Exploring the Influence of Team Gender Composition During Conceptual Brainstorming

Abstract

Design activities represent an important aspect of an undergraduate engineering education and preliminary and conceptual phases can have substantial downstream impacts on decision making. To improve engineering design outcomes for students it is vital that initial stages of design activities are conducted in ways that promote equity and address issues of power and privilege. While the influence of team gender composition has been studied in engineering design project-based settings, most work has investigated these phenomena over the course of a semester or academic year. As a result, relatively less is understood about the role of gender composition in the micro-level interactions that take place during various design activities.

The purpose of this work in progress is to explore the ways gender composition might influence power dynamics and language used during brainstorming and ideation activities. We conducted three unstructured brainstorming sessions and follow up focus groups. In each group, we varied both the team gender composition of the teams. Brainstorming sessions were audio-recorded and transcripts are qualitatively analyzed according to recommendations by Miles, Huberman, & Saldaña (2013) for open coding procedures.

The current work in progress focuses on the qualitative codebook developed to analyze power as it concerns conversation during unstructured brainstorming. We focus on unstructured activities because these represent spaces during design in which there might not be procedures or practices to promote equitable sharing of power and therefore influence over the decisions of the engineering team. Our findings suggest that power dynamics can play an important role in both what and how ideas are discussed by the brainstorming group. We recommend that future work be conducted to achieve larger sample sizes and explore trends across gender composition. For instructors, managing the gender composition while forming teams can help to create a more equitable team environment while potentially enhancing creative capacity within a team.

Introduction and Background

Despite decades of targeted effort and resources, women remain dramatically underrepresented in engineering fields (Yoder, 2012) and this underrepresentation can lead to a number or marginalizing experiences. Researchers have demonstrated the ways in which masculine norms and values are reflected in engineering practice and therefore code the discipline as male (Dryburgh, 1999; Secules, 2019). At the same time, technical/social dualisms map into male/female binaries in ways that inform and support beliefs about what counts as engineering work and what is peripheral to the practice (Faulkner, 2000, 2007). These factors combine to what amounts for an unwelcoming or chilly climate for women in most engineering fields (Ambrose, Bridges, DiPietro, Lovett, & Norman, 2010). The focus of this work-in-progress is to better understand how these factors manifest in the micro-level interactions that take place within an engineering curriculum as part of an engineering design process. In this case, we are interested in how gender composition might affect the ways engineering teams engage in and talk during brainstorming activities.

To do so, we developed an exploratory, mixed-methods study to examine potential factors that might influence ideation effectiveness for engineering teams. The present work is focused on our

qualitative codebook development related to the ways power manifests in conversation during brainstorming.

Engineering Design Processes and Conceptual Design

The engineering design process is often formalized and represented using a range of different metaphors, organizational diagrams, or flowcharts (Pahl, Beitz, Feldhusen, & Grote, 2007; Shigley, 2011; Ulrich & Eppinger, 2008). And while these processes vary based on their context or particular application or discipline, most engineering design processes can be described in terms of three overarching phases: conceptual, embodiment, and detail. During *conceptual design*, engineers are engaged in divergent processes such as ideation and brainstorming. They are exploring the problem statement and working with clients to better understand and scope their work.

The present research focuses on the conceptual phase for two key reasons. First, the conceptual design phase influences and constrains the downstream decision-making processes in critical ways. Researchers have emphasized the importance of the idea generation phase for the eventual success of the project (e.g., Nelson, Wilson, Rosen, & Yen (2009)) and illustrate how effective brainstorming can lead to innovative and novel solutions. Second, we focus on the conceptual design phase because it is during these initial phases that team roles are negotiated and behaviors are established. As a result, if equitable practices can be established for conceptual design activities, these practices can set the tone for team norms in subsequent phases of design teamwork. And while researchers have noted the importance of ideation on design outcomes, less work has explored the role of gender composition in engineering design team processes.

Gender Composition and Teamwork

Researchers in a number of different fields have been interested in the ways that gender composition might affect team-based activities within their disciplines. While work within engineering is relatively limited, scholars in sociology, political science, and business have explored the role of gender on teamwork, communication, and performance. For example, (Kathlene, 1994) investigated the role of gender in communication patterns and interactions during elected official debates and hearings. Her findings showed that men were more likely than women to interrupt others (and more likely interrupt women than men), take turns talking, and generally take more than their fair share of time and words in most deliberations.

Some research has explored the relationships between gender composition and team performance. Woolley, Chabris, Pentland, Hashmi, & Malone (2010) investigated the link between collective intelligence factor of a group and their corresponding performance on various teamwork tasks (e.g., brainstorming, planning events). They showed how collective intelligence was more a function of social sensitivity of the members than the sum of individual intelligence of each member. Notably, these factors were positively correlated with female participation and negatively correlated with the number of speaking turns took during execution of tasks. These findings emphasize that power dynamics and the conversations that take place as part of the activity within a group could contribute to the effectiveness of brainstorming.

More recently, Niler, Asencio, & DeChurch (2019) examined the role of gender composition on team performance over an 8-week project. They found that the proportion of women on a team increases team performance in part due to the positive influence on team identification and

collective efficacy. Such findings are noteworthy because, while women may have to work to belong in engineering culture, when representation of women increases within a group, they feel more of a connection to the group—an effect not observed in men. If this is also observed in short term engagements, such as brainstorming groups, it may inform the way groups are made in engineering classrooms which also could improve teamwork outcomes and products.

Gender Composition within Engineering Teams

Though research is limited within engineering education, some researchers have investigated the ways in which gender composition might affect team performances and interactions. For example, Laeser, Moskal, Knecht, & Lasich (2003) explored the impact of a team's gender composition throughout year-long introductory design courses that are required for first- and second-year students. Students were observed during class interactions and evaluated on their final design report. They found that gender composition had minimal impact on the roles filled by males and females, with all individuals contributing relatively equally. It was also found that in the first design course, majority male teams outperformed majority female teams with respect to total score but the opposite occurred in the second design course. Such findings suggest that women may become more comfortable in engineering groups as they progress in their coursework.

More recently, Aeby, Fong, Isaac, Vukmirovic, & Tormey (2019) explored the impact of gender on engineering students' work group experiences. They found that both male and female respondents anticipated greater challenges when working with a predominantly female team than when working with a male-dominant team. In particular, students in female-dominant teams reported that they were more likely to check over everyone's work to make sure they know about the entire project. Perhaps most notable was this that finding was consistent across gender in the sample—suggesting that women on female-dominant teams would expect similar kinds of challenges as men on a team made of only women. Moreover, they found that males reported that they are more likely to complete technical work and females work on the report writing. Such findings highlight the importance of teamwork in engineering and also point to important questions about the role of gender in the ways that teams form and function.

Methods

This research is part of a larger project in which we explore the ways in which both activity structure and gender composition influence ideation effectiveness and how power manifests during brainstorming to impact these outcomes. To that end, we pose the following research question:

> *How do team members use language to exert power or influence during brainstorming activities, and does that language differ according to the gender composition of the team?*

To explore this question, we conducted a thematic analysis of three transcripts of unstructured brainstorming activities. In each activity, we varied the ratio of men to women to explore the effect, if any, that gender composition might have on the ways individuals talk to each other as they perform brainstorming in teams. The following sections provide an overview of the population from which we sampled, the data collection and processing, and the development of the thematic analysis codebook.

Sampling and Recruitment

We recruited students in mechanical engineering from a large, public, undergraduate-focused institution in California. Mechanical engineering was selected for a few key reasons. First, mechanical engineering represents the largest engineering department in the college, therefore offering the greatest likelihood of obtaining a diverse sample. Given that one of the goals was to intentionally vary gender composition, it was critical that we select from a department with enough women to conduct that variation. Second, mechanical engineering is often centered on the development of consumer products and systems, so the consequences of effective ideation can have substantial impact on end-user and other downstream stakeholders.
Third, the primary investigator on the current project is a faculty member in mechanical engineering and was able to use access to a department-wide student listserv. In this way, the sample represents a convenience sample.

Participants were arranged according to six groups: two predominantly female, two predominantly male, and two with a balance of gender. In total, 19 men and 17 women participated in the study. Students were selected from either the second- or third year of their degree completion in order to mitigate effects due to expertise differences among students within a given group.

Data Collection

Data were collected via recording of brainstorming sessions and follow-up focus groups. Student groups were asked to perform either a structured or unstructured brainstorming activity in which they were tasked with designing playground equipment for children in wheelchairs. Table 1 offers a schematic of the team gender compositions and brainstorming procedures. During unstructured ideation, participants were given some basic brainstorming principles (e.g., withhold judgment of ideas, quantity over quality) but not instructed any further on how to best go about their process. During structured ideation, students were instructed about and performed the 6-3-5 method. During the 6-3-5 method, which members generate ideas individually and pass around each other's sketches and ideas to build off and generate new solutions (Linsey & Becker, 2010).

Table 1: Group breakdown and brainstorming procedure implemented.

Predominantly Female + Structured Ideation	Gender Balanced + Structured Ideation	Predominantly Male + Structured Ideation
Predominantly Female + Unstructured Ideation	Gender Balanced + Unstructured Ideation	Predominantly Male + Unstructured Ideation

Notably, this 6-3-5 ideation technique was selected because of its emphasis on both collaboration and individual creativity. That is, students in the 6-3-5 group got to see others' ideas and build on them while also having space and time to create their own solutions. Given the challenges noted above with engineering culture and women's experiences on teams, the authors expected that an ideation approach that prevented steamrolling or interruptions might result in more equitable processes and ultimately, a fuller exploration of the given design space.

After being read the prompt, teams were given 30 minutes to generate potential solutions. Immediately following the brainstorming, students participated in a reflective focus group to recap and summarize their process as well as explore their perceptions of the activity. During focus groups, participants were asked about choices they made during ideation, things that went well, significant challenges, surprises, ideas they were particularly proud of, and teaming interactions. Focus groups were semi-structured in order to allow for organic dialogue while also maintaining some level of structure for subsequent comparisons during analysis. Data were collected in compliance with IRB #2019-172 at the present institution.

In order to promote authentic dialogue among participants, the research conducted here required an incomplete disclosure of the research purposes and larger goals. That is, participants were not made aware of the researchers' questions related to gender dynamics, conversation analysis, or power more generally. Instead, they were briefed on the brainstorming process and informed about the goals of the research related to ideation. Doing so allowed participants to interact with each other in ways that were not influenced by a knowledge of the research goals and therefore resulted in an organic dialogue. However, students in this study were debriefed about the broader goals of the research after they had participated in the brainstorming groups and data had been collected. They were reminded of their rights and responsibilities as human subjects. No one withdrew from the research after being debriefed.

Data Analysis

While the larger project incorporates both qualitative and quantitative data to triangulate our findings, in the present work we focus on the qualitative findings that emerged from our thematic analysis of transcript data from unstructured brainstorming sessions only. We focus on unstructured sessions in particular because these are the spaces in which authentic dialogue is most likely to occur. Based on our research goals as well as relevant literature, we developed a codebook of emergent themes related to various ways power manifests across different groups. In this context, we defined power to be any instance where an individual, through their use of language or discursive resources, influences or constrains another individual's possible range of actions or responses. The codebook used to examine this theme is defined and operationalized in Table 2.

Table 2: Thematic analysis codebook used to explore power in brainstorming dialogue.

CODE	OPERATIONAL DEFINITION	CONTEXTUAL EXAMPLES
Subject Change	When an individual redirects discussion from prior discussion topic	Disregarding what was previously said Shifting ideas
Technical Talk	Engineering specific technical language used in ways that were not necessary	Complex terms or jargon Overcomplicated discussion
Affirmation	Agreement/acknowledgement with a previous idea	Approval of a proposed idea Signaling of paying attention Positive evaluations and agreement
Facilitating	Any type of conversation leading or directing (different purposes: to encourage idea forming, to include all members evenly)	Offering instructions to the group Positively progressing ideation Vocal leader

Interruptions	Cutting off speech, talking through someone, or engaging in crosstalk while someone else is speaking people were cut off during speech or	Speech cutoffs Arguments over speaking time Overlapped speech

These codes emerged from dialogue during unstructured brainstorming sessions and highlight the ways that team members might exert or display power in the present context.

Limitations

Before proceeding, it is important to interpret the present research in light of relevant limitations to the study. First, a primary limitation concerns sample size. Based on the small sample size and dataset from which these emergent themes were developed, it is possible that additional or different manifestations of power might emerge from consideration of additional data. We therefore recommend that researchers develop approaches to replicate this research design and increase the sample size and enhance credibility and trustworthiness.

Relatedly, given that our data only contains one group of each gender composition, we are limited in our ability to draw conclusions about how or if the gender composition may have influenced the talk that took place in each session. As noted, the purpose of this work-in-progress is to explore the ways in which power manifests during brainstorming dialogue. As a result, the findings here focus primarily on the ways in which power was expressed, and not necessarily on how that power was affected by gender composition within a team. We focus on the instantiations of power because our sample size (N = 3 brainstorming sessions) prevented us from making comparisons using gender composition as the dependent variable.

Finally, a critical limitation lies in the binary approach to gender that was used in the study. To collect demographic information related to gender, we asked students to identify their pronouns. In the present research, all respondents reported using either he/him/his pronouns or she/her/hers pronouns. As a result, this research was unable to account for the experiences of non-binary folk. Nonetheless, our current data do permit us to begin exploring brainstorming dialogue and the relevant factors—in this case, power—that might influence the effectiveness of the processes and outcomes.

Results

While the broader research leverages both qualitative and quantitative data to triangulate our findings, in this paper we focus on the qualitative coding related to notions of power. We examined the conversations that took place during unstructured brainstorming sessions to develop our codebook. Based on our thematic analysis, five overarching themes emerged to describe the different ways power was expressed through dialogue. The following sections highlight each theme in turn and elaborate on the ways they emerged from the data.

Subject Changes

We defined a *subject change* as any instance during which a speaker shifted the topic of discussion in a significant way. We argue that by changing the subject during an ideation session, the individual who enacted the subject change is also expressing some level of power over others in the group in order to more directly control the topic of discussion. For example,

the following exchange highlights a subject change from one particular kind of design theme to another altogether.

> *Male 1: Yeah, I mean it's for one that you'd be able to use in a wheelchair, just kind of like a ramp that you would go up on so it's some kind of platform that you can get onto. And then it would never hit the ramp, right, because it's swinging this one. It wouldn't touch it.*
> *Female 2: Something that's also not really a part of a playground but could still be part of a playground, we could have like a little like track for them to race each other just so it's like it's own separate thing."*
> [Unstructured/Balanced]

Here, Male 1 is describing a design solution that involves a platform and swing. While the idea has not been fully fleshed out, Female 2 changes the subject to a qualitatively different solution. Other times, subject changes guided participants' actions during brainstorming:

> *Female 1: I just thought of the one that we did from two years ago. I just remembered what it was finally.*
> *Male 1: Cool. You guys want to spend another three minutes, and then start sharing?*
> [Unstructured/Female-dominant]

In the quote above, Female 1 notes how she *finally* just remembered a particular idea. However, before she articulated the idea to the group, Male 1 changed the subject in order to direct the activity of the group. While fully exploring the design space requires divergent thinking and therefore changes in subjects of discussion, subject changes indicate important shifts in the subsequent direction of conversation and, in turn, solution paths. Such changes serve as indicators of who perceives to have the power to change the topic as well as the subsequent decision to start down a new path.

Facilitating

We defined *facilitating* as instances when a group member engaged in directing the conversation or guiding the activity of the group. And while facilitation is often an important function that individuals can serve while engaged in teamwork, such actions and language used indicate different levels of power that might be operating within a group. By engaging in facilitation, a group member is exerting influence over the collective action of the group and therefore exercising some level of power. Facilitation differs from subject change because the focus here is on the action of the group rather than the specific topic of conversation. For example, a member asking the group to write down ideas as they come up is directing the actions of the group but not necessarily shifting the content of the discussion. In the following exchange, Male 1 directs the activity of the group and places some constraints on how things will proceed.

> *Male 1: All right. How are your guys' ideas coming along? Want to spend more time? Or-*
> *Female 1: Can we have 30 seconds?*
> *Male 1: Go for it. Yeah.*
> [Unstructured/Female-dominant]

Here, Male 1 asked check-in questions that enabled his facilitation for the team. Notably, Female 1 seems to acknowledge and accept the authority implied by the questioning by asking for permission for some extra time (as opposed to simply stating that she needed more time).
At the same time, facilitating can take a more direct route, where individuals offer directions for how the group should proceed. In the passage below, Male 1 engages in facilitating behavior by directing the group to keep track of their ideas.

> *Male 3: Should we be writing down all our ideas?*
> *Male 2: Yeah, we probably should.*
> *Male 1: You might want to.*
> *Male 3: So we probably should.*
> *Male 1: I guess we probably should. Oh yeah, use scratch paper so that you can keep track of just how many ideas you generate.*
> [Unstructured/Male-dominant]

It is important to note that while facilitation within a team is, at some level, an expression of power, such expressions are often vital to the effective function of a team. That is, a team with a facilitator is often more effective than one without. Therefore, expressions of power such as these are not inherently negative.

Affirmations
We defined *affirmations* as a neutral agreement or acknowledgement with a previous statement. The presence and frequency of affirmations assist in our understanding of the distribution of power because they are nods to the speaker that the audience is engaged and respecting what the speaker has to say. That is, the act of acknowledging the speaker indicates who has the floor and who may continue to have the floor. In some cases, affirmations were used to offer positive evaluation of ideas. The following example shows how students used affirmations to express approval of another participant's ideas.

> *Male 2: Except instead of using your legs to push, you got maybe poles that you can pull up and down.*
> *Male 1: Mm-hmm (affirmative). Okay.*
> *Female 1: Nice.*
> *Female 3: Nice. Cool.*
> *Male 2: Cool.*
> [Unstructured/Female-dominant]

Here, the group members are notifying Male 2 that he is being heard and his idea is valued by the group. In other cases, affirmations were used to acknowledge the speaker and to keep the dialogue moving forward.

> *Male 1: Why not just a regular hamster wheel?*
> *Male 2: Yeah.*
> *Male 1: Just like a big enough hamster wheel that you could roll in.*
> *Male 2: Yeah, exactly. You roll in. And then you just go forward and spin it.*
> *Male 1: Yeah*
> [Unstructured/Male-dominant]

In both cases, the primary purpose of an affirmation is to acknowledge the speaker in ways that tend to move the brainstorming along.

Interruptions

We defined *interruptions* as instances where participants' sentences were prematurely cut off during a statement or where they were unable to finish a particular thought. We identified interruptions by looking for line breaks in the transcripts that were broken by another speaker and triangulated these interruptions with the original audio transcript. By interrupting someone while they are still speaking, the interrupter disregards the initial speaker's message, which we argue is an expression of power over that person. That is, the interruption constrains the person's ability to complete their thought and articulate it to the rest of the group. The following exchange is an example of a typical interruption.

> *Female 1: I mean, I was just going to say-*
> *Female 2: I was also going to say with the safety, but you could still hit yourself if you were to swing it. So it's like... there's always that risk.*
> [Unstructured/Balanced]

Here, Female 1 begins to share an idea, and Female 2 cuts her off in order to direct the conversation topic to her own idea. A similar interruption occurs in the following exchange.

> *Female 1: So like, even if you have a way to expand, or change-*
> *Male 1: Okay, and then just keep iterating. Okay-*
> *Female 1: An idea that somebody has, then we can like, add-*
> [Unstructured/Female-dominant]

During this interruption, Female 1 is still speaking, and Male 1 interjects. Female 1 then engages another interruption over Male 1 to finish her thought, and the two individuals end up talking over each other. Similar to subject change, interruptions switch the focus of the conversation, but instead of changing the topic, the person the group is focused on at that moment is changed.

Technical Talk

Technical talk serves as a means to signal that the conversation is an engineering one and that some people might not be able to participate without an understanding of both the relevant concepts and jargon used to describe them. Technical talk can be used by engineers to perform and draw boundaries around their engineering identity. Technical talk can be a way to exert power in and exclude others from a conversation. Here, technical talk was defined as the use of engineering-specific terms (e.g., kinetic energy, angular momentum, moment of inertia) to describe particular solutions. For example, the following passage demonstrates an engineering student's use of technical talk to describe a slide.

> *Male 2: But a little ramp, maybe a two-degree gradient, just so they can get their wheels moving, have some forward motion, just like a slide.*
> [Unstructured/Female-dominant]

In this example, the male student speaking uses the technical talk to describe the incline of a ramp, noting how it would have to have a "two-degree gradient." It is worth noting how in the example above, the discussion of the exact slope of the gradient is not necessary to communicate the idea being proposed. The authors argue that the use of such language communicates to others that Male 2 can "speak engineer" and, further, that such language is a valuable source of social capital. Instead of using the word ramp, Male elaborates in a way that signals engineering knowledge and potentially excludes others from the discussion by obscuring details with technical talk. Another example can be seen in the exchange below as students discuss a wheel-and-track type piece of equipment.

> *Male 2: Yeah. Okay. If you had a park with a really, really basic wheelchair or something that is all standard. And then, it's modular maybe.*
> *Female 1: Dimensions, the same. So that when you're getting onto one of those tracks, slides, it actually is the same distance between the two wheels.*
> *Male 1: Yeah. Yeah. Or those tracks are modular to clamp around some random object or something.*
> *Female 1: Yeah. That's some tech right there.*
> [Unstructured/Female-dominant]

Here, while discussing an idea, the group incorporates specific technical details. This exchange elaborates on the idea of technical talk and the level of technical talk seems to be acknowledged by Female 1 in the exchange ("*That's some tech right there*."). The use of technical talk is not inherently negative and can sometimes add clarity to a discussion. However, it can also be used to exclude individuals and introduce barriers to participation in conversation.

The above findings provide rich examples of the ways in which power is expressed through dialogue during brainstorming activities. In the present work, we do not present frequency counts related to how often different codes were applied across transcripts. While future work will examine the relative frequencies of these different codes across different brainstorming sessions, the current focus of this work is the development and application of the codebook in the present data. Indeed, the goals of qualitative analysis are often descriptive in nature as they unpack different aspects of a phenomenon. Moreover, reporting frequency counts can lead to problematic interpretations of qualitative findings based on the nature of a particular conversation and can lead to skewed findings based on the small sample size reported here. As a result, our findings focus on the ways in which power manifests during brainstorming dialogue (i.e., the descriptive codebook), not necessarily the differences in power expressions across groups of various gender composition.

Discussion and Implications

Our present findings highlight some subtle and not-so-subtle ways that power might manifest through conversations during engineering brainstorming activities. While our small sample size prevents us from being able to make claims about the influence of gender composition on the nature of brainstorming conversation, we believe our findings highlight important ways in which power might be embodied through dialogue within engineering contexts. As stakeholders in student success, it is vital that we attend to the ways that individuals use language and, importantly, how that language might mitigate or reproduce the inequities present within

engineering education and practice. By exploring the ways that power is enacted through various discursive acts, our research highlights important aspects of conversations that take place as students engage in brainstorming activities.

Further, our analysis presents an important finding related to the manifestation of power: not all use of power during brainstorming is inherently negative. Often, when discussing issues of power and privilege, most manifestations of power are seen as things to be avoided if possible. To be sure, irresponsible use of power or uncritical examination of privilege in engineering is deeply problematic and has no doubt contributed to the existing inequities we see in the field today. However, our data also showed ways in which power was used to create positive teaming interactions. For instance, while *facilitation* is an expression of power that directs the focus of the group, that direction is an important aspect of exploring the design space more fully. Conversations of all types will inherently have power relations kind of baked into them and it is important to recognize the different ways that different team members might wield power in group settings.

Conclusion

This work-in-progress is part of a larger project exploring the role of activity structure and group composition on design processes and creative outcomes. The current research focused on questions related to the role of power and the ways it manifests in brainstorming dialogue. Our findings highlight five major ways that power is enacted as engineering teams talk to each other to develop solutions to problems. These themes help illuminate some of the different ways that power is embodied and offer a lens through which future research might explore engineering language and dialogue. Nonetheless, the current work-in-progress also points to the need for more robust studies of the present phenomenon. Larger sample sizes and more diverse populations are needed to confirm the present findings, but a deeper understanding of how power is constructed in engineering and wielded by individual engineers can help faculty facilitate more positive teaming interactions and promote more equitable design outcomes.

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