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IMPACT OF DESIGN BRIEFS ON CREATIVE OUTCOMES: A FACTORIAL STUDY ON STUDENT DESIGNERS' CREATIVITY

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ABSTRACT
Our study focuses on understanding how design briefs affect the creativity of design outcomes by student designers. The stimuli contained in design briefs have the potential to either encourage creativity in designers or steer them away from creative outcomes. Therefore, educators need to craft design briefs that foster creativity in student project outcomes. We focus on two stimuli – quantitative product requirements and visual examples (i.e. videos), and we measure creativity according to two metrics – novelty and appropriateness. A design of experiments (DOE) approach was used to determine whether requirements, examples, or a combination of both stimuli can yield higher scores in both metrics. We conducted a Collaborative Sketching design exercise with our first-year undergraduates and evaluated the creativity of their concept drawings, then used a post-experiment survey to collect the opinions of student designers and assess if their perceptions aligned with our experimental findings. We found that the video example decreased novelty scores ($p<0.01$), yet there was a sizable group of students who asked to be provided with more examples during the experiment to enhance their creativity. In view of that, educators should consider: 1) avoiding videos of existing solutions in design briefs if they wish to promote novelty, 2) introducing quantitative product requirements and video examples if they wish to promote appropriateness, and 3) addressing student designers' misconceptions about how examples affect the creativity of their design outcomes.

Keywords: Design brief, ideation, creativity, full-factorial experiment, student misconceptions

1 INTRODUCTION

In undergraduate engineering design coursework, it is common for educators to set the scope of student projects by giving a design brief that states the context, requirements, and deliverables for the project. This brief is handed to students at the start of the project and sets the tone for the entire project. In the Singapore University of Technology and Design (SUTD), design briefs from different courses come in a diversity of formats and contain a variety of requirements and stimuli – in our freshmore Introduction to Design course, the brief is a broad theme that gives students flexibility in defining their project; in our sophomore engineering product design course, the brief includes specific quantitative requirements, videos, and schematics of existing robots and biomimetic inspiration; in architecture, competition briefs often include videos, site photographs, and contextual information. As seen from these examples, different disciplines and courses have different norms for design briefs.

At the same time, educators are interested in facilitating the creativity of students and thus have a vested interest in formulating design briefs that promote creative student project outcomes. According to Madni [1], creative designs share the common characteristics of novelty (i.e. new or unprecedented features) and effectiveness (i.e. ability to satisfy performance or capability requirements). Kampylis and Valtanen [2] state that creative products must be novel (original, unconventional) and appropriate (valuable, useful). Combining the above definitions, this paper defines creativity as a blend of novelty and appropriateness, with *novelty* being the extent to which the design is different from the usual way of completing the requested task, and *appropriateness* being the extent to which the design is aligned to the brief guidelines. Therein lies a paradox, where educators hope that students can be unconstrained and let their imaginations run wild, and yet expect students to conform to the requirements in the brief [3]. Therefore, it is critical for design briefs to strike the right balance between encouraging novelty and fostering appropriateness. There have been many studies that explore individual creativity [4] or group creativity among students [5-7] and professionals [8], as well as the effects of stimuli on design ideas [9]. But to the best of the authors' knowledge, little effort has been devoted coherently and purposefully to extracting guidelines or rules to be applied in writing design briefs for student projects.

Therefore, this project seeks to investigate the efficacy of different design brief formats for promoting creative idea generation in the early stages of student design projects. Specifically, we investigate the impact of stimuli in the design brief on the novelty and appropriateness of student concept drawings. Furthermore, we seek to investigate student perceptions of creativity and design briefs, so that we can identify if students have misconceptions that need to be addressed in the classroom [10]. The specific research questions for this paper are:

1. For design briefs: How do the stimuli in design briefs affect the novelty and appropriateness of concept drawings by student designers?
2. For student perceptions: What do students think will help them be more creative? Do the students' perceptions align with our experiment findings?

2 RESEARCH METHODS AND RESULTS – DESIGN BRIEF

2.1 Participants

To test the effect of stimuli in design briefs on the creativity of student outcomes, we conducted a product design experiment as part of SUTD's Introduction to Design course. This is a foundation module for all undergraduate SUTD students. The experiment was conducted with four classes containing a total of 93 first-year undergraduate engineering design students. The students were 18-21 years old and were allocated to classes with an even mix of genders, nationalities, educational backgrounds, academic scores, subject preferences for majors, and Myer-Briggs personality scores. Thus, our study assumes that the mix of students in each class is reasonably homogeneous.

2.2 Experiment and Analysis Procedure

The students were asked to "design a device to extract juice from fresh oranges at home," and each of the four classes was given a different design brief (treatment). In our experiment, *stimuli* refer to the input parameters in the design brief. We focused on two commonly used stimuli – design *requirements* (i.e. specifications) and *examples* of existing solutions. Specifically, we tested the impact of including quantitative product requirements (Q, which includes numerical requirements for product cost, the maximum number of manufacturing processes, washability/durability cycles, and product volume) and a visual example (V, a video showing a user extracting juice manually using a conventional orange squeezer). Using the DOE approach, each of the four classes was given a common baseline design brief, with one class receiving no additional stimuli (Brief A), one class receiving a visual example (Brief B), one class receiving quantitative product requirements (Brief C), and one class receiving both quantitative product requirements and a visual example (Brief D). This 2^2 full-factorial experiment design allowed us to test both main effects (Q and V) and two-way interaction effects (Q x V) of the design brief stimuli on the creativity of student concept drawings.

Each class was subdivided into 4-5 teams of 4-6 students each, and each team completed a Collaborative Sketching (C-Sketch) exercise based on their class' design brief. C-Sketch is a variation of the 6-3-5 concept development team methodology. The exercise starts with each student drawing three concept drawings in response to the design brief. At fixed intervals, the drawings are rotated around the team so that every team member can add sketches and annotations to every concept. We chose concept sketching as it is open-ended enough to permit flexibility and novelty in responses [11]. Apart from the experiment instructions, no prior C-Sketch training was given to the students. This exercise yielded 276 concept drawings (three students only completed two concept drawings).

To rate the creativity of the concept drawings, all of the concept drawings were judged for novelty and appropriateness. Three engineering-trained judges independently evaluated all of the drawings on a 1 to 5 Likert-type rubric-based system (see ***Table 1***). To test the inter-rater reliability, we used intra-class correlation coefficient (ICC) estimates calculated using SPSS version 25 software, based on an average-measures, absolute-agreement, two-way mixed effects model. The ICC results were in the good-to-fair range [12], with novelty scores ICC = 0.666 with 95% confidence interval = 0.578 to 0.735 and appropriateness scores ICC = 0.637 with 95% confidence interval = 0.488 to 0.736.

Table 1. Creativity scoring rubric

Novelty	Score	Level	Example
The extent to which the design is different from the usual way of extracting juice.	1	Entirely similar	Copy of existing product
	2	Quite similar	Minimal differences
	3	Some similarities/differences	Average, no surprises
	4	Quite different	Minimal similarities
	5	Entirely different	The idea is a real surprise

Appropriateness	Score	Level	Example
The extent to which the design is aligned to the brief guidelines.	1	Not aligned	Does not meet the guidelines
	2	Slightly aligned	Meets a few guidelines
	3	Somewhat aligned	50/50 aligned to guidelines
	4	Mostly aligned	Meets most of the guidelines
	5	Completely aligned	Fully aligned with the brief

Because C-Sketch exercises are done as a team, for this analysis, we chose to evaluate the results at team-level. Therefore, each team was assigned its mean novelty and appropriateness scores based on all of the concept drawings completed within the team. Since classes had 5 teams each, in that sense, we collected 5 observations from each class to obtain a reasonable estimate of error variance. For the statistical analysis, we did a preliminary test using Minitab® 17 software to run a one-way analysis of variance (ANOVA), which showed that there was a statistically significant difference between the means of each class/brief at $\alpha = 0.05$ confidence level. To get a more detailed view of which factors contributed to the differences between groups, we ran a factorial ANOVA to evaluate the influence of main effects and interaction effects on the creativity of the concept drawings.

2.3 Results – Factorial ANOVA

Table 2 lists the factor levels used for this experiment and values of the response variables (novelty and appropriateness) for each trial condition. Low factor levels are represented by '-1' and high factor levels are represented by '+1,' with each of the factors being studied at two levels – low and high. Each of the response variable columns lists the mean score and standard deviation for each class.

Table 2. Combination of factors levels and values of response variables (aggregated to class level)

2^2 full factorial experiment	Factors		Response Variables	
	Q	V	Novelty	Appropriateness
Brief A	-1	-1	3.00 ± 0.07	2.59 ± 0.21
Brief B	-1	+1	2.84 ± 0.21	2.84 ± 0.35
Brief C	+1	-1	2.94 ± 0.27	2.78 ± 0.48
Brief D	+1	+1	2.23 ± 0.24	3.13 ± 0.20

For novelty, our statistical results showed that the main effect of V (p=0.006) is the only statistically significant factor affecting novelty scores, and that the inclusion of V in the design brief decreases novelty scores. The factor Q fell just short of statistical significance (p=0.056) at α=0.05 confidence level. According to the main effect plots (***Figure 1***a), the best combination of factors for novelty is:

- Quantitative product requirement – No (low-level),
- Visual example – No (low-level).

Figure 1b shows the interaction plot. The graph shows that the effect of Q changes at different levels of V, but the interaction between the factors is not statistically significant (p=0.182).

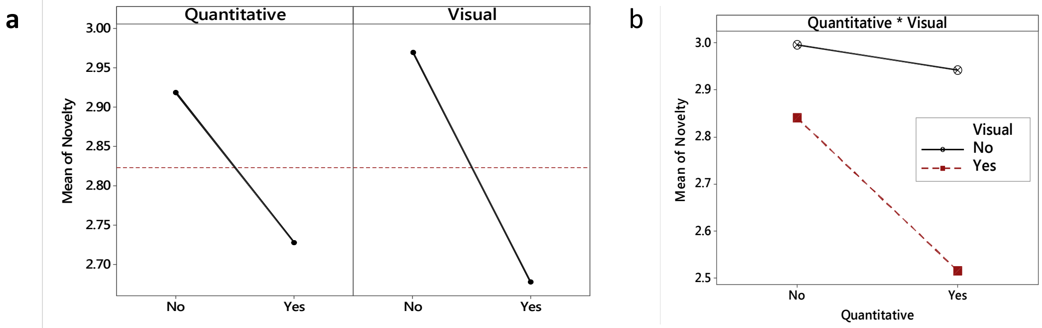

Figure 1 Main effect plots (data means) for novelty (a) and interaction plot for Q×V (b)

For appropriateness, none of the factors are significant at α=0.05 confidence interval level. Both main effects and interaction effects have p-values above 0.05. However, there is an indication of practical significance from ***Table 2*** since appropriateness increases when Q and V are set to high levels (in Brief D). The same outcome is also validated from the main effect plots of ***Figure 2***a. Based on the main effect plots, the best combination of factor levels for appropriateness is:

- Quantitative product requirement – Yes (high-level),
- Visual example – Yes (high-level).

Figure 2b illustrates the interaction plot for appropriateness, where non-parallel lines indicate interaction because the effect of Q changes at different levels of V. However, the interaction between the factors is not statistically significant (p=0.471).   .

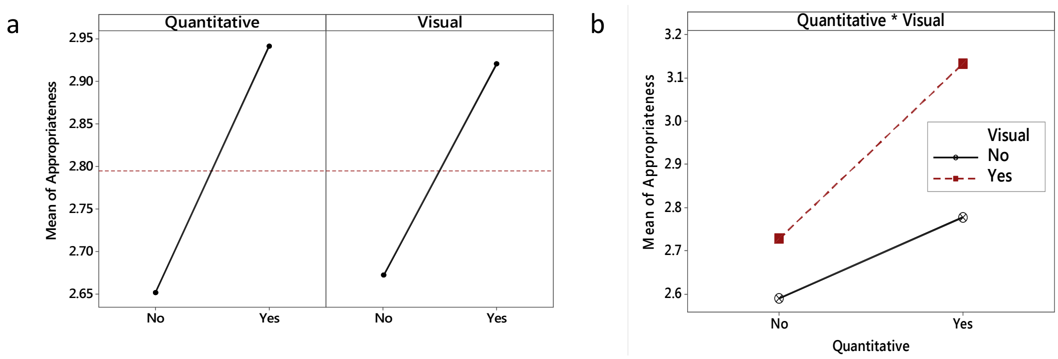

Figure 2. Main effect plots (data means) for appropriateness (a) and interaction plot for Q×V (b)

In summary, the only statistically significant result was the inclusion of a visual example in the design brief which reduced the novelty of the concept drawings. Also, novelty scores were highest when no additional stimuli were included in the design brief, and appropriateness scores were highest when both quantitative product requirements and the visual example were present in the design brief.

3 RESEARCH METHODS AND RESULTS – STUDENT PERCEPTIONS

To investigate the students' perceptions of creativity and the C-Sketch exercise, we conducted a post-experiment survey. In total 86 (out of 93) students responded to the online questionnaire after completing the C-Sketch exercise. The survey contained 10 questions asking for their details, their familiarity with the requested product (i.e. orange juicers), and their opinion on the exercise, and their perception of what influences creativity.

Since our factorial ANOVA results showed that the main effect of the visual example on novelty scores was statistically significant, for this paper, we will focus on students' perceptions of how examples in the design brief affect the novelty of their responses. These perceptions were found in the students' answers to the free-response question: "In your opinion, what could help you be more creative in an exercise like this?" As the students were not formally introduced to the idea that creativity comprises novelty and appropriateness, we assume that most students would interpret "more creative" as being more novel or original, in line with the widespread agreement that any definition of creativity must include a degree of novelty [13]. Thus, the responses to this question will help us to understand the students' perceptions of what can enhance their novelty in an exercise like this.

To analyze the responses, a coding sheet was created with seven codes that represent the most frequent categories of responses: Product Requirements, Examples, Design Problem, Experimental Conditions (apart from brief), Internal Cognitive Process, Not Sure, and No/Neutral Comments. We focused on answers coded as Examples and created three additional sub codes for these answers: 1) No Examples, 2) More/Different Examples, and 3) More Random/Unconventional Examples.

24 students (28% of all survey respondents) wrote answers related to examples (***Figure 3***). For each sub code, there were roughly equal proportions of respondents from each class/design brief. The majority, 16 out of 24 students (67%), stated that being provided with more examples or being allowed to search for more examples would help them be more creative/novel in the exercise. These 16 students were evenly distributed among the different briefs. Comparing the proportions of students in each class who requested for more examples, the students in classes that received the visual example were more likely to request for more examples – Brief A: 3 out of 25 students (12%), Brief B: 4 out of 16 students (25%), Brief C: 4 out of 23 students (17%), and Brief D: 5 out of 22 students (23%).

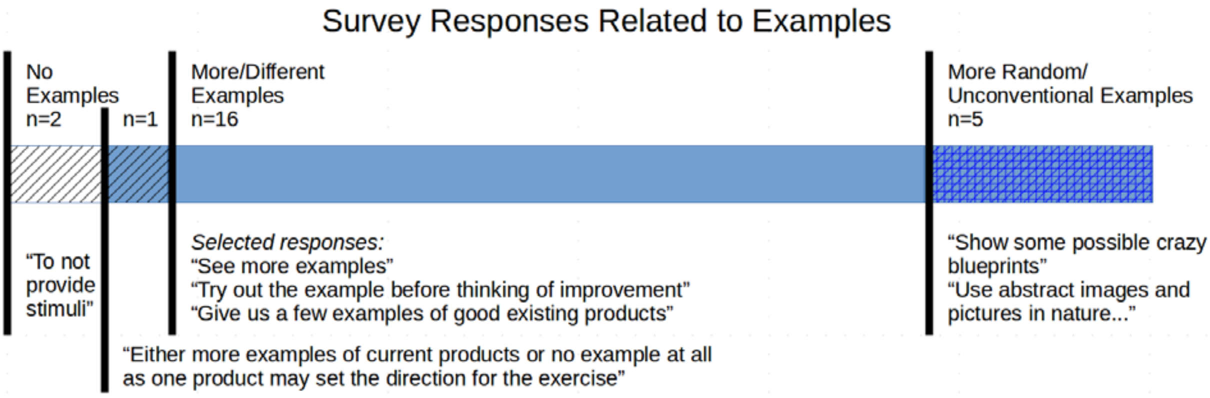

Figure 3. Chart of the 24 survey responses related to examples. Students were responding to the question: "In your opinion, what could help you be more creative in an exercise like this?"

Five additional students asked for random/unconventional examples. Two students said that examples should not be provided, while one student requested for either many examples or no examples.

4 DISCUSSION

Our factorial ANOVA results show that the inclusion of a visual/video example in the design brief lowers the novelty scores of student concept drawings. These findings are consistent with other studies which show that presenting participants with examples of existing products tends to produce less novel examples because of design fixation [14]. Smith, Ward, and Schumacher's research shows that this is true even when participants are presented with multiple examples of possible solutions [15]. This suggests that educators should be careful about including video examples of existing solutions in design briefs and at the idea generation stage, lest they inadvertently promote design fixation and thus reduce the novelty of their students' concepts. However, since the inclusion of the video example and quantitative product requirements may increase the appropriateness of concepts, it could still be useful to introduce examples of existing solutions and more detailed specifications at some other stage in the design process to ensure that students' concepts are aligned with the brief guidelines.

In view of our experiment findings, it seems worrying that 16 (out of 86) survey respondents wrote that having access to more examples of existing solutions would improve their creativity/novelty during the C-Sketch exercise. Surprisingly, this opinion was more common among students whose briefs included the orange squeezer video. These responses are consistent with our observation that students often search for images of existing products for inspiration during the idea generation stage. Unfortunately, this practice is at odds with experiment findings. Thus, there may be a need for educators to address this misconception, and there is also an additional need to investigate if challenging this misconception can improve the novelty of student project outcomes.

We note that a small number of students asked for "random phrases" or suggested that the experimenters "show a range of unrelated products [to] encourage us to link them to [the product]."

Some studies suggest that using analogies from unfamiliar domains or making associations with items that are distant from existing solutions can be effective at promoting novel idea generation, though other studies contest this [16, 17]. Thus it could be fruitful to explore whether the introduction of unconventional or unrelated examples can improve the novelty of student concepts.

5 CONCLUSIONS

Based on our findings, we have developed a deeper understanding of how the requirements and examples in design briefs affect the creativity of student designers' idea generation. One implication of our findings is that some of the design brief norms for our undergraduate courses may unintentionally limit the novelty of student outcomes by presenting examples of existing solutions too early in the design process. In the interest of promoting novelty, it may be more effective for design briefs to have less specific requirements and no examples. However, because examples and quantitative requirements may be able to promote compliance to brief guidelines, it is important to find the ideal time to introduce stimuli to encourage students to create appropriate designs without limiting their novelty. Furthermore, our survey results suggest that a sizable group of students have misconceptions about how examples promote or restrict novelty, and therefore educators should consider investigating if challenging these misconceptions can improve student designers' creativity.

REFERENCES

[1] Madni, A., Elegant Systems Design: Creative Fusion of Simplicity and Power. Vol. 15, 2012

[2] Kampylis, P.G. and J. Valtanen. Redefining Creativity — Analyzing Definitions, Collocations, and Consequences. *The Journal of Creative Behavior*, 2010, 44(3), 191-214.

[3] Beghetto, R.A. and B. Sriraman, *Creative Contradictions in Education: Cross Disciplinary Paradoxes and Perspectives*. Vol., 2016 (Springer International Publishing).

[4] Storme, M., N. Myszkowski, P. Çelik, and T. Lubart. Learning to Judge Creativity: The Underlying Mechanisms In Creativity Training For Non-Expert Judges. *Learning and Individual Differences*, 2014, 32, 19-25.

[5] Toh, C.A. and S.R. Miller. How Engineering Teams Select Design Concepts: A View Through The Lens Of Creativity. *Design Studies*, 2015, 38, 111-138.

[6] Demirkan, H. and Y. Afacan. Assessing creativity in design education: Analysis of creativity factors in the first-year design studio. *Design Studies*, 2012, 33(3), 262-278.

[7] Chen, B.-B. Conscientiousness and everyday creativity among Chinese undergraduate students. *Personality and Individual Differences*, 2016, 102, 56-59.

[8] Binyamin, G. and A. Carmeli. Fostering Members' Creativity In Teams: The Role of Structuring of Human Resource Management Processes. *Psychology of Aesthetics, Creativity, and the Arts*, 2017, 11(1), 18-33.

[9] Howard, T.J., E.A. Dekoninck, and S.J. Culley. The use of creative stimuli at early stages of industrial product innovation. *Research in Engineering Design*, 2010, 21(4), 263-274.

[10] Newstetter, W.C. and W. Michael McCracken, *Chapter 4 - Novice Conceptions of Design: Implications for the Design of Learning Environments*, in *Design Knowing and Learning: Cognition in Design Education*. 2001, Elsevier Science: Oxford. p. 63-77.

[11] Amabile, T.M. Social-Psychology of Creativity - a Consensual Assessment Technique. *Journal of Personality and Social Psychology*, 1982, 43(5), 997-1013.

[12] Hallgren, K.A. Computing Inter-Rater Reliability for Observational Data: An Overview and Tutorial. *Tutorials in quantitative methods for psychology*, 2012, 8(1), 23-34.

[13] Parkhurst, H.B. Confusion, Lack of Consensus, and the Definition of Creativity as a Construct. *The Journal of Creative Behavior*, 1999, 33(1), 1-21.

[14] Jansson, D.G. and S.M. Smith. Design Fixation. *Design Studies*, 1991, 12(1), 3-11.

[15] Smith, S.M., T.B. Ward, and J.S. Schumacher. Constraining Effects of Examples in a Creative Generation Task. *Memory & Cognition*, 1993, 21(6), 837-845.

[16] Smith, S.M., J.S. Linsey, and A. Kerne. *Using Evolved Analogies to Overcome Creative Design Fixation*. 2011. London: Springer London.

[17] Sio, U.N., K. Kotovsky, and J. Cagan. Fixation or Inspiration? A Meta-Analytic Review Of The Role Of Examples On Design Processes. *Design Studies*, 2015, 39, 70-99.