of creativity for comparison. It would be interesting to see, for example, if a control group provides any practical inputs for the modification of conceptual design task;

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