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Effect of Gender Orientation of the Design Task on Design Team Performance: A Preliminary Study

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Abstract

This study highlights the potential impact of the gender orientation of the product design task on the performance of design teams with different gender compositions. It then summarizes the methodology and results of a preliminary study conducted at The Pennsylvania State University during fall 2002 using two sections of an Introduction to Engineering Design course. The pilot study used 16 engineering design teams that completed two design projects. The first design project is a guided project and the second one is an open-ended, industry-sponsored project. The data collection was done during the second design project, which lasts about 8 weeks of the semester. Preliminary results indicate that design experience affects the performance of design teams. In addition, despite the fact that the gender orientation of the design task is not found to be significant—as it is quantified for this preliminary study—the increase of female students in design teams result in lower design performance. However, the data set included does not warrant a conclusion on the effect of the gender orientation of the design task on design team performance. Therefore, further experimentation is recommended.

1. Introduction

Due to their numeric minority in the engineering classroom, female students in engineering programs often report feeling isolated and undervalued by their male peers. For instance, a recent study reported that women are less likely to plan on attending graduate school because of their discomfort in the engineering academic environment [1]. This discomfort may be further magnified in a product design team environment resulting in inhibited performance within a mixed-gender team. Accordingly, homogeneous design teams were found to be better performing when compared to their heterogeneous counterparts [2].

In addition, the potential discomfort of female students in a design team may be affected positively or negatively by the nature of the design project because of: (1) their perception about the gender orientation of the product design task domain, and (2) their familiarity with the use of the product that is being developed. This positive or negative impact on the design team performance due to the nature of the design task has been suggested recently by Okudan [3]; and is referred to as gender orientation of the design task.

In a similar manner to the perception that occupations have a gender orientation, design tasks may also be perceived to have a gender orientation; thus, the gender orientation of the design task is a possible variable that affects the performance of design teams. An example of the perceived gender orientation of occupations can be inferred from Table 1, which suggests that engineering overall is perceived as a masculine occupation. The Shinar mean in Table 1 is from the study by Shinar [4] that had high school students rate the gender orientation of occupations using a 1–7 Likert scale where one is the most masculine, seven is the most feminine, and four is gender neutral. Later, this study was replicated by Beggs and Doolittle [5] (from which the Beggs and Doolittle Mean in Table 1 is derived). Both studies used the data for the percentage of women in various occupations collected by the Bureau of Labor Statistics for 1975 (Shinar's study) and 1988 (Beggs and Doolittle study). A portion of these data is included in Table 1 in the order of increased perceived femininity of the occupation.

Table 1. A comparison of perceived gender orientation of occupations from masculine to feminine.

Occupation Title	Shinar Mean	Beggs and Doolittle Mean
Mining Engineer	1.417	2.007
Forestry Engineer	1.917	2.401
Engineer	1.917	2.669
Mathematician	3.167	2.965
Computer Programmer	3.417	3.668

Beggs and Doolittle's [5] replication of Shinar's study showed a significant shift in the rating of these occupations towards gender neutrality, which can be explained by the increasing number of women in these occupations [6]. However, despite the fact that Heilman [7] predicted that women will begin to feel more comfortable with traditionally male dominated occupations as the proportion of women in these occupations increases, recent studies still indicate a gap in confidence levels of female and male students. For example, a recent study conducted at 17 institutions found female students to have consistently lower confidence levels in their background knowledge about engineering and in their ability to succeed in engineering [8].

Following this same logic, the domain of the product design task and the familiarity of the product's usage to the members of the design team may be influential on the performance of design teams. For example, when faced with a male-oriented design task (perceived masculine as measured in Shinar [4] and Beggs and Doolitle [5] studies) and their minority status in the engineering classroom, the female engineering students' performance can be inhibited. Thus, mixed-gender teams may not perform as well as their all-male equals. Conversely, male students may have inhibited performances when faced with a female-oriented design task. In fact, this was observed for most of the male engineering students enrolled in the Introduction to Engineering Design course during the fall 2000 semester when Kimberly–Clark, Inc. sponsored the design of a single-season rain garment and its automated assembly line.

The most relevant study with published findings in this area was conducted by Wentworth and Anderson [9] wherein they studied emergent leadership as a function of sex and task type. Three different tasks were used in their study. The groups were required to reach a consensus about their decisions. For the male-oriented task, the group members were instructed to invest a $10,000 inheritance their young cousin had just received. The neutral task directed the group to advise a young married couple on how they should best spend a recently received $10,000 inheritance designated solely for the use of entertainment items such as recreation vehicles. The female-oriented task required the group to advise a young female friend how she should best spend a recently received $10,000 inheritance designated solely for her wedding. All three tasks were pre-tested in classes of undergraduate psychology students in order to validate their gender orientation. A 7-point scale was used for validation (from 1 for most masculine to 7 for most feminine: masculine task, m=3.47, n=45; neutral task, m=4.31, n=13; feminine task, m=5.02, n=46). The duration of each task was only 20 minutes, and the perceived gender orientation of the task was not found to significantly affect team task performance.

No other published research findings have been found that would indicate that this potential effect of perceived gender orientation of the product design task on the performance of individual and team design performances has been studied for a longer period of time in an engineering classroom setting. This study is a preliminary attempt to fill this void.

2. Experimental design and application

For this preliminary study, two sections of the Introduction to Engineering Design course (ED&G 100) were used. During this course, project teams comprising four students each work on two design projects over a 16-week semester. Design projects focus on product improvement or solution designs. The first project is a guided project in that students follow steps out of a design manual to complete a prototype. The second project is industry sponsored. For this preliminary study data were collected during the second design project.

In fall 2002, the second design project was sponsored by Fleetwood Folding Trailers, Inc. (FFT). This company manufactures a line of pop-up campers under the Coleman trademark. As a design problem, students were asked to design and prototype a next-generation human-powered system for set-up and teardown of a pop-up camper that does not rely on any external power source other than manual power. Currently, Coleman folding trailers have a manual crank system that raises and lowers the roof. FFT has used this lifting system for many years; however, they were interested in ideas for a next-generation system that also used human power.

In this design task, the students were given the following critical design requirements in the design of their mechanism:

1. The system must be able to lift a minimum of 500 lbs in addition to the weight of the roof.
2. The system must be a human-powered solution, although it may have a powered option that does not rely on external power sources.
3. The system must have an integrated mechanism to allow the roof to be self-supporting.
4. The roof cannot require any external supports after the top is raised.
5. The system must have an internal "stop" so that it does not exceed limits and tear the

tenting material.

6. The system must have a materials cost goal of less than $145.
7. The system must operate in and be suitable for a variety of outdoor environments.

The students were expected to provide the following key deliverables:

1. A project report and a website with project write-up including user needs analysis; all concepts generated and a design selection matrix; calculations of required torque and forces to move the mechanism, particularly as related to a user; cost estimate,
2. Prototype of system/mechanism design,
3. CAD drawings of system/mechanism design.

Two sections included in the study were taught by different instructors and thus, inevitably, there were slight differences in course instruction and various relevant facilitations, such as the procedure by which teams were formed. In one of the sections (section 8) teams were formed randomly to yield 2 lone-male, 2 lone-female, and 4 gender-balanced teams. In the other section (section 11), teams were formed using the data collected on a questionnaire, which was administered at the beginning of the semester. The questionnaire contained the following questions: semester standing; (anticipated) major; expected grade in course; course load during semester; if they work, average hours/week; prior experience (if any) in graphics/technical drawing (drafting type, course, and level), computer skills (list general knowledge, specific software, computer platforms, estimate of proficiency), and lab work (physics class, chemistry, workshops, instruments, tools); what hobbies they have; why they are interested in engineering as a major and as a possible future career; and how committed they are to graduating as an engineer. Using these data, it was intended to ensure there is a good mixture of majors, prior skill sets, and hobbies represented on each team. In addition, an attempt was made not to isolate a single female on a team.

An identical design experience and familiarity questionnaire was administered to both sections right before the design project was introduced. This questionnaire included questions relevant to students' self-assessment on their 1) familiarity with camping, 2) familiarity with folding campers, 3) their like/dislike of camping, 4) their design project experience, and 5) their design knowledge. Answers to these questions, which were designed to be given using a Likert scale, were then reduced to two independent variables as 1) familiarity with product domain, and 2) design experience; and are tabulated as team averages. Table 2 shows these data for both sections.

Table 2. Design domain familiarity, design experience and gender orientation of task for both sections

Section	Team	Gender composition	Product domain familiarity	Design experience	Gender orientation of team towards design project
8	1	1	2.5	2.9	9.7%
8	2	3	1.9	2.8	61.4%
8	3	0	2.2	2.8	8.1%
8	4	2	1.6	2.2	48.4%
8	5	2	2.3	3.8	36.3%
8	6	1	2.2	2.9	42.4%
8	7	2	2.2	3.0	38.7%
8	8	2	1.8	3.5	36.5%
11	1	0	1.4	3.0	8.0%
11	2	2	2.0	2.5	35.4%
11	3	0	2.3	2.5	12.6%
11	4	2	2.3	2.7	33.1%
11	5	0	2.9	3.4	6.4%
11	6	1	2.8	2.4	48.5%
11	7	0	2.1	1.7	7.5%
11	8	0	1.9	1.6	12.6%

In Table 2, gender composition of teams and gender orientation of the team towards design project are also reported. Gender composition was quantified as the number of female students in the team. The design task's gender orientation was quantified as the average of differences between the ten-year average of a student's intended major's graduation percentage for student's gender at Penn State and that of the original and current designers of the lifting mechanism. In order to make this calculation for each student, we first requested and received from FFT the profiles of the original designer and current design staff at the company.

The original designer of the lifting system (back in the late 1960's) was a career engineer who did not have a formal engineering background. He went to the school of "hard knocks" and worked for Coleman his entire career. He was a very gifted designer and was self-taught in product development, having worked in manufacturing. The current FFT Engineering Department staff has the following training: 1) Director of Engineering and Product Development. Male. No college education, 33 years with Fleetwood. 2) Chief Design Engineer. Male. BS Civil Engineering, PE license (Civil), 25 years of engineering experience. 3) Design Engineer. Male. BS Aerospace Engineering, PE license (Mechanical), 17 years of engineering experience. 4) Engineer. Male. BS Mechanical Engineering, new hire. 5) Design Engineer. Male. BS Mechanical Engineering Technology, 20 years of manufacturing experience. 6) Product Development Manager. Male. AA Industrial Design Technology, 15 years experience. 7) Tooling Engineer. Male. No degree, 35 years of manufacturing experience. 8) Industrial Engineer. Male. BS Industrial Engineering, 10 years of manufacturing experience. 9) Industrial Engineer. Male. BS Mechanical Engineering Technology, 10 years of manufacturing experience. 10) Industrial Engineer. Male. No degree, 20 years of manufacturing experience. This information indicates a strong masculine orientation of the design task given to the students.

For this study, we have determined the following independent variables, which are summarized in Table 3.

Table 3. Independent variables.

Independent variables	**Levels**
1. Gender composition of the team	All male (0), all female (4), 1 male and 3 female (3), 2 male and 2 female (2), lone female (1)
2. Blocking variable (Section)	Included due to differences of instructor, teaching time, team-formation procedure for both sections
3. Product familiarity	As measured by the questionnaire using a Likert scale
4. Gender orientation of the team towards design project.	Quantified as explained above
5. Design experience	As measured by the questionnaire using a Likert scale

3. Results

Design performance of teams was assessed in a slightly different way for each section. For section 8, design performance evaluation consisted of team quizzes, peer project evaluations, and a blind review of project reports and websites. These assessments have weights of 5%, 23.75% and 71.25% respectively. For section 11, design project performance was assessed using the following breakdown: 10% for preliminary design review (a website containing user needs analysis through concept selection), 30% for oral presentation and prototype demonstration, and 60% for project report and website. However, for both of the sections second design project represented 25% of the overall grading for the course. For this study, only the blind review of project reports is included to minimize the potential bias due to subjective and peer-based grading. An instructor, who taught ED&G 100 during the same semester using the same industry-sponsored project, completed the blind review for both sections. Results of this blind review are given in Table 4.

Table 4. Design performance.

Section	**Team**	**Design performance**	**Section**	**Team**	**Design performance**
8	1	84.50	11	1	88.30
8	2	79.50	11	2	82.50
8	3	92.00	11	3	80.00
8	4	78.50	11	4	73.30
8	5	95.00	11	5	91.67
8	6	85.00	11	6	83.33
8	7	95.50	11	7	83.33
8	8	90.50	11	8	81.67

When the independent variables summarized in Table 3 were investigated for their potential effect on the design project performance using a multiple regression the following results were achieved, where:

C_1: Section
C_3: Gender composition of team
C_4: Product familiarity
C_5: Design experience
C_6: Gender orientation of the product design task
C_7: Design project performance

The regression equation is

$$C_7 = 84.4 - 1.42C_1 - 3.02C_3 - 0.12C_4 + 6.66C_5 - 0.004C_6$$

Predictor	**Coef**	**SE Coef**	**T**	**P**
Constant	84.36	15.18	5.56	0.000
C_1	-1.416	1.061	-1.33	0.212
C_3	-3.070	2.786	-1.10	0.296
C_4	-0.121	3.594	-0.03	0.974
C5	6.661	2.746	2.43	0.036
C6	-0.0038	0.1463	-0.03	0.980

S = 5.013 R-Sq = 58.2% R-Sq(adj) = 37.3%

Analysis of Variance

Source	**DF**	**SS**	**MS**	**F**	**P**
Regression	5	349.81	69.96	2.78	0.079
Residual Error	10	251.30	25.13		
Total	15	601.11			

As can be seen, the model accounted for 58.2% of the variation in design performance. Design experience is the only independent variable to have a significant positive effect on the performance of design teams. Gender orientation of the design task is not found to be significant. Gender composition of team has a negative impact on the performance of design teams. Although it is not significant, this means that an increase in the number of female students in a design team resulted in lower design performance. This point, in fact, is aligned with the hypothesis of this study in that when a design team tackles a male oriented design task, female members may perform in an inhibited way resulting in lower team performance. In this preliminary study, due to a limited number of design teams, it is not possible conclude on the effect of the gender orientation of the task on the performance of individual members, and the design team overall. Therefore, further experimentation with a larger number of teams is necessary.

4. Conclusion

This paper highlighted the potential impact of the gender orientation of the product design task on the performance of design teams with different gender compositions. It then summarized the methodology and results of a preliminary study conducted at Penn State, during the Fall 2002 using two sections of the Introduction to Engineering Design course. Preliminary results indicated that design experience affects the performance of design teams. In addition, despite the fact that the gender orientation of the design task was not found to be significant, as it was quantified for this preliminary study, the increase of female students in design teams resulted in lower design performance. However, the data set included does not warrant a conclusion on the effect of the gender orientation of the design task on the design team performance. Therefore, further experimentation is recommended.

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