Discourse Between Men and Women during PBL Engineering Group Work

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ABSTRACT

Students in STEM-related fields benefit from small group work. However, the gender composition of groups may influence learning outcomes, particularly in male-dominated fields such as engineering. We conducted an exploratory study, using a qualitative case study approach, and used video analysis to show how women interact with male classmates during small group PBL work. Students in a sophomore undergraduate engineering course were assigned to different groups for three assignment. Each five person group was made up of zero to two women and three to five men. We used constructivist grounded theory to develop inductive codes to analyze the discourse in the videos. We found that women in the 1-woman groups initiated discussions less, initiated and participated in conceptual discussions less, and their contributions were acknowledge less by their male peers, than in 2-woman groups. Particularly due to the lessened engagement with conceptual discussion demonstrated by women in 1-woman groups, our findings indicate that it is better to have two women than one woman in a group.

INTRODCUTION

Women are underrepresented in the physical sciences compared to men, despite calls for reform (Hill, Corbett, & Rose, 2010). For example, it is well established that fewer women enroll and persist in undergraduate engineering programs than men, and these differences are not explained by test scores or by preparation (Sawtelle, Brewe, & Kramer 2012). In 2006, only 27% of the bachelor's degrees awarded in mathematical and physical sciences were awarded to women (National Science Foundation, 2008). Three years later, in 2009, only 25% of those employed in these fields were women (US Bureau of Labor Statistics, 2009). Hence, the disparity of women in engineering disciplines (deeply grounded in mathematical and physical sciences) is both a national and global issue. From an economic perspective, drawing from a larger pool of students allows for selection of the most qualified and capable candidates and maximizes the diversity of perspectives that potential employees can bring to those professions.

While low retention rates in engineering programs in the United States (King 2012) have been identified as a general problem, disproportionally low retention rates of women (Sawtelle et al. 2012) further exacerbate the retention issue. Even for women who graduate from undergraduate engineering programs, 50% leave engineering, compared to a 10% attrition rate in men (Society of Women Engineers, as cited in Singh et al. 2013).

Science education researchers and educators have explored instructional strategies, including small group work, to address this problem. Working in small groups benefits all students in STEM-related fields by increasing achievement, persistence, and positive attitudes towards STEM (Springer, Stanne, & Donovan 1999). We describe the results of an exploratory qualitative study of in-class group work during problem-based learning (PBL) tasks. Our analyses centers on the experiences of the women and group interactions between men and

women during PBL tasks. The objectives of this study are interrelated to those of our other research, which explores how PBL prompts can be designed to best increase student affect and learning outcomes about engineering tasks. We posit that being sensitive to gender dynamics in purposeful grouping of students can be informative for instructors who hope to increase the attitudes and knowledge of all of their students.

Women in Engineering

Differences in test scores and student preparedness do not explain the low enrollment and retention of women and minorities in undergraduate engineering programs (Sawtelle et al. 2012). There is a push from the National Academy of Engineering (2005) to update undergraduate education programs to include more direct experience with real-world problem solving. While there is evidence that these kind of direct learning experiences are particularly key in facilitating learning for women engineering students (Sawtelle et al. 2012), the way projects and group work are structured may influence outcomes. Furthermore, because women in engineering are in a field that is not stereotypically aligned with female gender-identity, grades and performance in class do not have as direct an influence on retention and success in engineering as these factors do for men (Kronberger & Horwath 2013).

In a meta-analysis, Springer et al. (1999) found no significant difference in student achievement for all-female or mixed-gender groups, but did find a more positive effect on attitudes for all-female groups in one study. Trying to shed light on the experiences of men and women during engineering design courses, Laeser et al. (2003) investigated the contributions of male and female students during group work. They used Eberhardt's types of team functions, with five *task functions* (initiating, information seeking, information giving, clarifying, and summarizing), aimed at achieving the team objective, and five *process functions* (harmonizing,

gatekeeping, encouraging, compromising, and standard setting) aimed at effective team functioning. They found that groups of majority male, female, with gender parity functioned similarly.

The findings of Laeser et al. (2003) are in contrast both with prior, not engineering specific research, where males tended to do more task and females more process functions, as well as more recent engineering-specific research.. Based on their findings, Laeser et al. (2003) suggested that men and women in engineering may interact differently than a general population of men and women, and more research specifically studying the interaction of mixed gender groups in engineering is needed. However, recent research that looks deeper into gender issues in engineering indicates that even if a gender effect is not immediately apparent, there may be underlying ramifications of gender interactions, both during a student's undergraduate career (Ahlqvist, London, & Rosenthal 2013; Jagacinski 2013; Kronberger & Horwath 2013), and after they enter the workforce (Singh et al. 2013).

Studying group dynamics is important, but it is critical to recognize that there may be several explanatory variables for group outcomes or communication patterns. Barker (2005) studied group behavior in several computer science courses. She cautioned that when student groups feel pressure to accomplish tasks, they can make choices about the division of labor that are for the sake of convenience rather than learning. Students may be assigned tasks that use their existing abilities, preventing them from learning new skills. This can create a cycle during which students coming in with less technical knowledge or experience leave the group project with continuing experience gaps. Moreover, not all students, including women's experiences are exactly the same. Ingram and Parker (2002) described two students who were the only women on their respective teams in an engineering technical communications course. Both women demonstrated

some “traditionally female” communication styles (one tried to avoid conflict between group members by doing more work; the other expressed her lack of confidence with some tasks and adopted a secretarial role during meetings). However, the more functional of the two groups was led by a male student who gave significant attention to team members’ social and emotional needs. The authors concluded that assigning only one woman to a group should be carefully considered, and indicated that group assignments should be created in ways that encourage women to assert their contributions and for men to work cooperatively. PBL activities help to reinforce authentic applications of scientific concepts; therefore, studies exploring how tasks are interpreted and enacted by all students (men and women) are relevant and informative for educators.

The interactions that occur between students in small group work are influenced by the composition of the group. Gender, race, and social status bias the group views, and influencing how the students work together (Oliveira & Sadler 2008). When women perceive negative experiences in STEM fields as relating to their gender, their gender-STEM compatibility decreases, and their perceptions of evaluated threat increase (Ahlqvist et al. 2013). As stereotypical perceptions of women are opposite those of stereotypical perceptions of those in STEM fields, gender-STEM compatibility is a key component in women succeeding in STEM fields (Ahlqvist et al. 2013).

Groups that create a supportive environment with buy-in into collective cognitive responsibility are more able to negotiate disagreements toward conceptual convergence (Oliveira & Sadler 2008). Since women in undergraduate engineering classes are more likely to feel undervalued and unheard, whereas men are more likely to feel that they are doing an unfair amount of work (Felder, Felder, Mauney, Harmin Jr., & Dietz 1995), it is likely that the way

groups are structured will have a large impact on the outcomes from group work. While vicarious learning experiences have been identified as important for women students in physics (Sawtelle et al. 2012) , a closely related discipline to engineering, poor quality group work experiences are unlikely to positively influence student learning. However, the difficulty of small sample sizes of women in engineering classes makes it difficult to study the impact of gender in group work (Casper, Atadero, Balgopal, & Rambo-Hernandez 2013; Purzer 2011)

Previous studies have found that women may feel undervalued and unheard in group work (Felder et al. 1995) and may prefer working in women-only groups (Baker, Krause, Yasar, Roberts, & Robinson-Kurpius 2007). In fact, performance of those who participate in women-only groups is higher than those from mixed-gender groups (Laeser et al. 2003). Felder et al. (1995) recommends that women should not be outnumbered by men in group work, but the small number of women in engineering classes often limits the creation of women-only, or even balanced-gender groups. Even in classes with few women, groups of two women instead of a lone woman are logistically possible.

During a study examining how PBL prompts impacted the “nature of talk” and student learning outcome (Casper et al. 2013), it was observed that men and women in groups interacted with one another in different ways than when there were no women in the groups. This observation prompted the current study, examining how gender composition impacted group dynamics and discourse behaviors.

THEORETICAL FRAMEWORK

Problem-based Learning

Problem-based learning (PBL) is characterized by students working collaboratively in small groups to solve a problem (Hmelo-Silver 2004) and has been associated with increased student

motivation to learn (Gallagher, Sher, Stepien, & Workman 1995). The problem is central to the learning experience and is presented first; knowledge is then acquired through self-directed learning to solve the problem (Gijbels, Dochy, Van den Bossche, & Segers 2005). The best PBL prompts are described as "complex, ill-structured, and open-ended; to support intrinsic motivation, they must also be realistic and resonate with the students' experiences" (Hmelo-Silver 2004). Kittleson and Southerland (Kittleson & Southerland) examined engineering student participation in group work and classified students' "nature of talk" into one of five categories: *administrative, procedural, conceptual negotiation (CN), conceptual explanation (CE),* or *off topic (OT).* Because CN and CE discussions allow students to engage with disciplinary content matter, PBL tasks that promote relatively higher levels of CN and CE talk are preferred.

Discourse Theory

Knowledge is socially constructed and the meaning that words have changes within socio-cultural contexts (Vygotsky, 1986; Gee, 1996). Gee describes Discourse with a capital *D* as being distinct from the use of discourse with a small *d* in order to convey that Discourses reflect symbolic meaning that language holds for both the speaker and the listener. In other words, we use different words in different contexts because we know that those in our community of practice will understand the nuances and subtleties of the phrases used. Gee (1996) explained that, "meaning is something we negotiate and contest over socially. It is something that has its roots in 'culture,' in the very deep and extended sense that it resides in an attempt to find common ground" (p. 12).

Because what we hope to convey is not always perceived by others as intended, discourse researchers must be sensitive to the context of dialogue by considering more than just brief utterances, but exchange of utterances and positioning of verbal moves by those engaging in

dialogue (Goffman, 1959; Charmaz, 2005). For example, people respond to "contextualization cues" in order to make inferences about the speaker's intentions, which necessitate the researcher to be attentive during analyses (Wetherell, Taylor, & Yates, 2001). Through group dynamics individuals can impact conceptual agency (Greeno & van de Sande, 2007), and in turn influence learning outcomes (Greeno, 1997). Balgopal (2014) found that undergraduate science majors expressed concerns about their peers' perceptions of them during classroom discussions and lectures. The participants "were aware of their generalized selves (the "me") as they interacted with others and concerns emerged when they presumed that others had of them that the either could not or did not want to fulfill" (Balgopal, 2014, p. 19).

Considering discourse dynamics within group settings, we explored how men and women interacted with one another during PBL tasks during a sophomore-level engineering course. This study was guided by the following research question: *How did the nature of talk vary during PBL group work as gender composition changed from one woman per group to two women per group?*

METHODS

Our collaborative research team consists of four faculty members (two in civil engineering, one in science education, and one in educational assessment) and a science education graduate student. We analyzed videos from two semesters of a Statics course taken primarily by sophomore civil and mechanical engineering students.

Study Context and Participants

Each class had around 100 students enrolled, of which 35 (four women) students in year 1 and 60 (12 women) students in year 2 consented to video-record themselves participating in-

group work activities using flip cameras. Ninety percent of participants and enrolled students were Euro-American, with an average age of 19.5 years old. The class, Statics, is taken by all Civil and Environmental Engineering (CIVE) students and most Mechanical Engineering students. The content centers on foundational concepts of Newtonian mechanics that are prerequisites for most of the other engineering courses. The course did not have an associated laboratory or recitation section and met 2 1.5 hour periods a week. Because the course has long been regarded as a course that no one wanted to teach, it had traditionally taught by various faculty members who put little energy into revising and updating the course material. The current instructor, a woman assistant professor in the CIVE department, received a federal grant to integrate problem-based learning (PBL) design tasks into the curriculum and to study the impact on students' perceptions about engineering and learning outcomes of Statics concepts. Students were not informed of the interventions prior to registering for the course.

Intervention

All students, regardless of they provided consent to participate or not in the study, were expected to work in groups to complete three PBL tasks, all related to class lecture. In-class group discussions lasted about 5-20 minutes each. Each assignment required students to design and construct an engineering artifact as a group and produce a written report describing how the design task was supported with calculations. Each student was required to participate in each step of the process. Students were randomly assigned to groups with three composition profiles: one woman and three-four men; two women and two-three men; or four-five men. Students were assigned different groups for different projects. The three design tasks included a) building a Rube Goldberg machine to raise a flag; 2) constructing a bridge out of balsa wood and string that

was able to withstand weight from ball bearings; and 3) a strategy whereby friction was used to help the team mascot animal "climb" an inclined plane.

Data collection and analysis

Across both years and all projects, there were 10 videos of groups with one woman and six videos of groups with two women. Women appeared in different videos and in different group types, and while assigned randomly, differences between group types allowed us to make some comparisons.

Initial analyses of videos followed Kittleson and Southerland's (Kittleson & Southerland) "nature of talk" coding scheme, after which videos of mixed gender groups were recoded using inductive coding examining the roles of women in group work. In an earlier study students had significantly higher learning outcomes when CN was higher (Casper et al. 2013).

Informed by Charmaz (2005) constructivist grounded theory methodology, we made sense of group dialogue by carefully interpreting what was said, how it was said, to whom it was said, and the response of the group members. Propositions about how women interact in male-dominated PBL groups during engineering courses were discussed as a research group (drawing on our different expertise and research/teaching experiences), and were used to help inform the coding process. After several rounds of coding video transcripts by two coders, utterances and supporting gestures (e.g., taking notes, turning to a group member) were recorded in four categories: (i) Initiate/Respond (new concept introduced/comment made about a concept or idea previously introduced), (ii) Novel/Reiterate (new idea or information added/reiteration of statement previously made), (iii) Statement/Question (declarative statement/ query about concept), and (iv) Hesitant/Not Hesitant. Hesitancy was defined as displaying at least two of the following characteristics: use of filler words, breaks in speech, rising inflection as if asking a

question, or preface discrediting the claims being made. This is similar to “hedging” code that Oliveira, Akerson, Colak, Pongsanon, and Genel (2012) used in their study.

Additional memos were made about the interaction including, in particular, the way the men responded to women, and the ‘nature of talk.’ Data were organized as: 1) the types of participation and ‘nature of talk’; 2) who, if anyone, led the conversation; 3) if conceptual talk occurred; and 4) who was involved in conceptual talk. In addition, although assignments were submitted by groups of students, each individual was asked to respond to two reflection questions and submit these with the final group project. Students were asked what they learned about the project as well as how they might change how their group worked if they were assigned this project again. A case study methodology was employed for our final analyses to highlight women's interaction styles in small groups (Stake, 2005). The reflections were read by three members of our research team and the overall review of the relevant findings (instances when women discussed group work) allowed us to triangulate our findings of the video coding. Final propositions were informed by all of the data collected. To establish trustworthiness of our findings, a guideline for inter-rater coding was concurrently developed (Charmaz, 2005). One of us coded 21% of the video recordings to establish inter-rater coding reliability. Initially over half of the codes overlapped between two coders. We then discussed the discrepant results, and after clarification of coding criteria, completed the coding process with a 95% coding overlap.

FINDINGS

Women in the 1-woman groups initiated discussions less, initiated and participated in conceptual discussions less often, and their contributions were acknowledged less frequently by their male peers compared to contributions by male peers. Only half (5 of 10) of the 1-woman

groups had instances when a topic was initiated by a woman, compared to all 2-women groups (6 of 6 groups, 11 of 12 women in the groups; Figure 1). A higher percentage of the 1-woman groups (8 of 10) participated in conceptual discussion than 2-woman groups (3 of 6, Figure 1). However, there were more 2-women groups in the first project, were many groups had already worked on their project prior to class discussion.

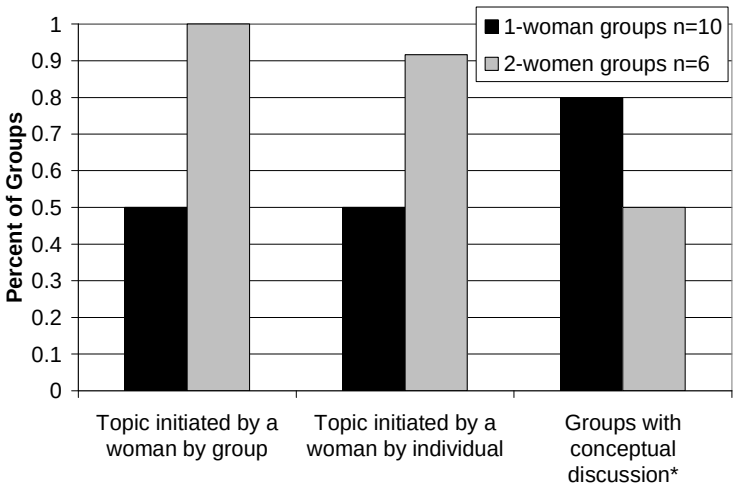

Figure 1: Topic initiation by women and presence of conceptual discussion in 1-woman versus 2-woman groups.

Overall, women, regardless of gender composition group type, rarely initiated the discussion regarding statics or Newtonian physics (CN or CE, Figure 2). For groups that engaged in conceptual discussion, women in 2-women groups initiated conceptual discussion more often (all 3 groups, 3 of 6 women) than in 1-woman groups (1 group). All of the women in 2-women groups participated in conceptual discussions. Of the 1-woman groups, six of eight women participated in conceptual discussions, but only one woman made influential contributions (deemed those that were used during the PBL design task). In two of the 1-woman groups, after a woman introduced a conceptual idea, her male group-mates ignored her comment, and within 1-

2 minutes, after a male peer re-introduced the idea as novel, it was quickly acknowledged by the group. In another 1-woman group, the woman's conceptual contributions were frequent but were mostly reiterative statements.

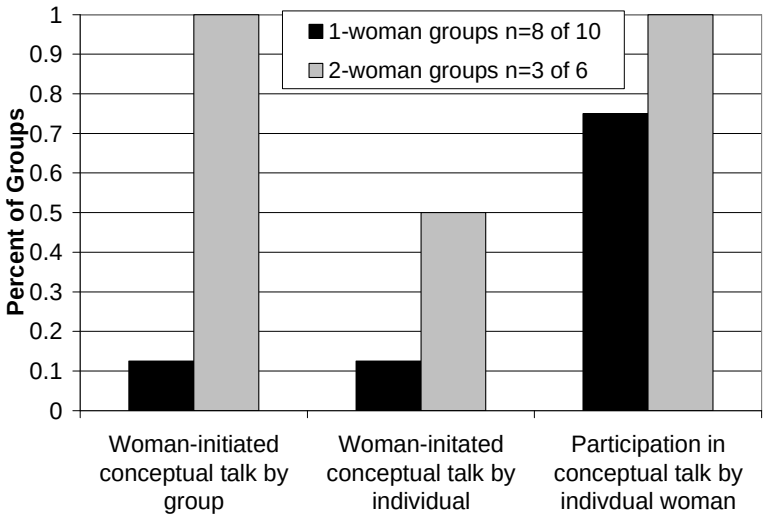

Figure 2: Conceptual talk initiation and participation by women in groups with conceptual talk.

The following dialogue is from one of the 1-woman groups while the students were negotiating how friction is beneficial. They discussed placing a small stuffed animal (school mascot) on a cart to move it up the ramp, a requirement of the friction assignment. All names used are pseudonyms.

> Sam: So then there won't be any analysis for friction.
> Mike and Jim together: The ram on the cart.
> Sam: That's [friction] holding it in there. Oh, so like on top of a cart with wheels that doesn't, it's not like in a box, it's just on top of it?
> Man2: Yeah
> Sam: I gotcha, that would be good. I was like, then there's no analysis if you just put it in a box. Well, we want some analysis.
> Betsy: And I think you can find the μ of sandpaper really easily. So… [who starts speaking while Sam is speaking]
> Sam: Well, we can get the roughest kind of sandpaper cause then it will have the most friction. We can probably even (laughing tone to voice) look up, like, yeah, what the values are for that.

Mike: [indecipherable agreeing statement]
Jim: You can just get the coefficient and put it on there
Betsy: I just don't want it to be too complex
[The conversation then continues on to how many points the project is worth.]

In this example, Sam continued his train of thought regarding the use of sandpaper and seemingly ignored Betsy's statement about looking up μ. None of the three men in the group acknowledged Betsy's contribution, nor directly responded to her suggestion. However, Sam's next comment, following Betsy's suggestion about μ, presents the idea of looking up μ, almost as if it would be a cheat or a work around. Neither he, nor the other group mates, acknowledged that Betsy had already made the same suggestion earlier.

A similar situation occurred in another 1-woman group discussing the same friction assignment, although in this narrative example, the concept that was initially introduced by the woman student was then co-constructed by two male peers in the group. However, the woman was interrupted while trying to state her claim:

Chris: Right, and if there's no friction between that then you're not gonna be able to get up the mountain
Alice: I was thinking the friction helps him go up because, like, because he…
Dale: [interrupting] well, yes [in response to Chris]
Alice: …doesn't slide down because of friction, so that's why friction helps.
Evan: Yeah [appears to be in response to Chris or Dale]
Chris: But…
Dale: Well, if if even if you use like something to push it up you know there's friction between your hand and the device your pushing it up, right? [pause] There's friction, yeah yeah, you can push him halfway up but he won't slide down, or maybe he will slide down because there's not enough or too much friction. So (pause) so, even if you're using your hand there's still friction between your hand and whatever you're pushing him up with.
(pause)
Evan: I don't see how friction needs to be important in achieving your goal.
Chris: Well, because, (pause) I guess it's [pause] you need the fiction, if you didn't have friction, this wouldn't happen.
Dale: It would slip

> Chris: Well, maybe that's why, when you're like tying like something to a weight you need the friction then to hold because the weight would just slip out if there was no friction
> Chris: to hold the weight

In the above dialogue, Dale interrupted Alice to respond to Chris' previous statement. While Alice was persistent in continuing her statement about how friction helps in the situation, none of the four men in the group acknowledged or responded to her statement. Instead, the men were still responding to the last thing Chris said, and Dale continued with his earlier thought about friction (what is doing the pushing and the object being moved). Evan, expressed his uncertainty about the importance of friction, pushed Chris and Dale to expand their explanations. The pauses in Chris' and Dale's statements may indicate that they were both working to understand the concept as they explain, instead of fluidly explaining a concept they already understood. It took the men several discourse moves to arrive at the concept introduced by Alice at the beginning, that friction holds the stuffed animal in place on the ramp.

The lack of acknowledgement of the women's contributions in both of these example narratives illustrates that the group dynamics prevented the respective women from participating fully in group discussions. In both cases, the women attempted to contribute meaningfully to the groups' problem solving efforts (Figure 2). Beyond simply being examples of ineffective group work, if these women perceived these situations to relate to gender, it is likely that this situation would be considered a negative academic event, which would decrease their gender-STEM compatibility, leading to increased perceptions of evaluated threat about being treated differently due to gender (Ahlqvist et al. 2013). This, in turn tends to lead to a decrease in STEM GPA (Ahlqvist et al. 2013). Conversely, if the women simply perceived the men in the group to be poor listeners in general, then the even is unlikely to negatively impact their gender-STEM compatibility (Ahlqvist et al. 2013).

A major difference between these two examples is that in the first group Sam almost immediately stated what Betsy had just said, whereas in the second group several of the men had to work together to construct the information that Alice stated. It would be easier to interpret Sam's restating of Betsy's information, particularly with the laughing tone he uses, as a gender-related situation. Because Chris, Dale, and Evan co-constructed the information the Alice stated, it is clear that they are not simply stealing her words. While the lack of interaction with Alice may still come across as gender related, they may not have understood what Alice said, and as such, dismissed her statement. While there could be many ways to interpret these two situations, it is important to be aware that seemingly subtle nuances in each situation could cause them to have different influences on the woman in each group.

Increased participation by women in pairs

The three women who are in videos in both one and two-women groups provide some insight into how women participate in discourse in different situations (Table 1). None of the three women appeared to be hesitant in either 1-woman or 2-women groups, but all three women were engaged in more discussion when they were in 2-women groups.

Table 1. Three women students were members of both 1-woman and 2-women PBL groups. Their group interaction behaviors are presented and will be described as three case studies. *pseudonyms

Nature of talk and interactions		
Case study	*1-woman group*	*2-women group*
Betsy	Male-led conversation; CN discussion occurred; No initiation of discussion; Responds with short statements, novel and reiterative; Not hesitant. Fears difficulty. CN contribution ignored.	Both male and female-led conversation; No CN discussion; Initiates administrative discussion; novel statements/not reiterative; Not hesitant.
Kelly	Male-led conversation; No CN discussion; Initiates administrative discussion; Responds to some procedural comments; Novel and reiterative statements; Not hesitant; Questions why she consented to study.	Female-led conversation (by the other woman); No CN discussion; Initiates administrative conversation; Supports and expands procedural statements made by other woman; Novel and reiterative; Not hesitant.
Sage	Male-led conversation; CN discussion occurred; In CN agrees with men's ideas; reiterates conceptual statements; Initiates conversation about administrative/ procedural issues; Not hesitant, except for one instance of being repetitive and questioning of herself.	Both male and female-led conversation; CN discussion occurred; In CN asks questions, reiterates conceptual statements, answers one calculation question; Initiates procedural discussion, gets group on task; Not hesitant; In CN men often answer women's questions.

For Betsy, there was no conceptual content discussed in her two woman group, possibly due to prior discussion, but there was in her one woman group (Table 1). In her two woman group the conversation shifted between being male led and female led, whereas in her one woman group the conversation was male driven. While she initiated a discussion of dividing the group work in the two woman group, she did not initiate any topics when she is was only woman. Additionally, when she was the sole woman in the group she interjected comments into the conversation, but rarely said more than one to two sentences at a time, except when helping plan when the group will meet. She also voiced a concern about the project, stating "I just don't want it to be too complex". Overall in both groups, she responded with both novel and reiterating statements and was not hesitant in her utterances.

Kelly had no conceptual conversation in either of her groups (Table 1). In her two woman group, the conversation was led by the other woman in the group, Annie, but Kelly played a supportive role, and often expands the other woman's ideas. Kelly only initiated a discussion in which she explains that it is difficult for her to schedule a meeting because she is rushing for a sorority. Otherwise, she responded, made novel statements or reiterated previous ideas and expanded up on them. She was not hesitant in her utterances. In her one woman group, the conversation was male led, although she did contribute by mentioning what she thought they should do. Additionally, she initiated administrative discussions planning what to do. During the video, she also stated that she didn't know why she agreed to be video taped, something she did not express in two woman group, which occurred first. She made responding novel and reiterating statements that were not hesitant, except for one hesitant question at the beginning.

Sage's group discussions both included conceptual knowledge (Table 1). In the two woman group the males primarily explained content knowledge, and the women primarily asked questions. Sage did answer one of the other woman's questions, but only to assure her that the calculations needed can be done, without further explanation. Both women in the group restated what the men said while the men were answering the women's content questions. While the discussion was both male and female led, the men primarily led with content knowledge, and the women led with questions or points they see as needing to be addressed. Sage initiated the administrative discussion of checking in with everyone's progress, and brought them back from an off topic discussion. She responded with novel and reiterative statements and novel questions. She was generally not hesitant in her utterances, except for when reiterating conceptual information a man had just explained, as indicated by a rising tone at the end of her

statement. In her one-woman group, Sage participated similarly: she asked the male leader of the group questions about what he was looking at in the textbook, and responded to statements he made. As with her other group, she only initiated administrative discussions about organizing the group. She responded with novel and reiterative statements, and was not hesitant, except for one instance where she was asking the male leader a question about what was in the textbook, and she repeats herself.

Contributing conceptually as the sole woman in the group

She was the only woman who initiated conceptual discussion in one woman groups at any point. One woman, Kate was in two videos of two women groups, and one video of a one woman group. In the two women groups, Kate initiated procedural and administrative discussions in the first group, which she clearly led. Kate initiated nothing in the second group, but the other woman in the group initiated conceptual discussions. In the third group, where Kate is the only woman, she initiated conceptual negotiation and procedural talk. However her initiated discussions stemmed from material she had looked up in the textbook during group work.

While we do not have video data on any other women across all three groups, it is possible that Kate's earlier experiences in her 2-woman groups gave her a strong foundation for her last 1-woman group. Additionally, since the information she introduced is based on her reading of the textbook, which she had for reference in front of her, she may have felt more confident than she would have, if she had been suggesting her own ideas.

Women as collaborators

Some women clearly worked together as a team to support each others' propositions during group work. For example, Kelly and Annie were randomly assigned to work together for two assignments (the Rube Goldberg and the Friction assignments). When they were both present during the video recording of the Rube Goldberg planning session, Annie would suggest how to build the machine and Kelly would endorse Annie's ideas, prompting Annie to take on a leadership role. During the reflection of that group work, Annie stated, "I can honestly say that working in a collaboration with other members in our group enabled us to produce a machine much better than one of us could individually." However, during the second group activity, Annie was absent during the initial planning of the Friction PBL task. Kelly then wrote on her reflection, "[if I could change what I did for this group assignment] I would promote thinking outside the box for creative ways to utilize friction," implying that she was not an advocate for her ideas. She continued, "I would seek outside help. I felt ill-equipped to effectively and correctly analyze some of the ideas my group had in mind. Communication is always a skill that can be improved." Annie participated in other planning activities reflected that "There is always room for improvement." This reflection was much less positive than her previous reflection about the importance of group-generated ideas. Although the reflection prompts were open-ended and did not explicitly ask students to comment on group dynamics, mostly women students (with the exception of a couple of men) wrote explicitly about how their group worked as a team.

Women's reflection of group dynamics

Usually comments were fairly positive, such as Alice's comment after the Rube Goldberg, "I'd want to work with my group more because I think working in a group was a good

opportunity to collaborate on things." Hannah concurred, "I enjoyed my group members and what we accomplished as a group." A couple of women made comments about increasing efficiency of their group time. Kelly, on her Bridge assignment reflection, wrote, "I would assign group members parts of the project work that would reflect their unique strengths and skills." This is interesting because she was the only woman for this assignment. When she was with Annie for the first assignment, she appeared to be empowered by her team member's ideas, but by the final and third assignment, she demonstrated a low self efficacy. Only one woman was explicitly negative about her group experience. Lacey did not enjoy her Friction group: "The communication between my group was very poor. I felt I did very little in this project because of the poor communication." The other woman in her group, Hannah, was less blunt but stated that there were "timing issues" and that they would have benefited meeting in class again.

A review of the student reflections (both men and women) does not indicate that students focused on the gender composition of their groups nor did they refer to the fact that their group members changed for each of the three design tasks. Students, both men and women, most often expressed feeling pressured for time. Time pressure has been identified as a key factor in promoting group work where students simply fulfill the tasks within areas where they already feel competent, widening both the experience and gender gap (Barker 2005). Students described the importance of planning ahead and using out-of-class time more wisely. This did not differ for men or women; however, women were more likely to make the comment "our group worked well together" and this comment was only occasionally mentioned in men's reflections.

DISCUSSIONS/ IMPLICATIONS

While all students show gains associated with group work, the experience of men and women in groups can be very different, particularly in engineering where women students are substantially outnumbered by men. In a longitudinal study of chemical engineering students Felder et al. (1995) found that women showed a greater preference for working in groups on homework assignments and during class, but also acknowledged feeling undervalued or ignored by peers when they worked in mixed groups. Conversely, men felt they did more work than others during group work. Women were more likely to identify the greatest benefit of group work as having concepts explained to them, while men were more likely to say explaining concepts to others. In our study we did not explicitly ask students to reflect on their perceptions of being in a group to complete design tasks; rather, we asked them to reflect overall on how their group worked together to complete the task. Therefore, our findings do not address the issue of group work preferences. Yet, we did find that in mixed groups, men were more likely to explain concepts to women than vice versa. Additionally, we also found examples of women's ideas not being acknowledged by male students.

Colbeck, Cabrera, and Terenzini (2001) found that female students were significantly more likely than male students to perceive a difference in how male students treated female students as opposed to other male students in the classroom; the difference in perceptions was even greater when students were working together in small groups. Fortunately, the peer climate was not associated with changes in the academic or career self-perceptions of students in Colbeck et al. (2001) study. However, Ahlquist et al (2013) found that when women perceived that they were being treated differently for being a woman it had negative effects on their gender-STEM

compatibility, higher perceptions of evaluated threat, and lower grades in only their STEM classes.

Parsing out the effect of the influence of gender on students can be difficult. Jagacinski (2013) found no significant gender effect on course grades or course interest, despite women in engineering having lower perceptions of their ability relative to other students in the class, and more doubts about their ability to learn the material, when compared to men in the same engineering class, as well as both women and men in a psychology class. However, Jagacinski (2013) did find that women's decreased perceived ability and self-efficacy did have indirect negative effects. Therefore, it is important to look beyond initial results for effects that may be harder to find.

Addressing the retention problem of women in engineering, which exists both at the undergraduate and professional levels Hill 2010; Singh 2013 is complex since many social factors are influential (Ahlqvist et al. 2013; Baker et al. 2007; Jagacinski 2013), and are stronger predictors of retention than grades (Kronberger & Horwath 2013). Because of these challenges we explored other variables within a classroom setting that might explain women's decisions to stay in engineering. Concurrently, engineering education is exploring ways to promote group work to better promote workforce readiness (National Academy of Engineering 2005). If engineering educators respond to these calls and begin modifying their curricula to incorporate such activities, it is essential that we identify how groups can be assigned or PBL prompts developed to not discourage women from persisting in engineering degree programs.

Due to the low numbers of women currently in undergraduate engineering programs, it is unrealistic to have all women groups (Laeser et al. 2003), or even groups where men do not outnumber women (Felder et al. 1995). Therefore, our study informs the literature that the

presence of two women in mixed gender groups is associated with more opportunities for women to more actively participate and engage in meaningful conceptual discussion. When there were two women in the group, it was more likely that at least one of them would contribute to the group discussion other than for planning and for procedural tasks, and that their conceptual contributions were more likely to be acknowledged. These findings indicate that even in classes with very few women, the women can be supported in group work by being placed in pairs.

Our study is a smaller part of a larger study on the impact of PBL group work during a lecture course, and the observation that women interacted in groups differently than men emerged during our study. For subsequent studies, it is worth examining the perception of all students about gender roles and participation during group work.

LIMITATIONS

As with any study, we recognize that there were limitations. In this study, because we had relatively few women from which to recruit for our study, our numbers of video-recorded groups was limited. However, we argue that studies such as ours are informative for engineering programs so they can explore ways to increase their enrollment of women. Another limitation was our method of video-recording in class in a large lecture hall space. Because students were sitting at fixed desks or on the floor, we could not always decipher their utterances. This second limitation has been addressed in a follow-up study during which we video-recorded mixed gender groups during laboratory sessions to improve the quality of the sound on the recording.

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