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Small Shifts: New Methods for Improving Communication Experiences for Women in Early Engineering Courses

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Abstract: This paper outlines methods and initial data from an educational intervention based on previous research published at ASEE. Students in introductory engineering courses face challenges communicating and integrating their ideas in team projects. Often these challenges with team communication fall along gendered lines, where women students experience marginalization in team settings. This paper builds from previous research in the field of engineering education which integrated frameworks from the domains of engineering education and technical and professional communication to implement this research into a classroom intervention aimed at reducing the gendered disparity in these communication challenges. To help resolve these issues, this methodological paper presents a new research method called, "infrastructural rhetorical analysis" derived from the field of rhetoric and communication. The paper then applies this method to an educational intervention case study involving the experiences of women in the first-year engineering classroom to determine a concrete classroom intervention that aims to make the most difference with the least amount of resources needed to implement it.

Keywords: Intersectional feminism, infrastructural rhetoric, gender equity, communication and teamwork.

1. Introduction

When we think about change, we often think of sweeping, noticeable changes. We want change to address our problems in dynamic and impactful ways. The problem should be identified, then the change is implemented, and the problem is vanquished. Problems, after all, are meant to be solved. As is often the case in engineering, however, the more real the problem, the more complex and slippery the solution. In this regard, issues of communication and gender bias hold no exception. While we might strive for sweeping, totalizing change, such change might take a substantial investment of time or effort. Long form change of this kind can have a significant impact, but it provides little comfort to those seeking help in the near term. Without the aid or resources of massive systemic support, it is often our individual ability to identify the small shifts that will make the most impact for our students and colleagues in the moment. It is more often the small shift which leads to the kind of change that lasts.

This idea of the impact of a small shift is particularly salient when we consider educational interventions designed to address the problems women and underrepresented students experience in engineering programs. Research shows that women face additional challenges in their engineering classrooms [1], [2]. For example, our previous research showed the prevalence of microaggressions, implicit bias, and negative stereotypes that impacted women's experiences working in teams, at times even hindering their ability to learn [3]. There is a need for more flexible, tailored curricular interventions to address these problems. Even professors that mean well and have the students' best interest at heart may find intervention difficult when doing so requires them to cut back on the engineering aspects of a course. Fully addressing marginalization in the classroom is a titanic ask for an institution, let alone an individual. There is a need, then, for more research exploring the methods of identifying potential educational interventions to foster more inclusive learning environments. Our team analyzed aspects of the introductory engineering course where positive, active change might be made without the resource availability for sweeping initiatives. Using new methods from the fields of engineering education and technical communication, we developed a specific methodology and method that would allow us to more precisely ascertain what educational interventions would lead to more meaningful change. The goal of these methods addresses the critical needs of students in engineering classrooms while creating a communication environment that was more supportive for women in engineering.

2. Literature Review

In this literature review, we draw together scholarship from the fields of engineering education and technical and professional communication (TPC) to better understand the experiences of underrepresented students in early engineering education and existing approaches to inclusive pedagogy.

2.1 Equity in Engineering Education

Research in engineering education has long established that women and gender-diverse students face additional challenges in engineering industry and educational contexts [4], [5], [6]. Women are underrepresented in engineering undergraduate programs as well as in industry, comprising only 16% of engineers in the US labor force [7]. The causes of this problem are many and varied: issues of access, student interest, stereotypes, and colorblind pedagogical approaches (a problematic practice where instructors profess to "not see race or ethnicity") all play a contributing role.

Problems with representation in university STEM education begin long before students enter the university. Students who identify as underrepresented on the basis of race and/or gender are less likely to have access to technical learning opportunities and technologies [8]. In K-12 contexts, Vakil [9] explains that "research unequivocally shows that high quality STEM learning opportunities in and out of school are largely denied to racially minoritized students" (p.90). Numerous studies have shown that in university programs, students benefit from previous technical experience [10], but women are far less likely to have such experiences because of gendered stereotypes of engineering processes e.g. computer coding [11].

There are also challenges arising from students' interests and the impact of gender stereotypes on career choice. For example, Potvin et al. [11] conducted a study of gendered interests and career outcome expectations in engineering. They found that within engineering programs, the gender gap disappeared in biomedical engineering, where female students expressed stronger associations with "helping others," while for electrical and computer engineering, female students expressed less interest and associated the disciplines with "inventing/designing things" [11, p.298].

Furthermore, students' networks of support are also highly uneven. Though networks of support, especially those including family members and friends with disciplinary experience, are crucial to student success, students from underrepresented communities are less likely to have these networks. In their research on social influence and STEM education, Ross, Hazari, Sonnert, and Sadler [2] argue that prevailing approaches to diversity in education tend to focus solely on women or racially minoritized students, eliding the unique situations experienced by women of color. In response, their research compares the educational experiences of Black women, Black men, and non-Black women, revealing how "Black women's social experiences are often different from the experiences of both Black men and non-Black women" [2, p.1]. Social influence is a significant factor in students' decisions to pursue STEM education. Black women, while sharing some experiences with Black men and non-Black women, were less likely to be introduced to the field by family and friends and more likely to be introduced to technology in K-12 educational contexts. Because social influence, friendships, and community are vital for underrepresented students' success in STEM education, they make a clear case for further intersectional research to support interventions [2].

Researchers have also considered how gender influences professional identity and communicative practice [12], [13], [14] and analyzed how workplace bias causes individuals with underrepresented identities to leave STEM fields even after finding success in college [15], [16]. Kim & Meister [17] analyzed the most common microaggressions women in engineering occupations experience: the devaluation of one's abilities, the ignorance of one's presence, the denial of one's situation, pathologizing, and devaluing specific behaviors. These negative experiences can make it more difficult for underrepresented engineers to thrive.

While equal representation will not eliminate larger issues within the industry, equity within engineering is still vitally important as the field continues to expand in reach and influence. Introductory engineering courses in particular offer a rich opportunity for equity-focused educational interventions [18]. However, engineering faculty often face competing directives, tasked with teaching content knowledge, technical skills, as well as aspects of engineering workflows like teamwork and communication. Our previous research revealed that while engineering faculty wanted to support underrepresented students, they faced significant time constraints. To that end, we turned to scholarship from technical and professional communication to determine what small interventions might be sustainable and impactful for students in introductory engineering courses.

2.2 Intersectional Feminism in Technical & Professional Communication

This study is grounded in intersectional feminism and technical and professional communication research on social justice [19], [20]. Crenshaw [19] defined intersectionality to better understand how interlocking systems of oppression affect marginalized individuals based on aspects of their identity. Chávez and Griffin [21] argue that intersectional research challenges "who has the power to name, whose discourses can be heard, whose ways of knowing are valid, and whose approach to communication can be valued" (p.20). The predicament and challenge of communication across difference also presents opportunities and ethical imperatives, contend scholars working on social justice in technical communication [22], [23]. These scholars, among many others, highlight a social justice imperative and work to foreground the influence of identity and culture on technical communication.

Problems of access, representation, and equity are not unique to STEM contexts. Social justice research takes up the problem of injustice and discrimination in TPC research and workplaces, illuminating both problems of inequity and possibilities for change [20]. Issues of power, privilege, and positionality circulate through professional communication. Jones [24] argues that technical communication is fundamentally about advocacy, urging researchers to adopt a critical stance to issues of social justice and diversity. Social justice research considers how technical and professional communication can be used to "amplify the agency of oppressed people—those who are materially, socially, politically, and/or economically under resourced" [25, p.242]. Walton, Moore, and Jones [20] argue for the necessity of centering and valuing underrepresented perspectives in order to make "space for people to move toward the center, allowing them to shape, re-imagine, and re-envision the institutions and organizations forming the context for much of TPC" (p.9). While TPC scholarship and intersectional feminism inform the focus of our study on the experiences of women and underrepresented students, we also turned to research on inclusive STEM pedagogy to craft and direct the goals of the intervention.

2.3 Belonging in Engineering & Inclusive Pedagogy

Research in STEM education has long established that feeling a sense of belonging is critical for students, especially underrepresented students [26], [27], [28], [29]. As Thomas [26] explains, "student engagement and belonging through their learning are integral to student success." At the same time, however, methods to promote students' sense of belonging remained understudied [29]. Within engineering education and STEM education more broadly, researchers have begun to examine specific practices of inclusive pedagogy that faculty might implement to foster greater belonging in their classrooms.

Faculty play an important part in students' sense of belonging. Rainey et al. [30] found that women "were less likely to feel a sense of belonging" when compared to men and that women students broadly did not feel as though their instructors wanted them to succeed (our previous research [3] echoes some of these claims.) However, when faculty emphasized their availability and willingness to help students with questions and cultivated an atmosphere of mutual respect, all students experienced a greater sense of belonging [30].

In a recent study of early career engineering students [31], students' self-efficacy and belonging were examined. Zabriskie et al. [31] found that a sense of belonging was strongly correlated with students' identity, pointing to the need for more research on inclusive pedagogy attentive to engineering students' identities. O'Hara, Bolding, Ogle, Benson & Lanning's research [32] confirmed the importance of belonging for student success, finding that students typically experienced greater belonging over their time in the program. Mallette [33] offered strategies for faculty to foster greater belonging through their engineering writing and communication.

There are many interventions available for educators trying to foster more equitable learning environments. Palid, Cashdollar, Deangelo, Chu, & Bates [34] conducted a systematic literature review of inclusive teaching strategies for STEM contexts. They considered multiple forms of intervention attempted by universities to increase retention rates, academic performance, and the feeling of belonging in students underrepresented based on gender, race, ethnicity, and other identities. Palid et al. categorized these interventions into 6 broad categories (mentoring, supplemental learning, bridge programs, socializing, financial aid, and skill building). They found that mentoring from peers, faculty, and professionals produced positive outcomes in retention, academics, and belonging 93%, 77%, and 83% of the time respectively. Supplemental learning such as workshops, tutoring, extra instruction, and learning communities produced positive outcomes in retention, academics, and belonging 94%, 81%, and 69% of the time respectively. Social interventions that include cultural events, networking, and retreats produced positive outcomes in retention, academics, and belonging 100%, 73%, and 60% of the time respectively. Financial aid including scholarships and stipends provided to underrepresented students produced positive outcomes in retention, academics, and belonging 92%, 100%, and 100% of the time respectively. Skill-building opportunities for students to apply their learned skills in existing literature, projects, or research produced positive outcomes in retention, academics, and belonging 89%, 70%, and 85% of the time respectively. With all these options, it can be overwhelming to decide on the appropriate intervention. For our study, we decided to design an intervention from the ground up, using data from our previous study on women in engineering and a new method: infrastructural rhetoric.

2.3 Infrastructural Rhetoric

While studies of feminism and belonging inform the scope and focus for our educational intervention, our methods come from the field of rhetoric and technical communication. Rhetoric is the study of persuasion. Practitioners of rhetoric specialize in understanding how individuals in a wide array of areas communicate with one another to accomplish shared tasks. This practice is accepted across universities as a valuable way to train students in communicative practice [35]. While we might think of rhetoric in terms of bombastic or politically charged rhetoric, rhetoric is more often employed in everyday communication to determine how to clarify points between individuals. Rhetoric plays a central role in our common conversations and engineering teams.

However, in engineering education, too often, communication advice boils down to a variation of, ‘have more moments of communicative interaction’ (see [36] for example). This advice can be problematic, as increasing moments of communication while ignoring the communicators’ positionalities may lead to further negative interactions. It may harm the interlocutors more than it provides help during negative interactions.

To prevent this outcome, we shift our rhetorical and communication practices using the contemporary theory of infrastructural rhetoric [37]. This theory focuses on understanding the surrounding forces of the classroom, like space, social norms, or authority, to make previously unforeseen communicative challenges visible to researchers. In brief, there are hundreds of factors that can affect a moment of communication between two individuals before either of them opens their mouth. Infrastructural rhetoric is the practice of identifying and understanding these factors. Most importantly, the theory advocates that communicative challenges might be rendered avoidable and persuasively malleable by understanding which factors may be changed in the present to enable better communication in the future.

Infrastructural rhetoric posits two significant communicative points for the purposes of our research:

1. Communication practices might be more significantly modified if we instead modify the factors that allow and shape their occurrence in the first place.

And,

2. The possibility for change in a given communication setting ([37] refers to this as a rhetorical infrastructure) may be seen clearly by first analyzing that infrastructure through a discrete taxonomy. To this second point, [37] provides a taxonomy of common infrastructural considerations and a method of mapping out various infrastructural factors that have an impact on communication. These initial taxonomic categories are summarized in Table 1:

Table 1: Infrastructural Rhetoric Taxonomic Categories

Infrastructural Taxonomic Category	**Brief Description**
Social Infrastructures	The longstanding relationships, values, and ideals that people bring into a communicative exchange.
Physical Infrastructures	The structural environment that the communicative practice is situated in and throughout.
Economic Infrastructures	The financial and fiduciary realities that affect communicative practice.
Authority Infrastructures	The structures of command and power that impact communication
Operational Infrastructures	The repeated chronological responsibilities and tasks that shift the style and nature of communication.

The categories in this table allow for focused action in a communication intervention. Considering a communication exchange within these categories allows a researcher to break up the infrastructural factors into manageable foci and avoid redundancy or spread, as actions spread out across the taxonomy become more difficult to successfully enact. Keying into these taxonomized factors and their relation to communication allows us to target specific, meaningful interventions in the engineering classroom. Infrastructural rhetoric makes broader, seemingly disparate infrastructural factors visible in a way that can facilitate meaningful change. The theory offers a clear way to begin an intervention targeting negative educational experiences. The process of taking a communicative moment, keying into its taxonomized factors, and then utilizing that understanding to enact change on a series of communications is known as “Infrastructural Rhetorical Analysis.”

Our past research outlined how infrastructural rhetorical analysis may be used in educational settings in STEM, providing meaningful changes in both instructor and student communication practices to prevent negative communication experiences.

For this intervention, our past use of infrastructural rhetoric highlighted a number of factors within the instructor's control that could influence students' negative communication experiences. The physical layout of classrooms, team leadership, and the introduction of preliminary background knowledge all affected the communication practices of students at our university. Our previous research collected this data, but it is analyzed in further detail as part of this educational intervention below.

3. Educational Intervention Study Design

After understanding the nature of the problem, and the methodologies used to address them, clarity might be had by putting these methodologies into the context of method. To this end, we now present a case study, which uses the above frameworks to address an issue of marginalization in a localized setting via an educational intervention. Our educational interventions were produced from a multi-stage process continuing from our previous research. After providing context for the interventions, we briefly give background on the previous research before moving into the creation of the interventions themselves.

3.1 Study Context

This educational intervention takes place in a small, engineering-focused college located in the Southwest. The study was done with participants in person to avoid complications and uncertainties associated with virtual environments. Initial data was collected from multiple participants across several engineering programs [3], but reflections and critical events were focused on experience in the first-year engineering course at the institution. The first-year engineering course is a design, build, test course that enables and encourages communication between students on teams. The teams are broken up into small groups of four or five and tasked with designing, building, and testing an engineering solution to a pre-conceived problem. This classroom serves as an ideal setting for intervention, as the students are early in their coursework. This chronological positioning yields students who are more focused on communication than mathematical analysis, which they may be less certain of, and makes any changes more impactful, as they have three more years to build upon their experience and grow as engineers.

The first-year engineering classroom also serves almost every engineering student on campus, giving us a significant representative sample of the campus population. The number of women in these courses (around 30%) while limited, is representative of the number of women in other engineering courses and the field broadly. Our findings, therefore, may be extrapolated to other engineering environments.

3.2 Study Participants and Recruitment

The educational intervention utilizes data from the previous research [3], which used interview data of the previous year's first-year engineering course to construct the analysis for the interventions in this paper. Data was collected through interviewing student and faculty participants who were recruited from the same courses that the present interventions were planned for, thus allowing the insights of the initial interviews to be transferred to the current classes.

Following data analysis of the interview data, four classes were selected for a quasi-experimental educational intervention. We selected two professors who were each teaching two sections of first year engineering. These sections represented a large enough sample (N=116) of the first-year engineering cohort to be useful, while allowing us to form two sets of control groups and experimental groups with identical coursework and near identical instruction. Student consent was gathered before the intervention and before the post intervention data collection. The post-intervention data collection was done with a series of anonymous surveys and the instructors of the course were interviewed to understand their perspectives.

While these classes do serve as a convenience sample regarding the professors that teach them, they are also a representative sample of first year engineering classrooms, where students are placed into these classrooms based on their scheduling choices, rather than by the choice of instructor. Ultimately our research holds that controlling for so many different variables by having the same instructor, assignments, and lessons for each day in the course outweighs some of the effects of the convenience sampling method. The participants sampled are discussed in the following sections.

3.2.1 Student Participants

Students for the educational intervention all came from the introduction to engineering class. The researchers came to the class with the professor’s permission to recruit students to the study. All students in the class were asked for their consent to participate and almost all students consented. In total, there were 4 sections with one professor teaching two sections each. Each section had 30 to 40 students. In each section, students were asked to participate in an interventional activity. This intervention asked students to complete an engineering design challenge in small teams. For the purposes of this intervention, 28 women students were included in the participant group. Only individuals who are 18 years or older were asked to participate in this study.

Student participant demographics paralleled the broader demographics of the university, with a few exceptions. 68% of participants identified themselves as male; 31%, as female; and 1%, as genderqueer. 69% of participants identified as white; 12%, as Hispanic or Latino; 13%, as Asian; 2%, as Black or African American; 2%, as American Indian or Native American; and 2%, as Native Hawaiian or Pacific Islander. 11% of participants identified as having a disability, and 22% identified as being first generation students. Interestingly, women participants were slightly overrepresented in our study, compared to their percentage of the overall student body (27%).

3.2.2 Faculty Participants

Faculty participants for this study include two individuals who are involved in developing and teaching the same introductory engineering class from which student participants were recruited. These faculty fully participated in the intervention and helped to facilitate the intervention, keeping autoethnographic notes on their experiences.

3.3 Data Collection Methods

This intervention collected data in several ways. First, the intervention used the interview transcripts from our previous research about women's experiences in introductory engineering courses. These interviews, utilizing techniques such as critical incident [38] aimed to connect faculty involvement in the classroom with students' reported experiences and behaviors. Next, we designed a classroom intervention activity and collected field notes and researcher observations. Finally, a digital survey was conducted with students and in-person audio-recorded interviews with faculty. The digital surveys collected qualitative data asking students to reflect on their teamwork experiences. The faculty involved in the intervention also collected qualitative data through reflection on their pedagogy and their students' experiences in the team projects.

3.4 Data Analysis Methods

Initial research [3] produced a dataset consisting of interview transcripts and insights from participants in last year's first-year engineering experience. To turn these into a workable shift for our intervention, an infrastructural rhetorical analysis method was applied. An abridged depiction of this method is pictured in figure 1:

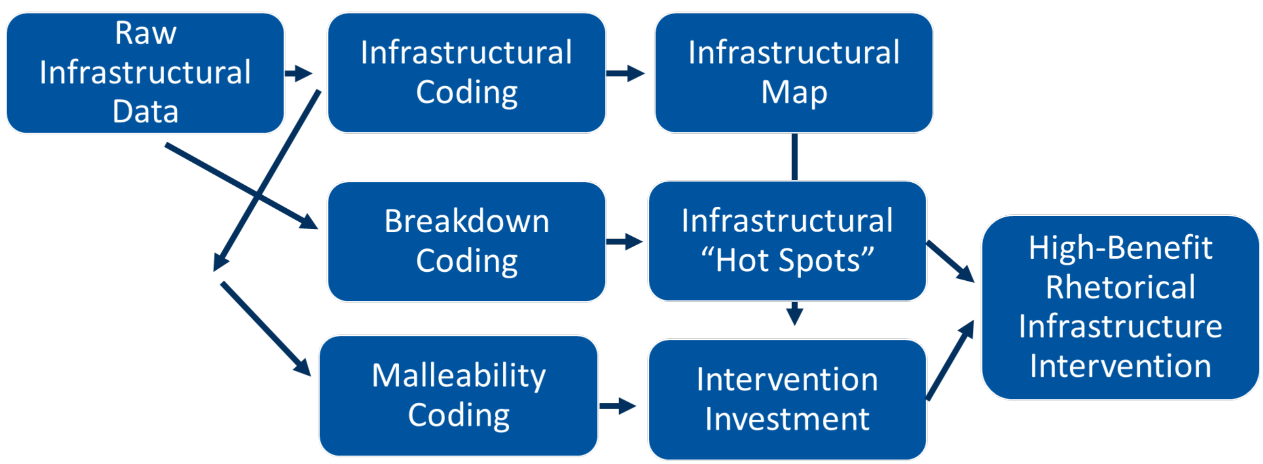

Figure 1: Abridged Depiction of the Infrastructural Rhetorical Method of Analysis

The method depicted above involves cross-referencing a series of communication practices described by individuals who may or may not be aware of their own communication practices on a meta level. Specifics of the cross referencing are discussed in 3.4.1.

3.4.1 Infrastructural Rhetorical Analysis of Critical Incident Data

Each of the transcripts from interview participants was first broken into parts consisting of two to four sentences, called chunks. These chunks made the data sets more manageable for rhetorical analysis (For more on chunking as an established practice in qualitative research and coding, reference [39]). These chunks were then cross-coded in three distinct stages:

1. First, the transcripts were coded based on the infrastructural taxonomy it was associated with. This "infrastructural coding" allowed the data to be viewed in infrastructural terms and determine which taxonomic category was drawing the most attention and focus within the critical incidents of our participants. This depiction of infrastructural rhetorical focal points is known as an "infrastructural map."
2. Next the transcripts were coded for moments of infrastructural breakdown, or moments where some aspect of the participant's experience was seen as dissatisfying, upsetting, confusing, or harmful. This round used emotion coding [39], as well as the specific critical incident questions [38] that were asked in the initial research. If the research participant passively identified a rhetorical infrastructure as part of a critical incident this was also flagged as an infrastructural "hotspot." These hotspot moments revealed which infrastructural aspects in the taxonomy were having the most severe impact on the population in question, which would indicate which infrastructural aspects, if addressed, might provide the most relief.
3. Finally, the transcripts were coded a third time, and the coded chunks that were identified as moments of infrastructural breakdown were given a subjective score by the researchers to assess the malleability of the issue causing the breakdown. Each moment was given a malleability score from 1-3 representing whether or not the issue at hand could be easily changed within a class period (one to four hours). Malleability is always subjectively defined based on the resources available for intervention and the perspectives of the interventionist. Because of this, malleability is subject to revision throughout the process of intervention and may adjust the infrastructural map.

After the transcripts were coded, the coded documents were cross referenced manually using an industry tool for user experience (UX) research and design called *Dovetail*. Cross-referencing the infrastructure with the moments of breakdown allowed the researchers to identify the infrastructures to focus our attention on. It allowed for a narrowing of scope in the proposed solutions into the specific areas of social and authority infrastructure, meaning that the intervention could focus on how people's beliefs, attitudes, and past conversations impact their current communication along with the authoritative powers that individuals are vested with while communicating.

Once these infrastructural foci were identified, they were then cross referenced with the malleability scores produced earlier. Cross-referencing these coded sets allowed us to compare the moments that were having the greatest impact on the students with the moments that were the most malleable or able to be changed without heavy investment of time, money, or attention. The intervention could use this cross referencing to determine a course of action that would be small in scope because it was highly malleable, while affecting the issues that were impacting students the most.

The results of the analysis, shown below in figure 2 indicated a clear area of intervention:

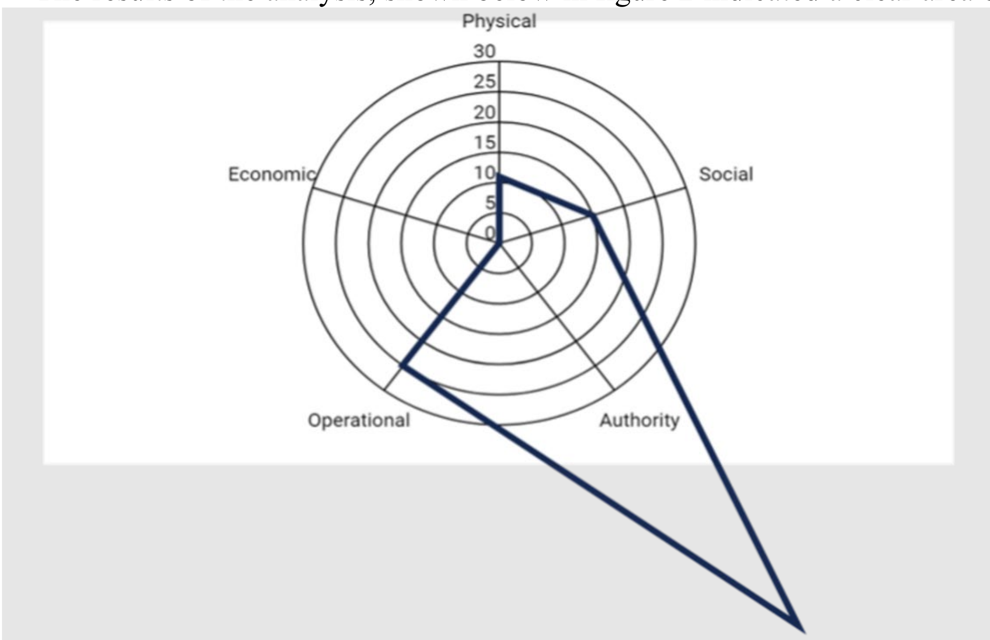

Figure 2: Results of Infrastructural Rhetorical Analysis

As shown in the figure above, after cross-referencing all of the data from the initial research, concerns of teamwork authority emerged, particularly in relation to social and operational infrastructures. Responses and interviews indicated that female students more consistently experienced marginalization in response to how the team was structured and who was allowed to have a final say in a discussion or design decision. Numerous instances occurred where the women in the engineering program were not allowed to directly access or make choices about their design because another teammate, often male, vested themselves with authority based on their past robotics experience in high school over the project. They would actively prevent their teammates from contributing to project to preserve control over the project. This led us to focus on analyzing the malleability of the authority structures in the classroom to see what might be easily adjusted in an educational intervention this year to have an impact against these communication exchanges regarding authority dynamics.

While the ideal outcome for an educational intervention into the authority issues of teams would have been a multi-week intervention with educational lectures, rewarding response structures, and consistent check-ins with teams, our malleability analysis revealed that such impactful interventional methods were anywhere from difficult to impossible to enact without sweeping university support or curriculum reform. Engineering classrooms are already busy and engaged in the process of training student engineers. There often isn't time to implement sweeping changes that are required to change social attitudes and ideological beliefs. When asked how much time and focus might be dedicated to helping improve the teaming infrastructures of students, most professors we spoke to were generous enough to dedicate a full class to the issue.

This dedication showed great support for our project, but it limited any interventions to 2 hours in length. The intervention team would need to focus on activities that could be accomplished in 2 hours, but that might still have a meaningful effect on this critical issue. This focus set the parameters of our malleability assessment.

3.5 Interventional Study Design

After discerning the need and scope for intervention through our initial research methods, the educational intervention was planned with the following guidelines:

1. The intervention should target the first-year engineering classroom to ensure a similar rhetorical infrastructure to the previous research.
2. The intervention should focus on fostering a sense of belonging in the engineering classroom for women in engineering.
3. As one of the primary infrastructural deterrents to belonging was authority being unintentionally or passively vested with individuals who either actively or unconsciously hampered women's learning opportunities on their team, the intervention should actively seek to adjust team authority structures to assist women with a sense of belonging.
4. To avoid highlighting and alienating women in the engineering classroom, the intervention should be framed as a communication improvement intervention outside of gender identity. The women in the intervention should not feel singled out or focused upon as a subject of intervention.
5. The intervention must be completed in under two hours.
6. The intervention must not consume more than one hour of instructor time outside of class throughout the semester.
7. The intervention should be something that has a lasting impact on the students throughout the semester.

Ultimately, the intervention needed to find a way to place students into supportive teams, while avoiding placing too much of the decision-making power with an individual who might not listen to or care about the women on their team. This intervention, we hoped, would shift the rhetorical infrastructure in a meaningful fashion. In other words, we hoped that shifting the team structures would change the conversations that were likely/possible to occur in a way that made conversations that supported women more likely. Each of the numbered considerations above responds to a specific infrastructural need in the intervention.

To be more specific, rhetorical infrastructures typically shift around two central variables: time passing and new rhetorical focal points. The first two guidelines were set to assure that the time passing had as little effect as possible and that the focal point for the initial rhetorical mapping remained as similar as possible to the intervention's initial focal point. Guidelines three and four came from the past rhetorical analysis itself and allowed us to determine the taxonomic focus for the intervention. Five and six were revealed in the malleability analysis, while seven was set in place to orient a change that might have increased impact, despite its limited time and reach.

With these guidelines in mind, several interventions into teaming were considered, ranging from professional team assessment tools to self-reported team selections. The intervention needed to focus on intentionally selecting and creating teams but needed to do so without "spotlighting" and drawing attention to underrepresented students [15], which also meant we needed to avoid segregating students into teams of a single gender. Ultimately, the intervention strayed away from professional team-making tools (CATME, StrengthsFinder, etc.), as many of them focused on team productivity, which might have proven counterproductive to fostering a sense of belonging. Additionally, many of these tools focus on skill matching, but students who are currently lacking skills may be mismatched with students who present an overconfidence in their skills relative to their first-year status.

The key challenge in planning a team-composition intervention was that the intervention couldn't fully rely on self-reported data. Often, students would say that they excelled at teamwork or communication, but then interview data from their teammates would reveal a counter-narrative that directly contradicted the student's self-assessment. More troubling perhaps were the several instances where a young woman engineer would state that they hadn't experienced any negative impacts of their gender and then go on to describe an occurrence where they were explicitly excluded from something because of their gender. This cognitive dissonance (See: [40]) is worthy of a study in its own right, but served to confound any interventional methods that were fully self-reported in our study.

After full consideration of the previous factors, it was decided that the selected intervention would happen in three phases:

First, students in the intervention group (one class from each instructor) would be given a brief design/build/test challenge under heavy time constraints to place them into an engineering mindset while creating a stressful, time-sensitive environment where poor teamwork and communication habits might reveal themselves. The remaining classes would not be given the challenge, and thus would remain as a control.

Second, the intervention team would meet with the professors for the course to use the data gathered in the first stage, along with their acquired knowledge of the students to intentionally sort the students into teams based on students' observed communication practices that would be more innately (infrastructurally but not explicitly) supportive of women. These teams would then be the design teams for the remainder of the semester. The control classes would be sorted according to the previous models, which were either random, or using CATME. The intervention team would then allow the rest of the semester to proceed without contact or intervention to allow the small shift in the rhetorical infrastructure to take effect.

Finally, at the end of the semester, both the students in the interventional classrooms and the control classrooms would be surveyed about their experiences in the course. The student responses would then be compared to the responses in the other classrooms to see how student experiences and sense of belonging shifted in relation to the infrastructural changes regarding teamwork. More detail about each of these phases is given in the following subsections.

3.5.1 Phase One: Design/Build/Test Challenge

In phase one of the intervention, students were given a time-sensitive design build test challenge to simulate the stresses and communication challenges present throughout a standard semester of first-year engineering. Students were told of the interventional nature of the activity beforehand and full verbal consent was gathered from all participants with an acknowledgement that their participation was voluntary and could be revoked at any time. While the students were told that we were conducting the challenge to see how they communicated in teams, the role that gender played in our study was left unmentioned, and the activity was constructed in such a way that the students were encouraged to focus on the competitive aspects of the process. The activity itself was modified from the experiences of one of our student researcher collaborators, who had done a similar activity in their earlier academic career. The intervention team provided the resources for the activity, and our research assistants served as the moderators and assistants for the activity. They were compensated for this labor as well. The activity sheet is replicated below in full:

Engineering Activity (Archimedes Launcher)

Background

The great mathematician and innovator Archimedes was one of the greatest engineering minds of the 3rd century B.C.E. For his students, he long proposed a simple competition early in the year to test each mind's ability to design the future. Each of the engineers would assemble into teams of four for the competition. The challenge presented to each team was to create a machine that could launch a boulder and compete in three trials in a single day. The first was a trial of strength to launch the boulder the farthest. The second was a trial of reliability to test the accuracy of the launcher. The third was a trial of documentation for the machine that would not be lost to time. Today, the competition begins again.

Learning Objectives

1. *Assess students' knowledge of design principles and the design process.*
2. *Introduce students to a project-based learning environment.*
3. *Introduce students to time-constrained projects.*

Instructions

Form into random teams of four and spend the next thirty minutes of class designing, building, and testing a boulder (ping-pong ball) launcher using the provided materials at the front of the room. Teams will test their launchers' accuracy and power at the stations provided in the classroom. Documentation forms can be found next to the materials. Each team will be competing for the strongest launcher, the most accurate launcher, and the most documented testing. At the end of the competition, the winner of each category will receive a small accolade.

Resources

1. *Paper*
2. *Popsicle Sticks*
3. *Spoons*
6. *Tape*
7. *Aluminum Foil*
8. *Super Glue*
9. *Notecards*
10. *Other classroom materials as permitted by the instructor*

Rules

1. *The launcher must be a machine that operates independently from the human body. (ex. cannot be a rubber band stretched between fingers or any other mechanisms that use the human body as a structure.)*
2. *Launching may only occur in the designated launch area.*
3. *Students must return to their group at their table to record an iteration and have that iteration signed off on by the experimental aid before testing again.*
4. *Only one test may be conducted at a time.*
5. *To maintain safety, students may not launch any object other than a ping-pong ball.*

Assessment

Launchers will be assessed on the following criteria:

1. ***Strongest launcher***

The launcher that launches the ping-pong ball the farthest is the winner of this category. This will be tested by measuring the distance from the front of the launcher to the point where the ping-pong ball first impacted the ground.

2. ***Most accurate launcher***

The launcher that hits the target the most times in a row without missing is the winner of this category.

3. ***Most tested and documented iterations of a launcher***

The launcher that has undergone the most reiterations that have been signed off by either a professor or the experimental aid is the winner of this category.

Iteration recording sheets will be provided by the professor and must be filled out to get credit for the iteration. Each documented iteration includes the change that was made to the launcher, the reason for the change, and the effects produced by the change.

The activity above was designed to have students constantly rushing back and forth to their teams, while designing and being forced to record and track the stages of their design process. While this activity did allow students room for creative group design work, (one group of students made a functioning ping-pong crossbow), the nature of the activity meant that most student time would be spent on communication in some form or another. The activity also presents a clear note-taking role, as research on gendered divisions has shown that women are frequently assigned note-taking or secretarial roles within groups.

At the beginning of the activity, the students were given nametags with their team number on it, so that the intervention team could take notes on their communication practices. Specifically, the team was observing moments where women were marginalized or ignored by others in the group.

Despite the brief nature of the activity, the stress of the competition brought a host of predicted behaviors to the group dynamics. In some groups, teammates were treated equally; in some groups, women were actively ignored or assigned to notetaking roles; and in some groups, there were no clear gendered distinctions, but individuals showed clear signs of not communicating effectively or restricting their teammates' access to the project. One student in particular approached the front during the activity and proudly informed the intervention team that he didn't think his teammates' ideas were very good, so he was going to build his own device by himself. Behaviors and moments such as these were recorded by the intervention team and linked to the individual. After the activity concluded and the winners were announced, the intervention team met with the professors to proceed with phase two.

3.5.2 Phase Two: Team Sorting

After the activity in the class, the intervention team and the professors for the courses met to discuss the team compositions for the major design projects that would take place in the remainder of the year. The intervention team shared their notes and observations with the professors to assist them in their teaming process. The professors were given complete autonomy into how the teams were sorted, but suggestions were made based on five criteria derived from the previous year's research:

1. Place women in positions and teams where their abilities will be respected and not challenged based on their gender. (If appropriate, support the placement of women in roles as design team lead.)
2. Avoid placing women in teams with students displaying openly misogynistic or overly controlling personalities. (Examples from our previous research include the student who told a female classmate "Women can't code" and another who refused to let a female classmate touch the robot at all.)
3. Avoid teams of all women. (Our previous research found that these teams sometimes faced additional challenges with "spotlighting" or extra alert attention from instructors in ways that did not materialize for mixed-gender teams.)
4. Place male students with directive personalities and those who prefer to work without teammates on teams together. (Previous research suggested that these students' direct communication styles might work best in groups of peers with similar communication styles.)
5. Place introverted women or students lacking engineering confidence with teammates who will nurture their growth rather than take over the group or designate them to solely note-taking roles.

As shown in the criteria above, creating a successful authority infrastructure for women in early engineering classrooms did not automatically mean vesting women with ultimate authority over the team. While some of the women in the course would serve as the design team lead, there were those without the engineering experience or confidence to be successful in such a role. The criteria, therefore, centered around removing barriers to the building of confidence and ultimately attempting to vest team power with those who showed skills in active listening and group decision making above any specific gendered considerations. One of the unique affordances of this approach is that it supports communication practices that are beneficial to students outside of the contexts of diversity and equity initiatives.

The professors of the courses were more than happy to work with these suggested criteria, and frequently suggested further modifications to team composition based on behaviors that they had seen in the first two weeks of the semester. Students' names and dispositions were discussed primarily in terms of how they might help each other to grow as engineers. After an hour of discussion all the teams were determined and the design team leads had been selected. From this point, the semester proceeded as normal until the return of the intervention team right before the end of the course.

3.5.3 Phase Three: Engineering Course Experience Surveys

After our initial classroom intervention and team sorting, feedback was collected from students in each of the classes in the last week of class. This feedback was collected in the form of student surveys, which asked students to reflect on their experience in the course using a series of questions:

Likert Scale Questions (Scale: Strongly Disagree to Strongly Agree)

1. I feel my team and I found success in Project 2.
2. I feel that one or several of my teammates were difficult to work with.
3. I feel that my ideas were valued in the design/build/test process.
4. I feel that I was respected by my teammates.
5. I feel that I had equal opportunity to engage in the technical (hands on) work of the project.
6. I feel like my gender identity directly impacted one or more of my interactions in this course.
7. After this course, I feel like I belong in the field of engineering.

Open-ended follow-up questions were included to better understand student responses (i.e., "What does success in the project mean to you"). While we are currently analyzing student responses and faculty interview data and anticipate sharing detailed statistical findings in the revised paper and the conference presentation, we did notice small but significant trends in student responses, which are outlined in the following section.

4. Preliminary Findings

The primary purpose of this paper is methodological in nature. Thus, while we now present initial findings and visualizations for our data, we acknowledge that more work is needed to make definitive statements about student behavior and belonging in the classroom.

Most meaningfully within our research set, the intervention found that the activities conducted impacted students' reported sense of belonging in the field of engineering. In response to question seven above (After this course, I feel like I belong in the field of engineering), we can see a distinct upward trend among the students in the test group shown in the data below:

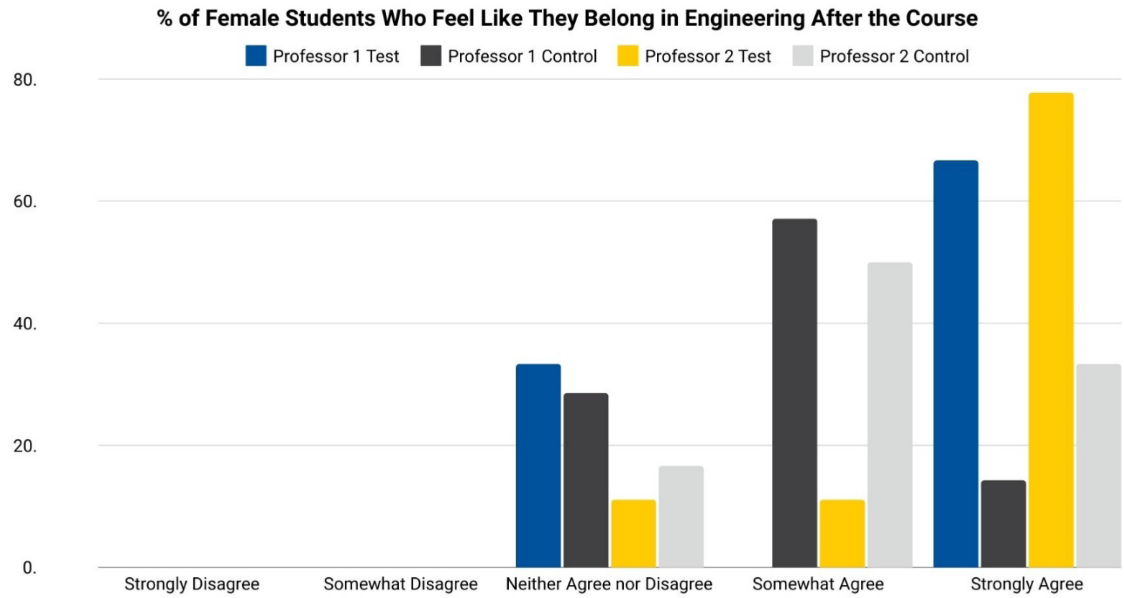

Figure 3: Students Belonging in the Introductory Engineering Classroom

As shown in the figure above, there is a small but noticeable shift in perceptions of belonging between the control and test groups. Surprisingly, while almost no students admitted that they did not feel like they belonged in the field of engineering, there was far less neutrality present in the intervention groups. **We interpret this trend to mean that a small intervention into the group formation process to intentionally impact the experiences of women in engineering can positively impact students' perceptions of their experience in the class overall.** This finding is particularly meaningful, because engineering education research has made clear connections between a student's sense of belonging and their future success as an engineer [30], [31], [32]. While it is surprising to see a lack of answers in the negative, initial speculation from the data suggests that student's sense of self-confidence in their future professions may account for a lack of negative answers. After all, students who felt that they truly did not belong in the program were likely the ones that have dropped out by the end of the semester. Following this logic, a move from neutral to strong agreement reflects the shifts that we would expect to see.

Interestingly, the intervention did not notice significant differences between control and intervention classes for questions that asked students to identify specific instances of gender-based discrimination they experienced in the class teamwork settings. This is shown in the figure below:

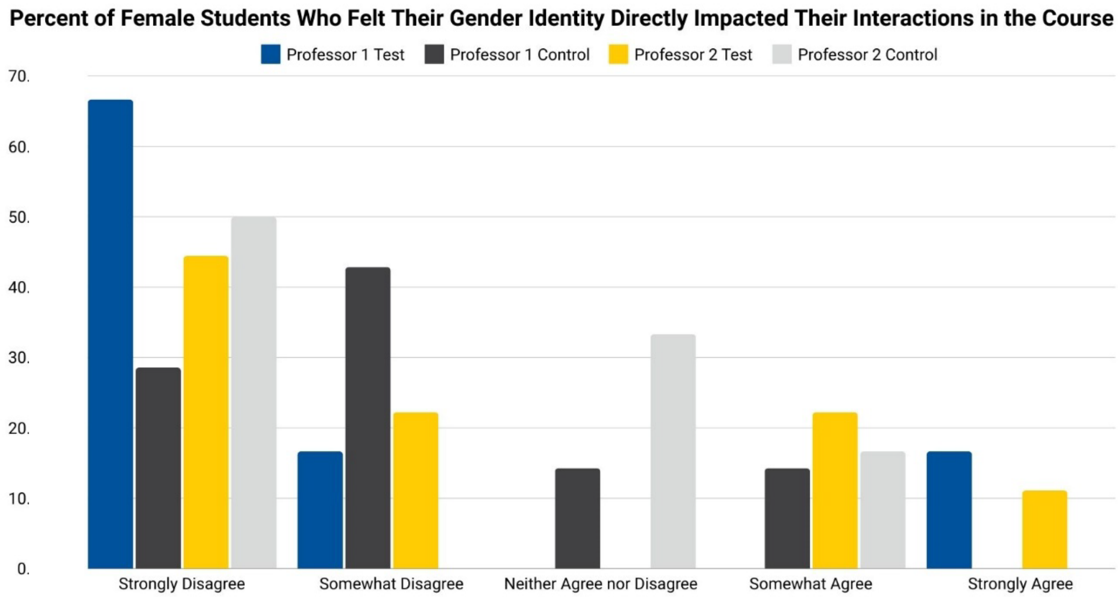

Figure 4: Female Student's Perceptions of the Impact of Their Gender

However, there does seem to be a reverse trend for some of these responses. As seen in the graph above, while blue and yellow bars are still present in the "agree" portion of the Likert scale, they are less evenly distributed in comparison to the control groups. While the control group elicited more neutral responses for gender related concerns, the intervention classes responded with staunch denial that gender related concerns had been an issue in class. Further research is needed to confirm a cause for these trends, but we posit that students who have negative experiences may be less willing to describe them as such even when they occur. By contrast, the students that had positive experiences of belonging may be more likely to staunchly reject the existence of negative experiences, as they truly did not occur for those students, ergo the students feel more secure in their learning and education. We find both implications highly encouraging for the intervention practices moving forward.

To further solidify the self-reported data, we also conducted interviews with the professors in the course after the class was over to gauge their qualitative impressions of the impact of the intervention. These informal conversations mirrored the results of our survey, and while we do not have space to transcribe them here in full, there were two significant statements that assist in contextualizing the value of this intervention.

When asked if the intervention had an impact on the course, one professor described a "noticeable difference between them [the test and control intervention classes]" He said, "It wasn't that 100% of my test teams were all better than 100% of the control groups, but if it were a normal distribution, certainly there is a noticeable difference as a class." This statement reflects the outcomes of the surveys and speaks to the value of the intervention. The intervention made noticeable differences in how students experienced the coursework and how the class impacted their growth and sense of belonging. Most importantly, he noted that the teams across the intervention section seemed to do better as a whole, not specifically along gendered lines. This confirms the work of Hogan and Sathy who contend that inclusive pedagogical strategies positively impact all students, not only underrepresented students [41].

Finally, we asked about the use of time to conduct the intervention. Both professors in the intervention agreed that the intervention was a valuable use of class time while not consuming too much course time that might be used on engineering topics. However, one professor made a point to go further stating that "For every hour used on communication training and practice [interventions] around ten hours of time are saved later in the semester." He described some of the team challenges and communication breakdowns that occurred in the control group, saying that these moments would have taken less time for him to intervene with the students if the teams had been set up differently at the start of the semester. While it is difficult to say with certainty how the adjustment of infrastructural variables would have impacted the outcome, the research confirms that an hour of class time seems to be a reasonable frame for a communication intervention to make a small shift in classroom dynamics and student sense of belonging.

5. Conclusion & Implications

Educational intervention need not change the world to be considered successful. By making tiny adjustments in our curriculum, educators in engineering can improve the experiences of students and set them up for successful careers. However, the first step to making these changes successful is understanding what possibilities exist and how those possibilities might affect other choices in our engineering classrooms.

To this end, our work has demonstrated a new infrastructural method of analyzing, applying, and understanding the nature of communication spaces. By using specific engineering classrooms as a case study, we have demonstrated that even sticky problems, like gender-based marginalization, have direct and practical interventions through this method. We demonstrated an increase in student sense of belonging and a clear direction for instructors of early engineering to move forward.

If we work to observe the infrastructural and rhetorical forces that impact our communication, we can make the real, lived experiences of students, especially those who may be traditionally impacted the most by our classroom decisions visible, so that we might begin to aid them in their education, not through passive, permissive, or ineffective interventions, but through genuine, small, careful changes within their daily lives. We continue to advocate for these empathetic and cautious methods, because they tend to make change that lasts, despite its small range of impact. These, we argue, are the small shifts that matter.

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