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Exploration of gender diversity effects on design team dynamics

Julie Milovanovic[1], John Gero[2,3],

[1] *UMR AAU-CRENAU*
Graduate School of Architecture and Ecole Centrale Nantes, France

[2] *Department of Computer Science and School of Architecture*
University of North Carolina at Charlotte

[3] *Krasnow Institute for Advance Studies*
George Mason University

Abstract

This article introduces and applies a methodology to analyze the effect of team diversity on team design cognition. We explore team diversity in relation to team members' gender. We studied two types of teams: heterogeneous teams composed of one female and one male mechanical engineering student and homogeneous teams of two male mechanical engineering students. We analyzed 28 design protocols using the Function-Behavior-Structure ontology to code protocols and measure team cognitive design behavior. We found that male design students in the mixed teams tend to dominate the design activity. Also, we found that mixed teams showed significantly more co-design activity compared to male only teams.

Keywords: genders, design cognition, co-design, protocol analysis

1 Introduction

Design team interactions, related to designers' participation in their co-design activity, their expertise and leadership, affect the design outcome and shape the design process itself [1]. In collaborative design, the cognitive effort is not only on the design task but also on the organization of the group process to structure the activity [2]. Studies of co-design using protocol analysis [3] have addressed a wide range of concepts such as differences between individual and team design [4], co-located design versus distributed design [5], the impacts of the use of different media environments [6], [7] and the development of team expertise [8]. In this article, we propose a method to study the effect of design team characteristics on the design process. Our method focuses on the diversity in design teams and its effect on the design teams' behaviors both at the individual and group levels. To illustrate our methodology, we address the question of team gender homogeneity and heterogeneity. According to gender stereotype beliefs, men tend to display a self-directed and agentic behavior, compared to women who are associated with a more communal and cooperative behavior [9]. Although the outcomes of studies on gender effect on creativity often show a lack of differences between men and women [10], popular conception of creative thought processes related to divergent and innovative thinking is associated with masculine-agentic characteristics [11]. Personality traits have been found to affect team's creativity and the diversity of team members personalities can increase the teams' creativity performance [12]. Gender diversity can also influence individual contribution to the team mixing females' ability to be process oriented and males' capacity to be task oriented. Mixed teams performance could be improved with skills diversity although some studies showed no effect of team gender diversity on design performance [13].

In this exploratory study, we will focus on the design process itself rather than the creativity or the quality of the outcomes. We analyzed differences between two cohorts of mechanical engineering undergraduate students: one cohort consists of teams with two male members and the other cohort consists of teams with one female and one male member. To study team behavior at the individual and team level from both quantitative and qualitative viewpoints, a protocol analysis is carried out on our dataset. The protocol analysis uses the situated Function-Behavior-Structure (sFBS) ontology [14], [15] articulated for collaboration and co-creation as a theoretical framework. The significance of the work presented in this paper is two-fold: we present a method to quantitatively measure and qualitatively represent differences in the co-design activity of different teams and we provide evidence of gender diversity effects on team co-design.

In the following section of the paper we introduce our theoretical framework, the FBS ontology and the sFBS co-design model used to encode our protocols, measure and represent the co-design activity. The methodology and the experiment are also presented in that section. In the third section, we focus on the initial results of gender diversity effects on team design. Finally, we discuss the suitability of our method to study not only gender diversity effects on team design behavior but any characteristic of team diversity such as expertise, design domain or team size.

2 Design framework, data description and methodology

2.1 FBS ontology and sFBS co-design model

The framework used in this research to study design cognition is the FBS ontology [14], [15]. The FBS ontology describes concepts called "design issues" about the design artefact: a Requirement (R) includes the design brief and norms; a Function (F) represents what the design object is for; an expected Behavior (Be) illustrates design intentions in terms of how it behaves; a Structure (S) is defined by elements or group of elements of the design object; a Behavior derived from structure (Bs) accounts for how the object behaves based on an existing design Structure (S) and a Description (D) is an external representation of the design object (Fig.1). The FBS ontology also accounts for design processes that are the transitions from one design issue to another: Formulation, Synthesis, Analysis, Evaluation, Documentation, Reformulation 1, Reformulation 2 and Reformulation 3.

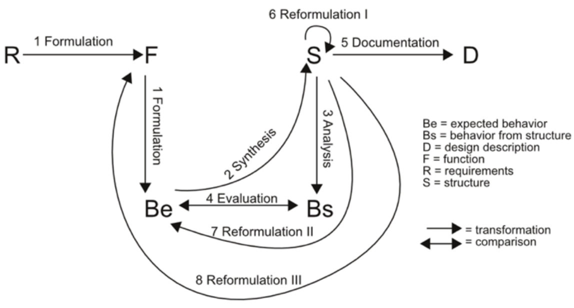


Figure 1. FBS framework (based on [14])

Design is a situated activity, at a social level and a personal level. The social level implies that the design activity is dependent on external inputs generated by other parties involved in the design process, social and cultural habits. The situatedness at a personal level implies that designers advance in the design process by referencing their past design experiences, referred to as design repertoires [16], schemata [17] or prototypes [14]. The situated FBS framework accounts for the situatedness of designing and expresses Schön's concept of design as reflection-in-action activity [19]. The situated FBS model divides the world into three (Fig.2). In the external world, the design object is represented by an instance of (R), (F), (B) and (S) and is outside of the designer. The interpreted world is personal to the designer and represents his/her own interpretation of the design object. The expected world sits within the interpreted world and represents the designer's intentions and predictions of what the design object could be. In both the expected and interpreted worlds, the design object is described by an instance of (F), (B) and (S). Transitions from one world to another is carried out by four processes. The design object in the external world is interpreted by the designer (process 1 Fig.2) and can be adjusted with existing design concepts from the designer's experience by a constructive memory process (process 2 Fig.2). The interpreted version of the design object can lead to a focus to alter design expectations (process 3 Fig.2) that can provoke an action on the external representation of the design object (process 4 Fig.2).

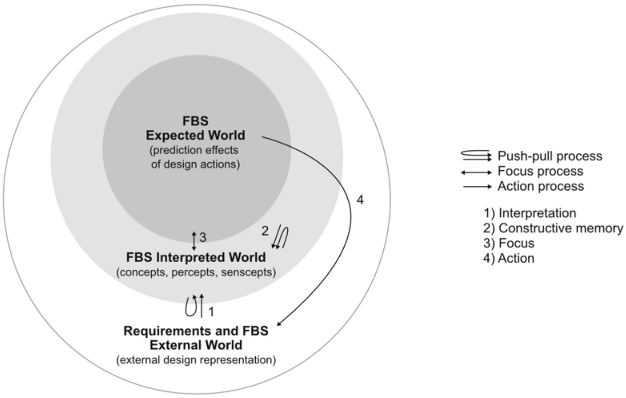
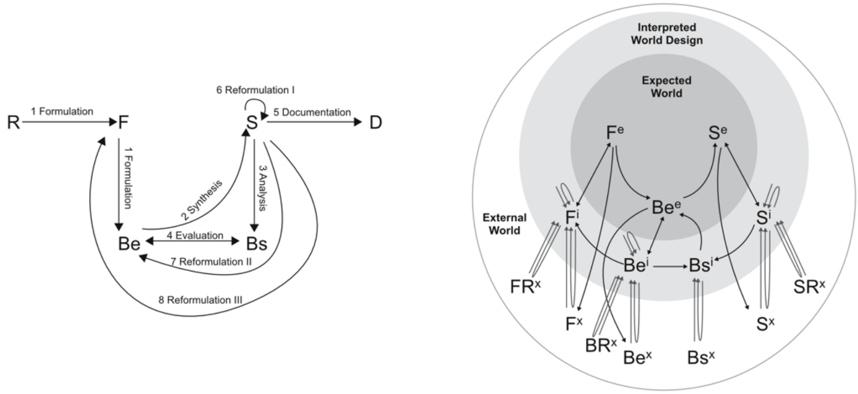


Figure 2. Situated design framework (based on [15])

Each of the eight design processes from the FBS ontology (Fig.3(a)) are mapped onto the situated design framework (Fig.3(b)). The diagram expresses situated design process of a single designer (see [15] for more details). In the sFBS framework we consider a co-design process, an FBS process that starts with a design issue formulated by one designer, followed by another design issue enacted by another designer. For instance, a co-constructed FBS analysis process would imply that designer A formulates a design Structure (S) that designer B analyzes by formulating a Behavior derived from that structure (Bs). The model is commutative which implies that designer A's actions are potentially similar to designer B's actions (Fig.4). Nonetheless, the situatedness of the design activity entails that designer A and designer B will potentially react differently to what their team mates do.



(a) (b)

Figure 3. (a) FBS framework, (b) situated FBS framework (based on [15])

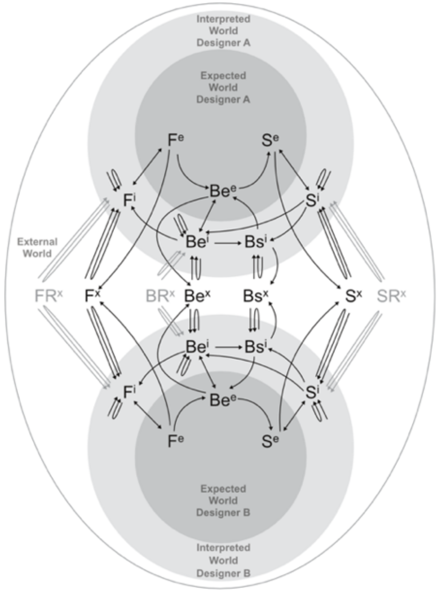


Figure 4. Situated sFBS co-design model

2.2 Data description

The source data for this study is two cohorts of undergraduate mechanical engineering students from a state university in Utah, USA, working on the same design task in teams of two: homogeneous teams are composed of two male students, and heterogeneous teams are composed of one female and one male student. A total of 10 heterogeneous teams and 18 homogeneous teams were analyzed for this study. The sample data used is taken from a wider study on mechanical engineering design (see [19]). The task was the design of a window lifter and each session lasted around one hour.

2.3 Methodology

Each co-design session was video-recorded. We ran a protocol analysis on our dataset using the FBS ontology [14], [15]. Each protocol was coded twice by two different coders who then arbitrated to produce the final coding to ensure data reliability. Rather than using Cohen's kappa we measured coding reliability by comparing each coder with the arbitrated coding which gave an average of 85% agreement. Each segment of the protocol is coded with one of the six design issues and with the speaker of the utterance (designer A male or female and designer B male). A double coding system (FBS design issues and speaker) was applied in order to measure the distribution of design process for four possible interactions: student A to student B, student B to student A, student A to himself/herself and student B to himself.

A t-test analysis and the effect size between the two teams' conditions provide statistical results of differences between the two cases. The t-test aims to test the hypothesis that our two cohort samples can come from the same sample data. For the effect size analysis, we used Cohen's D value to measure the magnitude of the significant differences we found between our two cohorts. A correspondence analysis covering the designers' interactions and the FBS design processes is carried out to provide a categorical basis for comparisons. To obtain a qualitative understanding of co-design processes for each cohort, we represent dominant processes on our sFBS co-design model.

3 Results: revealing diversity in team design cognition

For each of the 28 protocols, the distributions of individual and co-design processes were measured. Design processes are quantified based on syntactic relationship from one segment to the next, adjacent segment. A formal design process is counted when the transition from an FBS design issue to another of the FBS design issue represents one on the eight design processes defined in the FBS ontology (Fig.1). Otherwise, the transition is not considered a formal design process, although it is part of the design activity. For each design process, a speaker transition is associated from the four possible speaker transitions: student A to student B (A>B), student B to student A (B>A), student A to herself or himself (A>A), student B to himself (B>B). A co-design process is accounted to be an FBS design process co-constructed by the two students (A>B or B>A). Any other design process constructed by only one of the two students (A>A or B>B) is considered an individual design process.

3.1 Gender's diversity effect on individual design process

For each FBS design process formulated during a session, which represents between 60 and 70% of the overall protocol segment transitions, we looked at the associated designer's transitions (A>A, A>B, B>A and B>B). For the all-male teams, we observed that there is always a dominant or more involved student in the individual design participation and a less dominant one. For these homogeneous teams, the normalized distribution mean for the dominant student in individual design processes is 54.1% (SD=10.4) whereas the normalized distribution mean for the less dominant student in individual design processes is 30.4% (SD=7.9). When we looked at the heterogeneous teams, we found that for 80% of the cases, female students were the less dominant student in the formulation of individual design processes than their male counterpart. Individual design processes for female students in heterogeneous teams have an average of 34.3% (SD=11.5) whereas their male team mates' distribution mean for individual design processes is 44.7% (SD=12.1).

In order to explore if male students design behavior was different depending on the gender of their teammate, we conducted a t-test analysis between male to male design process distribution in mixed teams (mean= 44.7, SD=12.1) and dominant male to male design process distribution in all male teams (mean=54.1, SD=10.4). The p-value (0.055) supports that there is no significant difference in male students' distribution of individual design processes depending on the gender of their teammate. To obtain a more qualitative understanding of female and male students' design behaviors, we used a correspondence analysis between students' gender and individual mean distributions of FBS design processes (Fig.5). The results of the correspondence analysis cover the entire data variance (Dim 1 = 71,2% and Dim 2 = 28,8%). In our dataset, there were three possibilities regarding individuals and team mates' gender: females co-designing with males (F>M), males co-designing with females (M>F) and males co-designing with males (M>M). Each type of co-design appears in a different quadrant of the correspondence graph, that highlights relative differences concerning the design processes each individual uses (Fig.5). Females sit in the same quadrant with Reformulation 2 and Analysis. Males in heterogeneous teams and males in homogeneous teams sit in opposite quadrants on the graph. The former is in the same quadrant with Synthesis whereas the latter appears to be related with Evaluation (Be>Bs).

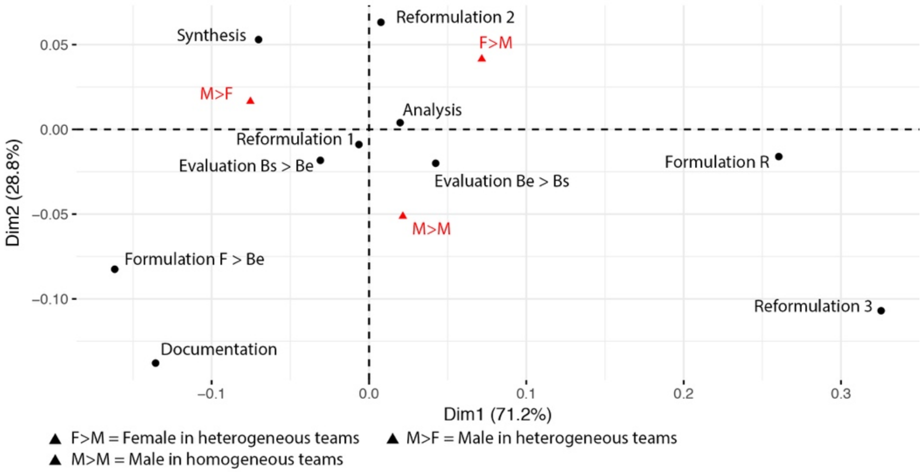


Figure 5. Correspondence analysis of design process and students' gender

3.2 Gender's diversity effect on co-designing

The normalized mean values of design processes from the two cohorts show that the distributions of individual design processes is similar for the heterogeneous teams (52.8%, SD=4.8) and the homogeneous teams (52.7%, SD=4.7). The distributions of co-design processes for heterogeneous teams is almost 1.5 times higher than homogeneous teams, (14.1%, SD=2.7, for heterogenous teams and 9.7%, SD=2.8, for the homogeneous teams). The t-test and effect size analysis on the design processes distributions show that the difference of distribution of co-design processes is significant between the two cohorts (Table 1). The p-value from the two tailed t-test on the co-design processes distribution is less than 0.05 that implies a significant difference between the heterogeneous and homogeneous teams concerning the distribution of co-design processes. The Cohen's D value of 1.6 shows a very large effect size and confirms the strength of the significant difference between the two cohorts.

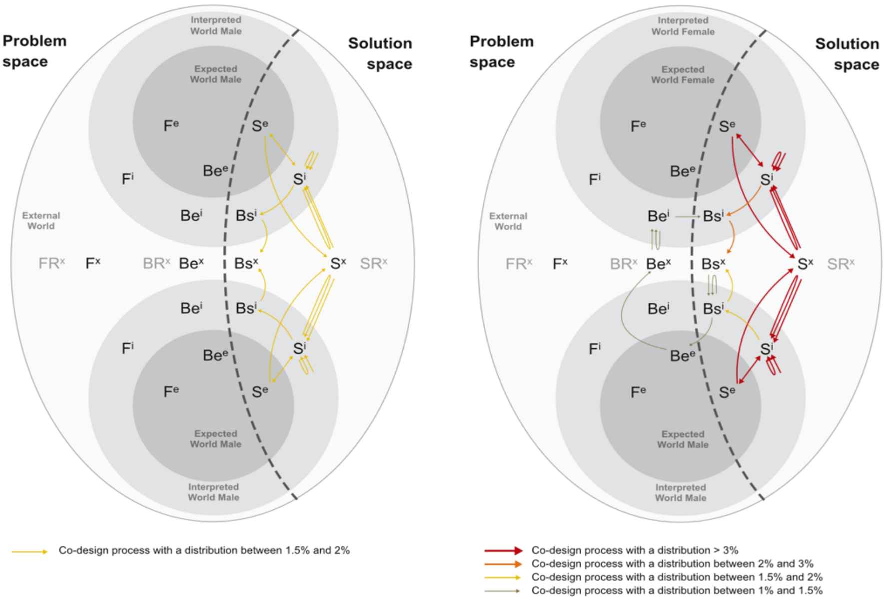
Table 1 – T-test and effect size of design processes between the two cohorts

	Significance (t-test p-value)	Effect size (Cohen's D value)
Co-design	**0.0007**	**1.6**
Individual design	0.96	0.0

3.3 Qualitative exploration of co-design behaviors depending on genders

Our sFBS co-design model gives a qualitative representation of co-design processes from which quantitative data can be derived and acts as a baseline to compare diverse co-design situations. Our model accounts for 22 potential co-design processes. We used the sFBS co-design model to represent dominant co-design processes for homogeneous teams (Fig.6(a)) and heterogeneous teams (Fig.6(b)). The normalized distribution for each co-design process varies between 0.0 and 2.7% of all sFBS design processes of the homogeneous teams and 0.0 and 3.7% of all sFBS design processes of the heterogeneous teams. In our sFBS co-design diagrams, we used a threshold of co-design processes that represent more than 1.0% of all sFBS design processes (i. e., at least 5 occurrences in a session) and did not consider processes with a lower occurrence level.

For homogeneous teams, both participants (males) have identical co-design behaviors. The co-design activity is uniquely set in the solution space, where designers either analyze or reformulate existing design structures (S). For heterogeneous teams, females (represented on the top of Fig.6(b)) and males (represented on the bottom of Fig.6(b)) display a different co-design behavior. For both, the reformulation of a design structure (S) formulated by the other into another design structure (S) is the dominant co-design behavior. Co-analyzing is also a frequent process they execute. We also observe co-constructed evaluation processes that were not present for heterogeneous co-design behaviors. Evaluation is the comparison between an existing design behavior (Bs) and an expected design behavior (Be), or inversely. In the heterogeneous teams, females tend to compare expected behaviors (Be) formulated by their male teammate to an existing behavior (Bs). While males tend to compare existing behavior (Bs) formulated by their female teammate to an expected behavior (Be).



(a) (b)

Figure 6. (a) sFBS co-design processes for homogeneous teams (b) sFBS co-design processes for heterogeneous teams

4 Discussion

We introduced a tool based on the sFBS ontology that gives quantitative measurements of co-design behaviors for different design situations. One strength of this tool is its capability to reveal the effect of diversity in team design. To explore this dimension, we looked at gender diversity and found design behavior differences between two cohorts: homogeneous teams of two male members and heterogeneous teams of one female and one male member. Popular gender beliefs depict male and female with different personality traits, associating design creativity with masculine-agentic characteristics more than feminine-communal ones [9], [11]. Although our study's focus was not on design creativity, we expected to observe differences in the design processes and team dynamics between our two cohorts. At the individual design level, we found that males in heterogeneous teams dominated the activity in terms of the quantitative production of design processes. Co-designing during the design session was significantly higher for heterogeneous than for homogeneous teams. Looking in more detail at the type of co-design processes dominating the sessions, we found that heterogeneous teams display a much richer set of co-design processes compared to homogeneous teams. Our findings align in a general way with gender stereotypes, but further experiments with all female teams should be carried out and analyzed before drawing any general conclusion on gender effect on team design. Indeed, the increase of collaboration in teams with female could be because those teams are heterogeneous not specifically because there is a female in the team. The design domain in which the experiment took place, mechanical engineering design, is dominated by male students. Different design domains where the percentage of female students is higher and greater than 50%, such as architecture or fashion, should be studied as well, to provide for a fuller understanding of the effect of gender in design teams. However, the research reported in this paper provides specific results of the effect of gender diversity in teams on which to build further.

This study of team dynamics related to gender diversity was also a means to explore and assess the relevance of our methodology to reveal differences in the design process linked to the concept of diversity. Our future work will consist of deepening our understanding of gender diversity effect on design and co-design and also exploring how other diversities affect team design processes.

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