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INFLUENCE OF THINKING STYLE ON DESIGN CREATIVITY

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Abstract: Past studies suggest evidence of lack of intuitive thinking and creativity training in engineering education. This becomes particularly relevant in the realm of design engineers, where creative solutions may expand horizons significantly. To better understand how design thinking style may influence design creativity, we propose to study the interplay among *thinking style (rational/intuitive thinking)*, *personality*, and *design creativity* in engineers through self-report surveys and design task logs. From the analysis of survey results and design performance measures, correlations among thinking style, creative behavior and design performance can be identified. Samples from Shanghai Jiao Tong University were applied in this study. The findings showed relatively strong correlations between rationality and creativity across subjects.

Keywords: *design cognition, creativity, thinking style*

1 Introduction

Design creativity is a key driver for innovation. One of the challenges for the research community of design is to provide theoretical underpinnings for the "think like a child" kind of ad-hoc methods (Brown, 2009), understand how intuitive thinking may aid and hinder design creativity, and build a foundation for training and tool development through the creation of models and metrics.

Observations have shown students becoming less divergent over the course of a four-year engineering education (Genco et al. 2012). As many models of creativity (Dijksterhuis & Nordgren, 2006; Epstein, 2003; Simonton, 2003) emphasize the importance of unconscious, stochastic thought in the creative process, it is conceivable that engineering curriculum's heavy emphasis on analytical thinking may be inadvertently impeding creative abilities, and therefore limiting the effectiveness of design education (Moore et al. 2016). It has been shown that creative idea generation can be improved to a certain extent for example using Synectics, a simple but intuitive method to stimulate abstract thinking (Ma, 2006). The research question is: should we incorporate intuitive thinking training into engineering design education?

It has been recognized that the humanities, arts, and social sciences are essential to the creative, explorative, open-minded environment and spirit necessary to educate the engineer of 2020 (Phase, 2005). Humanities and social science courses develop an intuitive and inferential component of thinking that functions independently from analytical reproduction, potentially increasing creative idea potential. "Inductive and deductive reasoning do not suffice to reproduce the phenomenon of creative behavior" (Simonton, 2003) as even in technical design, creative ideas are often the result of stochastic associations between external stimuli and experiences that are often random and open to a wide range of influences. Most existing conceptual design models, such as Geneplore (Finke, et al 1996), design by analogy (Linsey et al. 2009) and Generate-Stimulate-Produce (GSP) (Jin & Benami, 2010), do not effectively take into account this non-analytical component of creative idea generation.

As an initial step of providing useful answers to the question raised above, we look into design thinking style, and specifically examine how the dual-process model of thinking (Stanovich & West, 2000) can be applied to understand the influence of thinking style to designers' creativity and design performance (Moore et al. 2016). The contemporary views of thought emerge with modern philosophy and Rene Descartes, whose famous "I think, therefore I am" directed the field towards thought and thinking styles. Thoughts are defined as unique, introspective episodes, separate from sensations, images, tickles, itches, etc. (Sellars, 2002). The concept progresses as far as development of a recipe for thought, with its major "ingredient" being intentionality (Dretske, 2002). The strongest feature of intentionality is the "power to misrepresent" the reality (Dretske, 2002). Hence, one might think unreal or untruthful thoughts, which can continue to propagate into imagination, which is often the case in both design and education that always leave room for open-ended results and unrealized solutions and outcomes.

Such views on thoughts provide a ground work for the cognitive-experiential self-theory (CEST) (Epstein, 2003), a dualistic theory of personality. In our research, we define "thinking style" as the "parallel, interacting modes of information processing" (Epstein, 2003) in people's mind. In CEST, there are only two such modes: rational system and experiential system. An evaluation of rational and intuitive processes (Witteman, 2009) proposes an altered definition, calling a thinking style an "information processing style" that affects "habitual response preference" in research samples. This and similar studies do not assume that thinking style is a personality element. Rather, thinking styles are most frequently depicted as correlations between creative accomplishments or self-perception, and personality traits or dominant ways of thinking (i.e. rational vs. intuitive) (Silvia, 2012; Epstein, 2003; Witteman, 2009). A more recent study of thinking styles focuses on intuition and defines it as "the ability to detect patterns" (Eubanks, 2010). As such, it emphasizes the nurturing potential of intuition through iterative positive reinforcement.

In the educational context, information gathered on thinking styles shows that stimulus of thought declines over prolonged schooling, perpetuating loss of thought stimuli in students (Lipman, 2003). A proposed in-classroom thinking style encourages reflective and iterative thought, stimulating curiosity. Business journals and contemporary sources offer flexible definitions of thinking styles, where the term is interchangeable with that of cognitive style. Many sources pronounce division into numerous different cognitive styles, while some offer a more binary, CEST-like, considerations. One study considers thinking style in the realm of brain dominance theory, noting the binary left-brain thinking style and right-brain thinking style (Genovese, 2010; Winters, 2011) and hemisphere-based thinking styles are defined by dominant traits (Clayton, 2007). Furthermore, supporting literature proceeds to define thinking style as "the way [subjects] code information for further processing in the brain" (Fallon, 2004). Perhaps the most general definition rooted in psychology, pertains to "the way individuals think, perceive and remember information" (Allinson, 1996).

In this research, we apply CEST to assess thinking style by measuring designers' potential of rational thinking and experiential thinking through survey studies. The thinking style scores are then correlated to designers' creative behavior scores obtained from survey data and to their design performance scored from design logs. In the following, we first describe a proposed study framework of thinking style in Section 2 and introduce the method in Section 3. Experiment results are presented and discussed in Section 4, followed by concluding remarks and future work in Section 5.

2 A framework of design thinking style study

Dual-process theory (Stanovich & West, 2000) is an established model from cognitive psychology that divides cognitive processes into two camps: Type 1 (fast, intuitive, and heuristics-based) and Type 2 (slow, rational, and analytical) (Moore et al, 2016). Our framework of design thinking style study is built based on CEST, a dual-process thinking model proposed by Epstein (2003) that considers that people operate using two separate systems for information processing: an analytical-rational system and an intuitive-experiential system. As shown in Figure 1, our proposed framework is composed of four major variables: independent variable *thinking style*, and correlated variables *personality*, *behavioral creativity*, and *design performance*.

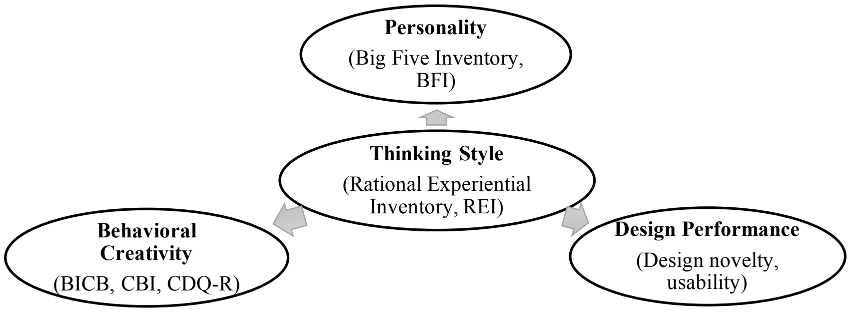

Figure 1. A proposed framework for design thinking style study

Thinking style in this study is defined based on the cognitive and experiential self-theory (CEST) (Epstein, 2003). By this definition, thinking style of an individual indicates his or her preference between two cognitive styles, more rational-analytical or more intuitive-experiential. We propose that a designer's thinking style correlates to his or her personality, behavioral creativity, and design performance. The correlations may or may not depend on domain, grade-of-education, cultural background, and gender. Our research aims to reveal the correlations and associated conditions. Thinking style assessment will use Rational-Experiential Inventory (REI) (Pacini & Epstein 1992) based surveys analyzed in Section 3.

Personality in general represents a combination of characteristics or qualities that form an individual's distinctive character. We adopt a Big Five personality traits based definition (Goldberg, 1992). In Big Five, personality is framed in terms of its five dominant dimensions: *Extraversion, Agreeableness*, *Conscientiousness*, *Emotional Stability* and *Openness*. The personality variable is included in the framework for two reasons. First, it complements the "thinking style" definition by providing five important personal traits in addition to two thinking types. We expect further integration of the two concepts will lead to better understanding of designer's thinking. Second, there have been studies that correlates REI scores with Big Five scores. The results of these studies can be applied to verify the validity of our study results.

Behavioral creativity in this study is attributed to an individual to indicate his or her tendencies of engaging in creative activities, in the past, currently and in the future. Silvia (2012) treats creativity as an interactive variable, interconnected with social, cultural, behavioral, and cognitive aspects of life. Eubanks (2010) considers creativity as a function of errors, mental models, insight and intuition, as it pertains to creative problem solving. Furthermore, work of Shah proposes that ideas crucial for creativity stem from quantity, quality, novelty and variety (Shah, 2012). We hypothesize strong correlations between thinking styles and behavioral creativity, considering thoughts drive behaviors. A set of inventory based survey methods are applied to assess individual designers' behavioral creativity.

Design performance in assessed by *novelty* and *usability* of design results supported by observed design processes. Correlating thinking styles with design performance is a major task for this research. Although REI based studies have been carried out in the areas of psychology and social psychology, little work exists in the field of design that addresses the effect of varying thinking styles. From an education perspective, a better understanding of how students' thinking style influences their design processes and results is especially important because it may lead to more effective training of design thinking and more useful intervention techniques. Design logs can be used to evaluate design performance by a panel of experts.

3 Methods

Through the review of the literature and our own experience with engineering design education, we have formed following hypotheses: H1: Creative behaviors are *more common* in individuals with more intuitive thinking style. H2: Mechanical engineering training tends to *confine* intuitive thinking and creativity. H3: Intuitive thinking and creativity *can be acquired as skills* through appropriate training.

3.1 Subjects and procedure

In this study, 52 undergraduate students of Shanghai Jiao Tong University participated. As the first sample group, called "*non-engineer class*", 29 students (54% female) were enrolled in *Innovative Thinking* *and Modern Design* class for students of upper class standing without restriction by field of study (the sample was composed of students of economics, arts, communications, or life sciences). As the second sample group, called "*engineer class*", 23 students (18% female) were enrolled in *Introduction to Engineering* class for freshman students, restricted to engineering fields of study (68% mechanical, 14% electrical, 14% naval, and 4% materials engineering). Both classes were taught by the same professor, and during the same semester. The students were surveyed using a Chinese direct translation of each survey. The identifiable survey data was obtained on paper, during scheduled class hours. After data collection, three correlation profiles were generated:

Personality profile depicts correlation of REI and BFI data, and indicates internal properties pertaining to one's broad identity traits. It is hypothesized that a certain personality profile will lead to better engineering designs, and that personality training can alter one's designer profile.

Creativity profile correlates REI and creativity survey data. It provides general, broad context creativity report, frequency of creative behavior or action, and inner belief about personal creative achievement.

Design profile correlates REI and designer performance scores and serves as the master set of graded design performance and design log analysis.

3.2 Survey assessment

We use self-report survey methods to find relationships between the proposed variables.

Thinking style is assessed using the *Rational-Experiential Inventory (REI)*. REI is a questionnaire aiming to measure a person's habitual preference for either rational or intuitive thinking style (i.e. habitual response to decision situations). It allows responses ranging from 1-5 (completely false to completely true).

Personality is assessed using the Big Five Inventory (BFI). BFI is a scale for measurement of big five dimensions of personality: *Extraversion, Agreeableness*, *Conscientiousness*, *Emotional Stability* and *Openness*. Subjects respond on a scale 1-5 (disagree strongly to agree strongly), and are then assigned their final score using official scoring methodology.

Behavioral creativity is assessed using three different self-report scales (Silvia, 2012): Biographical Inventory of Creative Behaviors (BICB), Creative Behavior Inventory (CBI), and Creative Domain Questionnaire (CDQ). BICB is a scale of creative behaviors, ranging broadly, from common creativity domains such as arts and crafts, to social creativity such as leadership or coaching. It allows binary (yes/no) responses. BICB is used as an early and simple creativity assessment. CBI is a scale of creative behavior accomplishments in daily creative activities and behaviors. It allows four ("never did it" to "more than 5 times") responses, stating frequency of creative activities. CBI will allow us to evaluate daily creativity. CDQ is a scale of creative achievement and personality traits, across different domains (such as acting, computers, writing, etc.). It allows responses in range 1-4 ("not at all", to "extremely"). It assesses factors such as empathy, hands-on creativity, and math/science. CDQ allows us to observe not only general creativity traits, but rather those also specific to engineers (such as hands-on or science-oriented creativity).

Design performance is another variable to be evaluated. In order to align design evaluation with the variables considered throughout the research, it was determined early to assign one variable dedicated to design performance, which is normally defined as *novelty* and *usability*. The problem assigned to the two subject samples was a modified problem from Atman et al (2005) and we required 2-hour completion. For purposes of accuracy, the document was translated to Chinese. Its English version is shown below.

> *You're creating a new game with your fellow engineering students. Your goal is to launch a ping-pong ball at a bull's-eye target, which lies horizontally on the ground. As part of the game, you are to design a ball launcher: a device that can lift up the ball, and deliver it at the target. The most accurate launch wins. Initially, you are located 5 meters away from the center of the target. (As you only aim for the center of the target, you do not need to know its diameter, just location from the center.) Your entire device is not to exceed 1 m x 1 m x 1 m in size (length, width, and height). You are not allowed to throw the ping-pong ball at the target. You are, however, encouraged to pursue novel or unusual solutions, while holding precise delivery aim imperative.*

Students were required to keep a design log and submit it to the instructor. Such design logs were later assessed by an expert panel. The two design measures are described in greater detail. Usability was accessed via the method of expert panel review, with expert panel consisting of a professor and 11 graduate students of mechanical engineering working on design-oriented research projects. Each expert assigned a score of 1-5 to each design log submission, per their view of usability rating of the project.

Novelty has been standardized as a measure, and used in numerous past studies as a variable of design (Chulisp & Jin, 2006; Shah, Vargas-Hernandez, & Smith, 2003; Song & Agogino, 2004). It was calculated using the proposed function. First, main functions used in subjects' design logs were identified and each was assigned a weight based on their individual importance and number of appearances: *launch*, $f_1 = 0.5$, *aim for target*, $f_2 = 0.2$, and *ball feeding*, $f_3 = 0.1$.

Upon doing so, different fulfillment of functions are identified, and the repetitions of same conceptual ideas were counted. Here, novelty sub-score is introduced in equation (1), where j is an identifier, $T_j$the total number of ideas generated for f_j, and C_j count of the current solutions for f_j.

$$S_j = 10\times\frac{T_j - C_j}{T_j} \qquad (1) \qquad\qquad N = \sum_{j=1}^{n} f_j S_j \qquad (2)$$

This sub-score, S_j is included in the expression for novelty score, N defined in equation (2). The higher the novelty score, the more unusual or unexpected the design is.

4 Results and discussion

The three different profiles mentioned above were created based on their corresponding correlations. With these correlations some expected trends were noticed, but the majority of findings were surprising, calling for both new conclusions and reconsiderations within the study. Such findings are discussed below within their respective profiles, and supported by the correlation charts.

The personality profile correlations expose curious relationships proposing dimensions of the kind of mindset that subjects had going into the creativity and design assessments. Many correlations were consistently positive for both rationality and experientiality correlations in both classes.

As the rational-experiential inventory (REI) is our evaluation method of thinking style, it is relevant to note that the engineer class ranked 10% more rational than the non-engineer class (t = -2.14, $p = 0.037$).

4.1 Personality profile

The personality profile consists of two charts depicted in Figure 2, which portrays correlations between the *rational and experiential scales* of REI, and *Extraversion, Agreeableness, Conscientiousness, Emotional stability,* and *Openness*.

In most dimensions of Big Five engineer class scores 3-13% higher than the non-engineer class, with the highest difference being extraversion, with 13% higher score among engineers (t = -2.332, $p = 0.012$). Non-engineer class, on the contrary, outperforms engineers by 12% in the dimension of emotional stability (t = 1.60, $p = 0.058$), where the highly rational engineering sample ranks low.

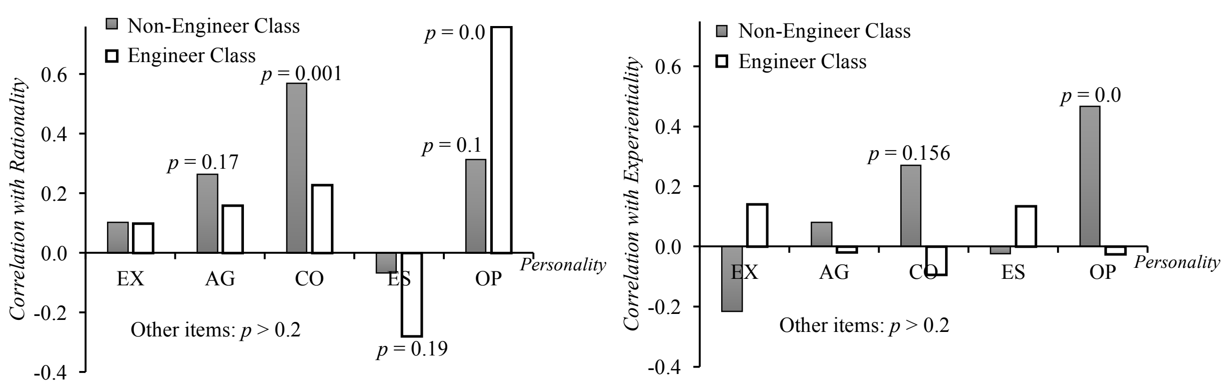

Figure 2. Correlations between REI and BFI, where EX, AG, CO, ES, and OP stand for Big Five personality dimensions: Extraversion, Agreeableness, Conscientiousness, Emotional Stability, and Openness, respectively.

Such findings were correlated in Figure 2. For non-engineers, openness ($p = 0.1$) and conscientiousness ($p = 0.001$) are predictors of rationality. For engineers, similarly, openness ($p = 0.0$) and conscientiousness (insignificant due to small sample size) are contributors to rationality. These results are consistent with those of a previous study that had a sample size of 774 (Witteman et al. 2009). For experientiality, openness ($p = 0.0$) and conscientiousness ($p = 0.156$) made contribution for non-engineers, while an opposite trend can be observed for engineers, who had extraversion and emotional stability as contributors (both insignificant due to small sample size). The correlation of emotional stability to rationality appears to be negative in engineers ($p = 0.19$), indicating that more rational engineers tend to be more neurotic. Hence, the emotionally stable engineers were those who relied more on intuition than rationality.

4.2 Creativity profile

The creativity profile consists of charts in Figure 3, which specifically portrays correlations between the *rational and experiential scales* of REI, and scores of *biographical inventory of creative behaviors (BICB), creative behavior inventory (CBI), and revised creativity domain questionnaire (CDQ-R)*, the self-report scales assessing different kinds of creativity.

In cases of two out of three creativity measures, engineer class performed worse than the non-engineer class, scoring 5% less in BICB (insignificant) and 11% less in CBI ($t = 1.99$, $p = 0.026$). The engineering sample did, however, score 3% higher in CDQ-R (insignificant). From the quantitative, it can be deduced that engineers, as compared to the non-engineer sample, are somewhat less likely to be creative on the daily basis, or be domain-specific creative, yet possess slightly more confidence in their creative abilities.

The results in this study are unexpected. From Figure 3, one can notice the strong positive correlations between rationality and creativity scores, in both classes, with non-engineers offering slightly stronger correlations ($p = 0.007$ for CDQ-R, $p = 0.027$ for BICB, $p > 0.2$ for CBI). Furthermore, this finding is contrasted with the trend of negative correlation between intuitiveness and creativity (insignificant due to small sample size). The only positive correlation with the experiential scale holds for the CDQ-R scores of the non-engineer class, which demonstrates positive correlation between intuition and creative confidence in experiential subjects.

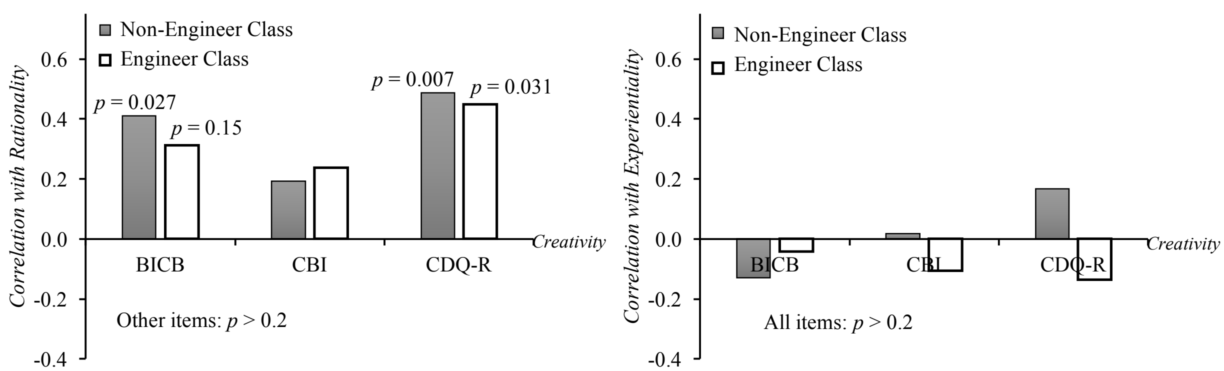

Figure 3. Correlations between variables of REI and self-report creativity scales, where BICB, CBI, and CDQ-R stand for measures of every-day creativity, creative accomplishment, and creative confidence, respectively

Both results are surprising, as the opposite was initially hypothesized. Given the belief that the intuitive and experiential are those who indulge in the creative, these samples have shed such a different light on thinking style-creativity relationship. Several considerations can be proposed. For one, we question how appropriate standard self-report creativity scales are for evaluation of creativity in engineers, considering the possibility that creativity in engineers might be a unique subset requiring another form of evaluation. Furthermore, no social concept is ever completely binary, and binary approach tends to be a simplification of reality. As such, categorizing subjects as only rational or only intuitive might be posing a challenge. For a preliminary study, these results are highly intriguing for future studies.

4.3 Design profile

The design profile consists of charts in Figure 4, which specifically portray correlations between the *rational and experiential scales* of REI, and scores of *novelty* and *usability*. These correlations structure the proposed design profile, such that proposes the dependence between thinking style and design performance.

In case of the two scales of design performance, the difference between engineer and non-engineer samples was very small and insignificant.

The results of this study are also unexpected. Figure 4 depicts contrasts in correlations between thinking styles and design performance. It is apparent that usability maintains similar correlations regardless of thinking style, where merely non-engineer class positively correlates both rational ($p = 0.101$) and experiential ($p = 0.141$) scales to usability, while the engineer class had smaller, negative correlations (both $p > 0.2$) . In case of novelty, a curious behavior is noticed. Novelty of both classes correlates positively to rationality (insignificant), and negatively to intuition (insignificant), which is a result opposite from that hypothesized. As this is a preliminary results from studying two small samples of 52 participants in total, two major considerations can be given. Upon closer inspection of the design work handed in, it is observed that students with higher rational scores tend to provide more thorough, better explained, and more unique designs. Conversely, experiential students appeared to have given less effort to the task. Hence, the question arises whether the thinking style of these students corresponds to their college performance at large. Under an assumption that educational approach is largely rational, it is a fair derivative that rational subjects would also be better students. As such, they might ambitiously deliver better projects. Another possibility involves cultural differences, as the study was proposed at an American university, yet conducted in China. Hence, cultural preferences and cultural differences in education might be impacting the assumption made considering American engineering students.

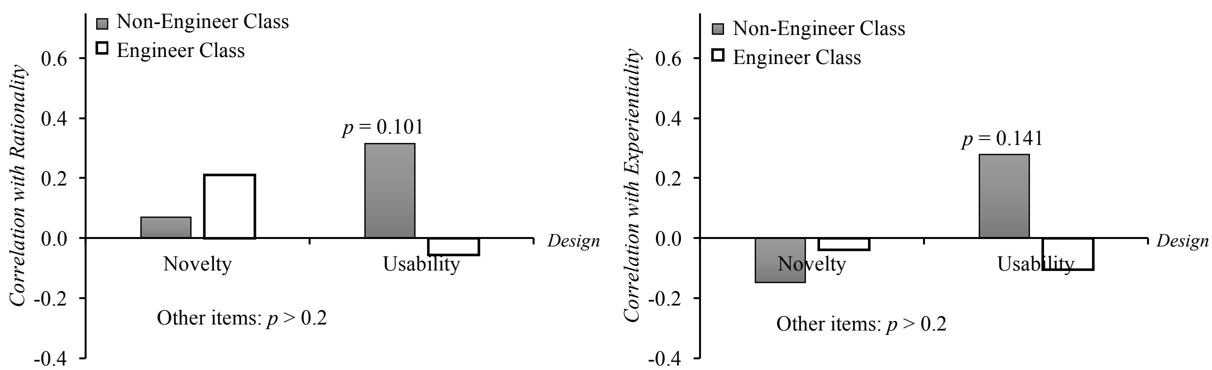

Figure 4. Correlations between variables of REI and design, where Novelty assesses the innovativeness of design, and Usability its likelihood of successful implementation.

5 Concluding remarks and future work

In this research, we address the theme that thinking style influences design creativity and proposed a framework of study to identify relevant concepts (or variables) and investigate correlations between them. Our preliminary studies have yield interesting, and sometimes surprising, results. Major considerations are given to the findings of rational subjects performing better in domains of creativity and design, than their experiential peers. As such, the question is posed whether the tradition and discipline present in engineering education really requires much of a challenge. Furthermore, the proposed binary thinking styles are challenged, considering there might be a more precise scale available that can deal with the difference between engineering design work and simpler psychology tests. A final consideration is given to the behaviors which might be specific to Shanghai Jiao Tong University, which is one of the best universities in China, gathering the finest engineering students from around the country. As such, their personal records and behaviors may be unique or outstanding, and it requires closer assessment.

We propose an intervention study in the future, which could involve intuition training mid-way through the semester, attempting to make students more intuitive and observe arising differences and sequential changes. We also plan to conduct studies with upper class students. A study identical to the one completed at Shanghai Jiao Tong University will be conducted at University of Southern California in the fall. This study will involve a larger sample, consisting of advanced (senior and graduate) students enrolled in a course on design theory and methodology, with a strong focus on creativity.

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