# "Can I drop it this time?" Gender and Collaborative Group Dynamics in an Engineering Design-Based Afterschool Program

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## Abstract

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## Keywords

## Document Type

Article

# "Can I drop it this time?" Gender and Collaborative Group Dynamics in an Engineering Design-Based Afterschool Program

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## Abstract

The 21st century has brought an increasing demand for expertise in science, technology, engineering, and math (STEM). Although strides have been made towards increasing gender diversity in several of these disciplines, engineering remains primarily male dominated. In response, the U.S. educational system has attempted to make engineering curriculum more engaging, informative, and welcoming to girls. Specifically, project-based and design-based learning pedagogies promise to make engineering interesting and accessible for girls while enculturating them into the world of engineering and scientific inquiry. Outcomes for girls learning in these contexts have been mixed. The purpose of this study was to explore how cultural gender norms are navigated within informal K-12 engineering contexts. We analyzed video of single- and mixed-gender collaborative groups participating in Studio STEM, a design-based, environmentally themed afterschool program that took place in a rural community. Discourse analysis was used to interpret interactional styles within and across groups. Discrepancies were found regarding functional and cultural characteristics of groups based on gender composition. Single-gender groups adhered more closely to social gender norms. For example, the boys group was characterized by overt hierarchies, whereas the girls group outwardly displayed solidarity and collaboration. In contrast, characteristics of interactional styles within mixed gender groups strayed from social gender norms, and stylistic differences across group types were greater for girls than for boys. Learning outcomes indicated that girls learned more in mixed-gender groups. Our results support the use of mixed-gender collaborative learning groups in engineering education yet uncover several challenges. We close with a discussion of implications for practitioners.

*Keywords:*   informal education, project-based learning, design-based learning, collaboration, middle school, gender, engineering

Regrettably, the decades-long push to increase the proportion of women in the field of engineering has fallen short (Hill, Corbett, & St. Rose, 2010). Although women receive better grades than men in high school math and science courses (Shettle et al., 2007), the representation of women in engineering occupations still remains in the single digits despite considerable strides in other science, technology, engineering, and math (STEM) fields. For example, women comprise 52.9 percent of biological scientists, yet only 6.7 percent of mechanical engineers (Chao & Rones, 2007).

Promoting the entry of women into engineering fields is important for several reasons. First, participation in financially lucrative professions such as engineering (National Science Board, 2016; U.S. Census Bureau, 2013) stands to decrease the gender pay gap, which is largely due to occupational segregation (Dey & Hill, 2007). Second, as the world's economy

becomes increasingly global and dependent on products designed by engineers, women are needed to provide a balanced perspective that advocates for the needs of half of the world's population. Third, a larger and more diverse engineering workforce will expand capacity for innovation, which has been a staple of the U.S. economy in an increasingly global market (Hill et al., 2010).

Increasing participation of women in engineering fields is unfortunately only half the battle. Women in engineering and tech occupations have higher attrition rates that those in other occupations (Hewlett et al., 2008). Additionally, out of all STEM occupations, the field of engineering consistently bears one of the largest gender gaps (Hill et al., 2010). Therefore, equitable engineering education reform is tasked with not only increasing interest and skills in engineering; efforts must focus on setting women up for success in a workforce currently dominated by men.

Success in the field of engineering is increasingly dependent on an ability to work with others collaboratively. In a 2004 vision statement, the National Academy of Engineering stated, "the engineering profession recognizes that engineers need to work in teams" (p. 43) and that "the challenge of working effectively with multicultural teams will continue to grow" (p. 35). This shift has resulted in a recent propagation of collaborative, Project-Based Learning (PBL) pedagogical techniques in engineering education (Caprano, Caprano, & Morgan, 2013).

The broader collaborative movement in education also stems from a paradigmatic shift towards socio-cultural theories of learning (e.g., Lave & Wenger, 1991; Vygotsky, 1987). Thus, in addition to developing twenty-first-century skills such as collaboration, PBL techniques give students hands-on experiences (Krajcik & Czerniak, 2007) that promote critical thinking, student achievement, self-efficacy, and motivation to learn (Krajcik, 2001). From a socio-cultural lens, these experiences are modeled as a process of acculturation into the engineering professional community (Brown & Campione, 1994), which has its own set of intellectual and social norms (Cobb & Yackel, 1996).

Middle school is an opportune time to introduce youth to collaborative, engineering activities within a safe, "maker" space. Specifically, Design-Based Learning (DBL) techniques are often introduced at this age (Krajcik & Czerniak, 2007). In DBL, problems presented to collaborative groups necessitate engineered, designed solutions. The design, construction, and testing of a device solves the problem, and youth typically work in teams to design a solution. Design is to engineering what inquiry is to science; they are both problem-solving activities that use cognitive reasoning, mental models, evaluation, rely on content knowledge, and operate within constraints (Lewis, 2006).

Middle school is marked by a focus on identity formation, and social experiences play a critical role in this process (Marcia, 1980). As girls are more drawn to instruction that places emphasis on social interaction and

cooperation (Wolfe & Powell, 2009), DBL may foster an initial interest in engineering. When positive peer interactions and reactions occur during DBL opportunities, girls experience gains in engineering confidence and competence (Sacerdote, 2001). This timing is especially critical for girls because motivation and academic performance in middle school makes or breaks their trajectory towards engineering fields as they enter high school (Maltese & Tai, 2010).

Problem-Based or Design-Based Learning outcomes for middle school girls are mixed (Johnson & Johnson, 1989; Taconis, Ferguson-Hessler, & Broekamp, 2001), and young women face many barriers to success in collaborative group work (Southerland, Kittleson, Settlage, & Lanier, 2005). Low self-efficacy and the presence of gender stereotypes can lead to decreased outcomes for girls working in groups (Hill et al., 2010). These inequities have been found in K-12 and post-secondary contexts; thus, engineering teamwork has the potential to perpetuate sexism and gender stereotypes throughout the educational process (Wolfe & Powell, 2009). Preventing these negative experiences from occurring is critical, especially during the formative middle school years. The dynamics of student collaborative groups are nuanced and complex. Although these topics necessitate qualitative investigations, this type of research is greatly lacking, especially in informal middle school engineering contexts (Baillie & Douglas, 2014; Capobianco, French, & Diefes-Dux, 2012). As a result, experts have called for more rigorous qualitative analyses of engineering education techniques in recent years (Baillie & Douglas, 2014).

This study explores collaborative group interactions of single-gender and mixed-gender student groups participating in a middle school engineering design afterschool program. Discourse analysis was used to interrogate the collaborative interactions of boys and girls attempting to design windmill generators and gravity-powered lights. We interpreted our findings based on a cultural difference approach to gender. Results of this exploratory study will help researchers and practitioners understand the nuanced micro-interactions that contribute to group work utilized in informal, design-based engineering work. Additionally, descriptions of functional characteristics of group dynamics lay the foundation for future prescriptive studies that investigate how practitioners can create more equitable engineering design classrooms.

## Background

### Gender Gaps in Engineering

A large volume of research has sought to explain and remediate the engineering gender gap. Research has focused either on the environmental or physical "deficits" girls bring to engineering or the cultural gender differences that make engineering male-dominated. Consequently, attempts to reduce the gender gap in engineering fall within one of two broad strategic categories: (a) reduce environmental, social,

and cultural barriers to address the gender "deficit" for girls and women as they travel through the engineering pipeline, or (b) "re-gender" the engineering climate and culture so that it celebrates the feminine perspective and promotes gender equity (Bryson & De Castell, 1996). In this section, we outline critical research from both of these perspectives.

The primary gender deficit typically considered by researchers is that of sex-dependent cognitive ability. Theories in this "nature" camp point to deficits in spatial reasoning and problem solving, as males have traditionally outperformed females in tasks involving spatial orientation and visualization (Sorby, 2009; Voyer, Voyer, & Bryden, 1995). Although the connection between sex, spatial skills, and engineering seems logical at face value, research in this area is not conclusive (Ceci, Williams, & Barnett, 2009). Additionally, the odds of successfully completing tasks involving spatial ability have been drastically increased for girls using simple training models (Sorby & Baartmans, 2000). Thus, innate differences in ability, if they do exist, cannot be blamed solely for engineering gender gaps.

Self-efficacy gender gaps may also contribute to this observed deficit. Regardless of ability, if a female student has a low perception of her engineering self-efficacy, she will be less likely to develop an interest in activities involving engineering (Correll, 2004; Jones, Paretti, Hein & Knott, 2010). Further, if she buys into negative stereotypes about women's math and science abilities, she will tend to perform at lower levels in these areas as a result (Shapiro & Williams, 2012). This phenomenon, known as "stereotype threat," has been shown to affect girls and women of all ability levels (Shapiro & Williams, 2012).

Inexperience with "tinkering" may also contribute to girls' lack of confidence when experimenting with tools and devices (Griffin, Brandt, Bickel, Schnittka, & Schnittka, 2015; Damour, 2009). Tinkering is used in engineering literature to describe unstructured time examining and experimenting with objects or phenomena (Honey & Kanter, 2013). Although girls may need extra time with an object in order to feel confident and excited about it (Damour, 2009), they typically have less experience tinkering in non-school contexts (Beverley, 2006). Considering these "experiential" deficits, it is not inconceivable that males aged $8-17$ are five times more likely than females to be interested in an engineering career (Hill et al., 2010).

A lack of more "feminine" engineering-oriented toys marketed to girls may influence their lower interest in tinkering. Although strides in this area have been made in recent years, many of these toys are still geared towards the masculine aesthetic. Additionally, many stereotypically female craft-type hobbies (sewing, knitting, and crocheting) include design, mathematical, and spatial problem solving, but are not identified as an outlet for engineering tinkering or thinking (Bain, 2016; Minahan & Cox, 2007). This masculinized tinkering environment stands to present engineering as uninviting and uninteresting to girls.

Instead of focusing on cognitive, social, and experiential deficits for girls, other researchers have targeted change efforts on social and cultural shifts within the broader engineering discipline. A field traditionally dominated by men, engineering culture has been described as "stress[ing] the acquisition of organizational power" and "requir[ing] that interest in technology and organizational power be interactionally 'presented' in the appropriate form – a form closely tied to the male gender role" (McIlwee & Robinson, 1992, p. 19). Others have described engineering as fostering a patriarchal culture that places value on "male" traits and values (such as rationality and competence) instead of "female" traits and values, such as emotional or relational thinking and social complexity (Hacker, 1981). A perception that engineering culture places high value on power and masculinity may cause women to overlook engineering as a career.

Cultural prescriptions dictate that women choose "nurturing" or people-oriented fields instead of those that appear self-promoting (Eccles, 2006). A career in engineering, however, is perceived as not directly benefitting society (National Academy of Engineering, 2004). In fact, when girls were exposed to messaging explaining how engineers benefit society, they were more likely to be interested in the career (National Academy of Engineering, 2008; Plant, Baylor, Doerr, & Rosenberg-Kima, 2009). In addition, women tend to be more adverse to competitive environments than men (Baron-Cohen, 2002; Seymour, 1995). A lack of female role models in the field of engineering perpetuates these issues and makes it more difficult for girls to see the connection between "competitive," "thing-oriented" engineering and "femininity" (Latu, Mast, Lammers, & Bombari, 2013).

Strategies to improve large-scale engineering culture focus on making changes to the dominant discourse in the engineering process and workplace. These types of systemic and cultural shifts require grand-scale change in post-secondary educational institutions and in the workplace, which involves making sure "inclusion is an explicit organizational goal" (Bryson & De Castell, 1996, p. 125). Collaborative, design-based learning techniques, such as those utilized in the present research project, aim to combat engineering gender gaps through both broad categories: (a) by reducing experiential tinkering deficits for girls, and (b) by providing exposure to engineering culture in a supportive and inclusive environment.

*Gender and Collaborative Learning in K-12 STEM Education*

Most research on gender and collaborative group work in K-12 STEM education is situated within technology- and computer-based PBL applications. Barbieri and Light (1992) looked at both single- and mixed-gender groups of 11- and 12-year-old children attempting to solve a

computer-based novel problem-solving task. They found that the level of success on a performance measure was higher for single-gender boys groups and mixed-gender groups, and lower for single-gender girls groups. They also found mouse-use disparities for mixed-gender groups, with boys spending a disproportionate amount of time with the mouse. Additionally, they observed that boys were more likely to sit in the position that gave them right-hand control over the mouse. Thus, boys dominated both the technological tool and the learning space, possibly reflecting male-dominated resource allocation in greater society.

Jenson, De Castell, and Bryson (2003) investigated the effectiveness of a new model of technology-focused colla-borative group work aimed at promoting gender equity. In an attempt to transform the "masculinized community" of technology, they provided training in the use of a new elementary school computer center for female students and teachers, who then trained the male students and teachers. The idea was to create a "critical mass" of female "experts" to "model […] equal participation in science and technology-related courses" (p. 563). They found that, despite increased self-advocacy and ownership of technol-ogy by girls, gender stereotypes still persisted, specifically ones that labeled boys and men as already computer competent, and acquiring new skills more quickly. They found short-term gains in gender equity and technology access; however, these gains were reversed one year after the conclusion of the program.

Findings for both studies suggest that gender equity is not easily remedied in K-12 STEM education, and that positive gains may be short term at best. Engineering-specific education poses an additional challenge: *students are tasked with designing a useable product* instead of merely solving a problem. Designing an object based on engineering principles, functionality, and form requires the back and forth of multiple perspectives. Engineers in the workplace similarly need to apply content and navigate complex human interaction in order to complete an engineering design task. Non-design projects may involve tasks that can easily be divided and delegated. Thus, adequate gender research in K-12 engineering education necessitates the utilization of design-based elements. The present study therefore addresses an area that is relatively untouched in engineering education.

*Gender and Teaming in University Engineering Education*

The field of post-secondary engineering education has become increasingly focused on improving the effective-ness of engineering design teams (Tonso, 2006). In 1996, Tonso conducted an ethnographic study that included an investigation of cultural norms in three mixed-gender undergraduate engineering design teams. Consistent across groups was a tendency for male team members to set

cultural norms with few opportunities for women to redefine them. Typical male behaviors that served to set the tone included profanity, "semi-sexual, double enten-dres, and metaphors that encouraged symbolic violence" (p. 224).

A decade later, Tonso (2006) used large-scale ethno-graphic methods to investigate how collaborative engineer-ing design teams functioned in the university context based on social identities produced via campus culture. As a participant-observer, she analyzed interactions of both women and men in two undergraduate design teams with the same gender composition (two women and three or four men), finding that women with similar characteristics had widely contrasting roles depending on the identity com-position of the males in their group. These findings work to combat the misconception that group gender composition is the key variable in interactional team dynamics. Instead, the dynamics and role attribution in a group is dependent on campus culture, social identities, motivation, and academic ability. One limitation of this study for our purposes is that *the design projects were graded*, and so many of the motivational variables mentioned by Tonso related to the desire for a higher grade point average.

Wolfe and Powell (2009) took a more hypothetical approach to investigating gender and teamwork for under-graduate engineering students. They administered a survey asking engineering and non-engineering students to rate perceptions of speech acts made by either women or men in a team setting. They found that men were harsher than women when rating female-typical speech acts (specifi-cally, speech acts that signified weakness or admitting mistakes) regardless of the gender of the speaker. This prejudice existed even in situations where the speaker was admitting a mistake in order to lessen the blame on another teammate, preserving group solidarity. They conclude that their findings support that engineering culture is prejudiced against female interactional styles and instead promotes norms of aggressive self-promotion.

These three studies are critical because they demonstrate how gender dynamics can be manifested in post-secondary engineering education contexts. Still missing in the lite-rature, however, is an understanding of how gender dyna-mics operate in middle school design teams. Identities of middle school students are still burgeoning, and the "bubble" within which college engineering students ope-rate may define acceptable behavior more strictly than middle school contexts. The research is greatly lacking in this area (Capobianco et al., 2012).

*Theoretical Underpinnings*

The overarching theoretical gender paradigm we utilized is that of "analogy." In this view, gender symbolizes sex, but is not directly equivalent to sex. Thus, women draw from gender roles present within the particular context and

culture in which they belong (Wodak, 1997). Tonso's (2006) work concerning expectation states also draws from this paradigm: "gender is a diffuse (rather than specific) status characteristic that is defined in the broader society and entails expectations for normatively appropriate behaviors in social contexts" (Herschel, 1994, p. 212).

The mechanics of how men and women interact in a group setting are well researched in the field of gender studies (as reviewed in Cameron, 1998). From this research emerged two main theoretical frameworks to explain language differences between men and women. In her book *Gender and Discourse*, Deborah Tannen describes an "unfortunate dichotomy that has emerged in the literature, suggesting that approaches to gender and language fall into two categories: the 'cultural difference' approach, as opposed to the 'power' and 'dominance' approach […] it falsely obfuscates more than it clarifies" (Tannen, 1994, p. 9). She further explains that the intent to dominate does not always preclude dominance; sometimes dominance is unintended and a result of cultural factors. This more inclusive framework was chosen to reduce bias, which can be common in qualitative gender research. Instead of making the assumption that gender dominance was present, we uncovered small group norms before beginning an analysis based on both context and gender-dominance reinforcing societal gender norms.

## Areas of Inquiry

We focused this study on the interactional dynamics that contributed to group design processes that took place as middle school students began their journey in engineering practices. Our purpose was to investigate how middle school students navigated social gender norms within the context of the informal engineering-design space. We did not begin our investigation with a focus on power and social dominance; however, we did see power as playing a role. We saw power as primarily drawn from the responses and consequences to verbal and non-verbal actions. In this study, we examined these responses, yet maintained an exploratory lens aimed at describing functional group dynamics in comparison to traditional conceptions of gender in engineering.

Discourse analysis focused on the collaborative group dynamics of (a) female single-gender, (b) male single-gender, and (c) mixed-gender collaborative groups. We looked specifically at the communicative characteristics that contributed to the function of groups as entities accomplishing an engineering design task. The first research question was: How do male and female students participating in small group, engineering design-based projects collaborate depending on the gender makeup of the group? Our second research question was: To what extent do middle school students fulfill traditional gender roles within single- and mixed-gender design teams?

## Method

### Instructional Context

Studio STEM was a voluntary afterschool program for middle school students operating in three rural middle schools along the Atlantic seaboard. The project was funded by a grant from the National Science Foundation, and operated from 2011–2014. It served 128 children who were interested in experiencing a STEM afterschool program.

In an experiential, collaborative, and casual afterschool environment, Studio STEM used a design-based, environmentally themed curriculum aimed at promoting change around students' conceptions of physical science phenomena. Students self-selected into small groups of 3–4 at the beginning of the semester and were given a design-based task that required them to think critically about physical and environmental concepts. The curriculum used during the data collection period is called *Save the Snails, Salamanders, and Other Slimy Creatures* (Schnittka, 2013). The objective of this curriculum is to teach students how coal, wind, and solar power can generate electricity. To "save the snails" from pollution generated by coal-fired power plants, students built their own wind and/or gravity-powered generators using motors, gears, and other materials. Groups used information presented by the program instructor to make improvements on their structure each week. Program instructors and college-aged mentors circulated around the room, scaffolding conceptual development and posing facilitative inquiries.

### Participants

Of the three afterschool sites, "North" Middle School was chosen for data collection by Studio STEM principal investigators. At the time of this study, North Middle School comprised a majority of poor and working class youth (42 percent were eligible for free or reduced lunch) who were White (White: 95 percent, Black: 4 percent, Hispanic: 1 percent). Participants were chosen to be a part of Studio STEM through an application process. More students applied than were selected. Preference was given to students who qualified for free or reduced lunch. Attention was also given to demographic characteristics such as gender, age, and academic achievement to ensure that each group was heterogeneous and composed of youth from a variety of backgrounds. The instructor was a 52-year-old White female teacher at the school. Mentors were students from a nearby university.

Prior to their participation in the study, students' families were briefed about the nature of the investigation and signed letters of consent to participate. All research methods were approved by the Institutional Review Boards of the participating universities. Pseudonyms have

been used for the school name, instructor, mentors, and students to protect their identities.

The afterschool program at "North" consisted of 16 youth in sixth and seventh grade (nine girls and seven boys), one instructor, and three mentors. The 16 students who participated in this program self-divided into four small groups: two single-gender groups and two mixed-gender groups (see Table 1). The curriculum guide (Schnittka, 2013) gives the following instructions relating to cooperative group assignments:

*Ideally, students should be placed in small groups of three or four. Each student should be assigned a role in the group, such as material collector or data collector. Either allow students to pick their own groups, or assign them based on what you know about how your students get along and work together. Since students will be working with the same group members for the duration of this unit, it is best if the students like one another and work well together. Have students sit together with their group members from the beginning of this unit, ideally around a table where they can each see and talk to one another.*

### Data Collection Procedures

Data were collected by the principal investigator and co-investigators of the Studio STEM project. For this particular semester of Studio STEM, the following qualitative data were collected:

(a) video taken of the whole room
(b) video taken of small groups
(c) open responses to prompt (see Figure 1)

Approximately 12 hours of video were captured over the course of seven weekly sessions: 7 hours of whole group discussion and lecture, and 4 hours 45 minutes of small group discussion videos. Videos of small groups were taken by a research assistant who was instructed to systematically spend an equal amount of time with each group. The average time spent on each group each session was 10 minutes. Thus, these videos provide a "sample" of

group interactions (similar to methods utilized in Barbieri and Light, 1992). This "sampling" method was chosen to (a) reduce the video analysis time to a manageable amount, while (b) still maintaining an accurate snapshot of group interactions. Videos were transcribed by the authors.

Pre- and post-tests on the science and engineering content were also administered to the students to assess their level of understanding about how electricity is produced from various forms of energy. This assessment was chosen because it closely targets the goals of the lesson, and is therefore instructionally sensitive (Ruiz-Primo et al., 2012). The question, accompanied by two photos, simply asked, "How does this happen?" See Figure 1.

Responses to the prompt were scored using the following rubric for a possible total of 10 points. This rubric was based on the main components of the process taught in the lesson. One point was given for each of the following statements:

coal was burned
water is involved
water is boiled
steam is produced
something is turned or moved
a turbine is involved
magnets are involved
coils of wire are involved
a generator is involved
energy is involved

In order to assess the validity of this assessment, it was administered to 36 mechanical engineering students in the final semester of their senior year, and 56 elementary education students with the assumption that the mechanical engineering students would perform better than the education students. After engaging in the *Save the Snails* curriculum, the education students scored much higher. An independent sample *t*-test indicated that the engineering students did indeed score higher than the education students before their lesson on energy. Before instruction, the education student mean was 1.68 points out of 10, and the engineering student mean was 4.58 points out of 10. An independent sample *t*-test demonstrated that these means

Table 1
*North Middle School Groups.*

| Group Number | Gender | Students |
|---|---|---|
| 1 | Boys | Mark (age 11), Charles (age 11), Tate (age 11), and Luke (age 11) |
| 2 | Girls | Anna (age 11), Bonnie (age 11), and Jennifer (age 11)* |
| 3 | Mixed | Lizzie (age 12), Craig (age 12), Heidi (age 12), and Sally (age 11)** |
| 4 | Mixed | Penny (age 11), Candy (age 11), Meredith (age 11), and Albert (age 11)*** |

*A fourth, Chuck (male, age 12), left the program before the group design-process began
**Sally was only present for a few sessions
***Albert joined this group after the first couple of sessions, once the design-process began
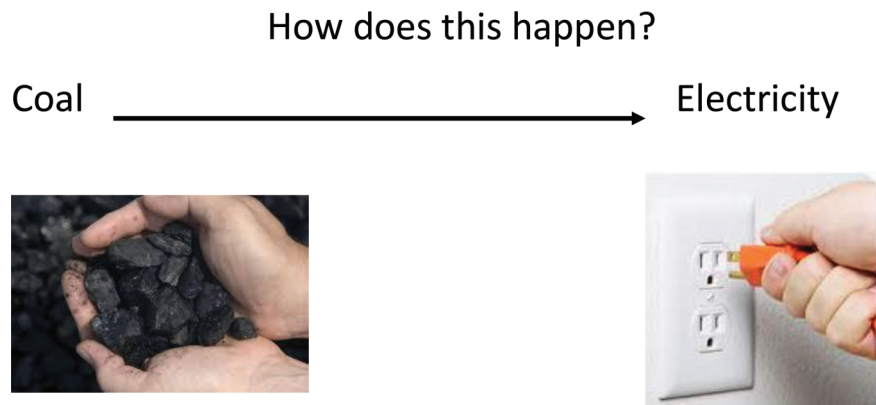
# How does this happen?

Coal ⟶ Electricity



*Figure 1.* Pre- and post-test.

were significantly different ($p < 0.001$). After instruction, the education students' post test scores were the same as the engineering student scores ($p = 0.86$) with a post-test mean of 4.71 out of 10 possible points for the education students and a mean of 4.58 out of 10 possible points for the mechanical engineering students. In order to assess inter-rater reliability for this assessment, a second rater was trained and given a subset of 32 of the education student tests. Scores from the two raters were compared after several trials and many discussions, and the rubric interpretation was clarified. The inter-rater reliability was determined to be 98.4 percent.

## Methodological Framework

Discourse is more than a way to convey information; it is "language in use" (Gee, 2014). According to Fairclough, "There is not an external relationship 'between' language and society, but an internal and dialectical relationship. Language is a part of society; linguistic phenomenon *are* social phenomena of a special sort, and social phenomena *are* (in part) linguistic phenomena" (2015, p. 56). More specifically, we ascribed to Gee's approach, which views discourse "as an integration of ways of saying (informing), doing (action), and being (identity) and grammar as a set of tools to bring about this integration" (2014, p. 8). We chose this view over more critical approaches (see Fairclough, 2015) because we did not want to restrict our perspective to one that views discourse as merely reproducing or resisting forms of gendered interaction present in greater society. Our methods did not ignore power, but viewed power as secondary to cultural difference, and constituting both the cause and the outcome of interaction. According to Gee, researchers do not need to begin from this viewpoint to critically examine language: "all discourse analysis needs to be critical, not because discourse analysts are or need to be political, but because language itself is, as we have discussed above, political" (p. 9). Thus, our analysis was primarily cultural, but used a critical lens to interpret cultural differences.

## Analysis Procedures

Discourse tools outlined by Gee (2014) were selected based on qualities of the raw data and the specified areas of inquiry. According to Gee, researchers need to select and adapt tools used in discourse analysis based on the "needs and demands" of the study. His framework for discourse analysis was chosen because it promotes the use of multiple perspectives. Unlike other methods that focus solely on one linguistic characteristic, Gee's involves selecting from a menu of 28 questions or "tools" that address contextual, functional, lexical, and theoretical aspects of interaction.

The combination of tools outlined below was chosen based on the available data format (verbal and physical interaction), the purpose of the study (to investigate gender- and design-based group dynamics), and the quality of the dialogue. The short, simple sentence structure used across groups of students prevented the use of more complex grammar-based tools. Descriptions of each of the tools used are as follows:

**Deixis tool**. In linguistics, Deictic features are those that index location and distance, both physical and social. To use this tool, researchers "ask how deictics are being used to tie what is being said to context and to make assumptions about what listeners already know or can figure out" (p. 16). The **fill in tool** was used in conjunction with the Deixis tool to "fill in" the meaning of deixis terms (and document remaining questions to be asked of the data). Next, deixis words were categorized and counted to determine how often different speakers used deixis words referring to particular contextual factors.

**Subject tool.** According to Gee, the subject of an utterance is "what we are talking about" or the "the point around which the information is organized" (p. 24). Once this subject is mentioned, pronouns are used to refer back to the main subject (such as "it" or "she"). A predicate is then used to provide more information on the

Table 2
*Discourse analysis codes.*

| Code Type | Description |
|---|---|
| Subject Orientation | |
| Self | Sentence or clause subject is "Me," or "I" |
| | *"I'm going to change the gear because it's too big"* |
| Group | Sentence or clause subject is "We" or "Us" |
| | *"We should think about switching out the gear"* |
| Other | Sentence or clause subject is "You" or "You all" |
| | *"You need to change the gear because it is too big"* |
| Processual Speech Acts | |
| Idea | A type of declaration that asserts an opinion or idea for action, including those made to rebut statements made by others |
| | *"I don't think the gear will work if we attach it there because it is too small"* |
| Interrogation | A question posed to others to elicit information or ideas |
| | *"Why do you think the gears aren't meshing?"* |
| Indirect request | A request made in an indirect instead of direct manner, such as those in the form of a question or statement |
| | *"Why don't we move the gear over there?"* |
| | *"We need another gear over here"* |
| | *"I think you should try moving the gear over here"* |
| | *"Should I move the gear over here?"* |
| Direct request | Imperative sentences used to direct other members of the group |
| | *"Move the gear over there so it meshes better"* |
| | *"Don't touch this gear"* |

subject of the sentence. For the subject tool, we asked "Why are [speakers] organizing information the way they are in terms of subjects and predicates?" To do this, all subjects and pronouns were identified and "filled in" to provide counts of each type of subject used by the speakers. We used the terms *self-orientation, group-orientation*, and *other-orientation* to describe patterns of subjects used by students while participating in the engineering design process. See Table 2 for codes corresponding to these categories.

**Doing not just saying tool**. This tool was used to analyze student speech acts. A speech act is "verbal action," or what the speaker it trying to "do" with their speech. Discourse patterns identified by Fairclough (2015) were used to develop a set of codes based on speech acts (see Table 2). We specifically chose to examine speech acts relating to the group *design process*, thus these codes are labeled *processual*.

**The context is reflexive tool.** *This tool acknowledges the reflexive* nature of context, meaning how context both shapes and is shaped by each student's communication. It asks whether the speaker is "shap[ing] (possibly even manipulat[ing]) what listeners will take as the relevant context," whether he or she is "reproduc[ing] contexts like this one" consciously or unconsciously, or whether he or she is transforming or changing previous contexts (p. 91). We used this tool to assess whether group differences resembled (a) broader socially enacted gender expectations, and/or (b) engineering "culture" as described by research on post-secondary engineering design.

Transcripts were coded by two researchers, and inter-rater reliability was assessed on a 14-minute transcript using the percent agreement approach advocated by Miles and Huberman (1984). The number of codes for coder A (67) was used as the baseline from which the codes selected by coder B were compared. Codes were marked as a match if they were placed in the same category and had the same numerical value. After several iterations, 54/67 of the codes matched, for a total of 80 percent agreement.

Qualitative data analysis was followed by a set of member checking procedures to verify the accuracy of the results. First, structural follow-up questions that emerged from the analysis were compiled and discussed among the two researchers. Second, a follow-up interview with the instructor was conducted. During this interview, the instructor was questioned and asked to verify initial findings. She indeed verified them and found them to be quite on-point with what she observed. Individual student pre- and post-test scores were also triangulated with the findings to provide a complete picture of the learning context for each individual learner (as advocated by Fetterman, 2010).

*Design Limitations*

The most significant design limitation of this study was the quality of video used for analysis. Because only one camera was used to videotape small groups, inevitably some interactions were not captured. Though the research assistant was instructed to spend an equal amount of time at each group, her actual time spent at each group was not

equal. This may have been due to subconscious or conscious preferences for particular groups (perhaps one was more entertaining or she identified with students in one particular group).

The second limitation inherent to this design is the inevitable presence of participant observational reactivity. Students in this study knew that they were being filmed, and may have changed their behavior when the camera was nearby. To account for this, we reviewed static videos of the whole room (these cameras were less conspicuous and remained on and in one spot for the entirety of each session). During this video review, we compared the behavior characteristics of students to ensure their behavior did not change based on the camera being used.

### Findings

*Group 1: Girls*

The girls group was composed of three sixth-grade girls: Jennifer, Anna, and Bonnie. Jennifer appeared confident, spoke loudly and clearly, and tended to do most of the design work. We coded 347 utterances from Jennifer (48 percent) compared to 167 (23 percent) from Bonnie and 207 (29 percent) from Anna. Bonnie appeared to take on an "outsider" role within the group, and experienced what she may have interpreted as micro-aggressions, which are explained further below. Anna, on the other hand, played the role of "helper" and "collaborator" to Jennifer, and displayed preference towards group involvement, albeit a bit quieter than Jennifer. They called their group "The Exterminators."

The majority of clausal subjects spoken by students in the girls group were oriented to the group (*we/us*) compared to the self (*I/me*) or other (*you/you all/you guys*). See Table 3 below for these proportions overall as well as over time. These speech preferences served as demonstrations of group cohesiveness and unity.

The following excerpt is an example of the girls group utilizing group subject orientation:

*The girls are trying to attach the windmill to the gear train, which they had already assembled in a previous session. They just discovered that the cups on the windmill were rubbing against the body of the gear train, and that they have to move one of the gears and redo some of their work.*

**Anna**: It's not gonna work.
**Jennifer**: Oh my gosh!!!
**Jennifer**: Why do we have all the problems?
**Bonnie**: We're The Exterminators. The Exterminators always have problems.
**Jennifer**: We can move the stick over there. We can move this thing completely.
**Anna**: How? If we move this here …
**Jennifer**: Well we've got a stick there and a stick there. This stick there …
**Anna**: It needs to be small so that it can go faster.
**Jennifer**: [Excitedly] We can move the stick!
**Anna**: But how's this gonna get to that?
**Anna**: Cuz it still won't do that. (11.4)

Although this group demonstrates frustration (using verbal expressions such as "My gosh!"), the subjects used are primarily group-oriented (e.g., "We can move the stick" instead of "I can move the stick"). The use of their team name, *The Exterminators*, further emphasizes their group-orientation, and shows that they have defined themselves as a group, albeit one with "problems."

Overall group subject orientation trends demonstrated a general cohesiveness; however, when we examined student-level subject orientation data, differences emerged. Figure 2 displays subject orientation by speaker. Bonnie's pattern did not fit with the group, as she used more self-oriented clause subjects than group or other-oriented clause subjects. When we investigated these utterances, we found that the majority of them were self-advocating attempts to be involved in the group's work. For example, when the group was ready to test their gravity light, Bonnie asked multiple times, "Can I drop it this time?" and the other students did not acknowledge her request. She also used self-oriented clauses to alert the group to what she was doing. When the other group members were busy working without her, she told them, "Can I put the [dowel] in the hole?" as she grabbed the dowel and attempted to insert it (11.4).

Members of the girls group also outwardly displayed solidarity by utilizing more indirect processual speech acts. The girls used ideas and indirect requests more frequently than direct requests while engaging in the design process. Table 4 displays these speech acts overall, as well as over time. Interestingly, the percentage of direct requests utilized decreased over time, whereas percentage of ideas and interrogations increased. Across all sessions, the most commonly used processual speech acts were ideas (29.1 percent) and indirect requests (27.6 percent).

The girls in group 1 utilized a large variation of indirect requests. Although we used a dichotomous categorization of request directness, it can be viewed as existing on a

Table 3
*Girls group 1 − self, other, and group subject orientation.*

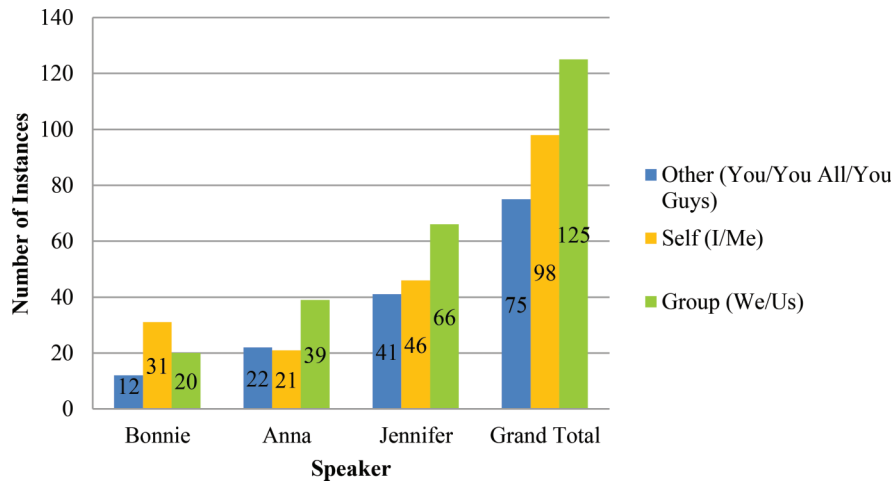| Date | Self | Other | Group |
|---|---|---|---|
| 10.21 | 36.0% | 24.0% | 40.0% |
| 10.28 | 28.4% | 40.5% | 31.1% |
| 11.4 | 26.9% | 15.4% | 57.7% |
| 11.11 | 34.2% | 21.1% | 44.7% |
| Overall | 32.5% | 25.8% | 41.7% |

*Figure 2.* Girls group 1. Self, other, and group subject orientation by speaker.

Table 4
*Girls group 1 − processual speech acts over time.*

| Date | Indirect Request | Direct Request | Idea | Interrogation |
|------|------------------|----------------|------|---------------|
| 10.21 | 19.4% | 25.8% | 32.3% | 22.6% |
| 10.28 | 36.8% | 29.8% | 12.3% | 21.1% |
| 11.4 | 26.0% | 15.0% | 36.0% | 23.0% |
| 11.11 | 20.0% | 13.3% | 40.0% | 26.7% |
| Overall | 27.6% | 20.7% | 29.1% | 22.7% |

continuum. Some of the least direct requests were "should" statements such as, "Alright, should we put a yellow one [clip] on the back?" (Anna, 11.4). Declarative statements were also used, for example, "We gotta get that hooked up" (Anna, 11.4). Interrogative indirect requests were used in a slightly more direct way, for example, "Bonnie, can you hold this?" (Jennifer, 10.28). The following excerpt is an example of the group using questions instead of directives to drive the group design process.

*The group is attempting to attach a ribbon to the spool that they just added to the gravity light.*

**Bonnie:** We could put one right here since it's pretty long.
**Anna:** Well just remember we gotta save the tape. Save the tape! [Anna laughs.]
[Anna and Jennifer working on attaching the ribbon.]
[Bonnie wanders off then comes back.]
**Anna:** Can you hold this?
**Bonnie:** Yeah [she holds it].
**Jennifer:** Okay let's stop there then we will tape it [Jennifer tapes the ribbon].
[Bonnie is looking away while other girls are helping to tape.]
**Bonnie:** Are we taping every time we go around?
**Jennifer:** Yeah, every time. So we make sure it doesn't ....
**Anna:** It's just getting tangled. Alright. (10.28)

In this excerpt, Anna indirectly requests that Bonnie assist the group by holding the gravity light steady ("Can you hold this?" instead of "Hold this"). Jennifer also uses, "let's stop there," as a way of directing the group using what comes across as a cohesive statement. In addition, Bonnie uses an interrogation to validate her view of the process ("Are we taping every time?"). Requests took different forms depending on the speaker, as displayed in Figure 3. Bonnie utilized a larger proportion of indirect requests over direct requests compared to the other group members. Perhaps she used fewer direct requests in order to encourage the other group members to involve her more in the group process.

Indeed, in one session, Bonnie overtly attempted to insert herself into the group by making a series of three indirect requests, all of which were not acknowledged by the other group members. First, she used an indirect statement, "Guys, we can push the three chairs together so that we can all be on one bench?" After no response, she later said, "Can we put three chairs together so it's a bigger bench?" and following that, "Can we put, like, three chairs together?" (11.4). Each time she requested to join the group, the other girls either did not hear her or did not acknowledge her. This demonstrates a limitation to looking solely at speech acts for allusions to power differences within groups. Power is generally garnered by an individual when others grant her requests. In Bonnie's case, the lack of request acknowledgement may have been interpreted as a group exclusion. The group facilitators did not act upon these micro-aggressions.

Overall, the girls group displayed a marked variety in processual speech acts as well as a cohesive subject orientation. The group process and cohesiveness, however, cannot be ascertained by description alone. The context of these speech acts demonstrated that the group dynamics were not equitable, as one member of the group was consistently excluded. To determine whether lack of content knowledge precluded Bonnie's circumstances, we
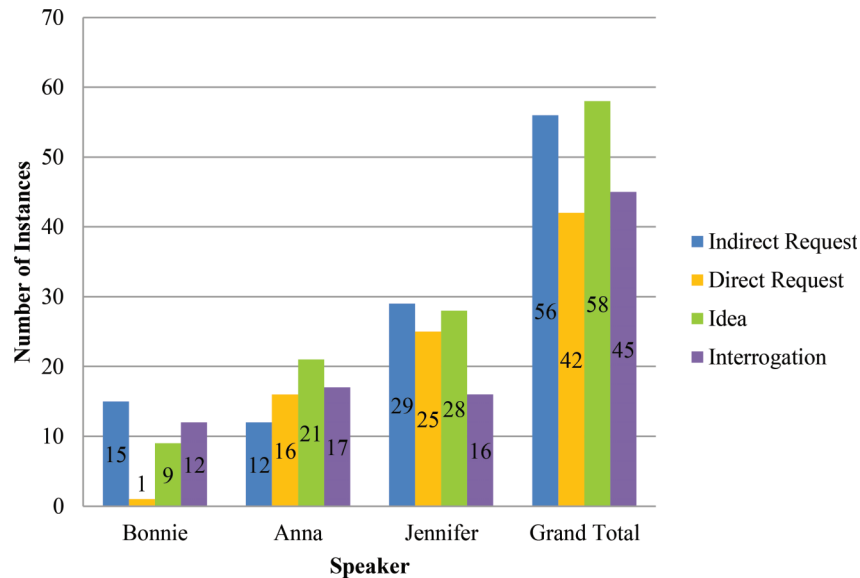
*Figure 3.* Girls group 1. Processual speech acts by speaker.

examined pre- and post-test content knowledge scores. Bonnie was the *only* student in this group who demonstrated any gains in knowledge from the pre- to the post-test (increasing 3 points compared to 0 for both Jennifer and Anna). The overall pre-test mean on the question prompt for this group was 1.3 points out of 10, and the post-test mean was only 2.3, owing to the slight gain by Bonnie. Therefore, the group's dynamic appears to have resulted from other, non-cognitive social factors. Prior research has found examples of these covert forms of bullying among cohorts of middle school girls (Espelage & Swearer, 2003). Indeed, Crick and Grotpeter (1995) found that relational aggression is more frequent between girls. It is important to note how single-gender group dynamics might influence the engineering design process at this age.

*Group 2: Boys*

The boys group fluctuated in size, with three to four boys out of five present throughout the five group sessions recorded. The two most engaged group members were Mark and Charles, who were present for all five group sessions compared to four for Luke, and three for Tate. Mark and Charles dominated the group's verbal process, making up 79 percent of all utterances transcribed, 62 percent of which were spoken by Mark. Mark was playful, energetic, and displayed an excited demeanor when interacting in the design space. He seemed eager to be involved in the process, even when another student was attempting to tinker with the design object. Charles engaged in banter with Mark, and was successful in advocating for his own design time. Luke did not speak much, but seemed accepting of the group dynamic. Tate, however, expressed dissatisfaction with his lack of time taking part in the design process, which was outwardly

expressed on 10.28, his last day participating in the boys group. For the remaining two group sessions, he remained in the program but instead worked with another student (Candy, from Group 4).

The majority of clausal subjects spoken by students in the boys group were oriented to others compared to the self or group. See Table 5 for these proportions overall as well as over time. The proportion of self- and other-oriented subjects stayed within a few percentage points of each other. The proportion of group-oriented speech doubled from the first to the last session, however there was a high degree of fluctuation in percentages over time.

The following excerpt provides an example of self- and other-oriented dialogue, and also represents a critical moment in the group collaborative process. In it, Tate becomes frustrated that he is not given an opportunity to work on the gear train, and asserts himself in an attempt to participate. This was the last time he participated as a member of this group. Although he succeeded in garnering tinkering time, he had to defend himself from Charles, who made several attempts to take the design object back from him.

> *Mark, Charles, Tate, and Luke are working on attaching a spool to the gear train they previously created. The spool will eventually be connected to a ribbon that will be used in the gravity light. Charles and Mark have been tinkering with the gear train for several minutes. Tate has moved around in what appears to be an attempt to get a better view, but he has not participated in the process yet.*

**Tate**: Miss [Teacher]! I know how to do it but they won't let me do it!
**Mark**: I'll help. I'll help [tries to grab for the gear train but Charles and Luke don't let him].

Table 5
*Boys group 2 − self, other, and group subject orientation.*

| Date | Self | Other | Group |
|------|------|-------|-------|
| 10.14 | 65.6% | 26.2% | 8.2% |
| 10.21 | 50.9% | 28.1% | 21.1% |
| 10.28 | 47.4% | 33.3% | 19.2% |
| 11.4 | 41.9% | 32.6% | 25.6% |
| 11.11 | 51.0% | 32.7% | 16.3% |
| Overall | 51.7% | 30.6% | 17.7% |

**Tate**: [Tries to look at it the gear train but Charles blocks him.] You have control over the entire gear train. Can I work on it some?
**Charles**: Yeah. [Charles lets Tate work on it.]
**Charles**: I was trying to push it [Charles tries to take it away from Tate again].
**Charles**: Tate, Tate! [Comes over with a gear] Here! [Tries to take it away and Tate won't let him] Dude, can I try it?
**Tate**: But I want to work on it.
**Charles**: I haven't gotten to work on it at all.
**Charles**: Why are you so mad!?
**Charles**: I have been working on it like the least. You haven't worked on it less.
**Mark**: My idea, he said I'm a genius.
**Luke**: Mark's a work hog.
**Charles**: He's not. A work hog?
**Luke**: Well we're working together…!
**Charles**: We're trying. (10.28)

The students in this excerpt are vying for time with the gear train, which indicates a preference for controlling the design object. Each advocates for his own time, and thus places value on individual work over group-oriented, collaborative work. The self-oriented speech ("Can I") in addition to other-oriented speech ("You have control") further demonstrates a lack of group cohesiveness. One explanation is that they saw the design process as a competition for time or control. Another explanation is that they preferred to work alone, and did not see value in observing others working on their own.

When we examined individual differences in subject orientation, we saw that Mark and Charles oriented their assertions to the self or other more frequently than the group. Although he did not speak much, Luke used mostly group-oriented utterances (such as the one in the above excerpt: "we're working together"). Tate, on the other hand, preferred self-oriented speech, perhaps because he was attempting to assert himself into the design process. See Figure 4 for a display of these differences.

Processual speech acts utilized by the boys group were mostly directive as displayed in Table 6. Examples of direct requests included imperatives used in an attempt to take control over the design process (e.g., "Let me see the black one," Mark, 10.14) as well as those used to modify the actions of others ("Stop pulling it!" Charles, 10.14).

Students also made several attempts to take objects away from others, most of which were successful. Although indirect requests were utilized less than directives, about half of them (21 out of 39) were accompanied by an "I" statement, for example, "Can I give it a try please?! Please!!" (Mark, 10.28). In this example, Mark asks in an indirect form textually, but the high volume of his speech makes this request hard to ignore, and thus more directive. Other examples of indirect requests included:

**Tate**: "No, I think you should scoot it down there..." (10.14)
**Mark**: "Why don't you just touch the wire to it?" (10.14)
**Charles**: "Want me to shake it?" (10.14)

Table 6 demonstrates how the proportion of directives remained high from the first to the last group session (ranging from 35 percent to 60 percent). In contrast, the girls group used directive requests 13−30 percent of the time. The boys group used a smaller percentage of ideas over time (26.8 percent to 2.6 percent), whereas interrogatives increased (from 9 percent to 29 percent). This demonstrates a shift from students making their own ideas known, to soliciting ideas from others (e.g., "You think this is better guys?" Michael, 11.4). This may indicate an increase in solidarity among the group members; however, the increase in task complexity over time may also explain these changes.

The following excerpt demonstrates how students used a combination of directives and self-oriented indirect requests to participate in the group process.

*Mark, Charles, and Tate are connecting a multimeter to a generator that creates energy when students shake a magnet back and forth through a tube surrounded by coils of wire. For some reason the multimeter is not recording any electricity when they shake the magnet.*

**Tate**: No, I think you should scoot it down there... [takes device].
**Mark**: It's supposed to be in the middle. Let me see my magnet.
[Mark tries to take the magnet, but Tate pulls it away.]
[Tate puts the magnet down and Mark picks it up.]
**Mark**: [to Charles] Don't connect those. Let me try it.
[All three are trying to connect the magnet and wires to the multimeter.]
**Charles**: I don't think that's supposed...
**Mark**: Let me wrap it around this. Let me see the black one. Tate, don't shake it [Mark is wrapping the wire around].
[Tate starts shaking the magnet tube.]
**Charles**: Not yet! [Shakes finger at him, then looks at the camera].
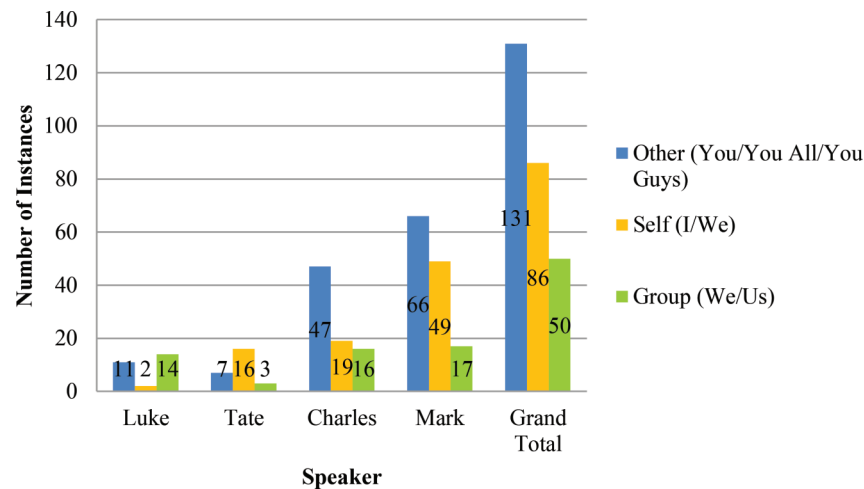**Charles**: Alright, now shake it.

*Figure 4.* Boys group 2. Self, other, and group subject orientation by speaker.

Table 6
*Boys group 2 − processual speech acts over time.*

| Date | Indirect Request | Direct Request | Idea | Interrogation |
|---|---|---|---|---|
| 10.14 | 10.7% | 53.6% | 26.8% | 8.9% |
| 10.21 | 10.6% | 57.4% | 21.3% | 10.6% |
| 10.28 | 31.7% | 34.9% | 14.3% | 19.0% |
| 11.4 | 8.0% | 60.0% | 12.0% | 20.0% |
| 11.11 | 21.1% | 47.4% | 2.6% | 28.9% |
| Overall | 17.9% | 48.9% | 16.6% | 16.6% |

[Tate shakes it.]
**Mark**: Now connect them, now connect them. Put them back on. (10.14)

Tate's statement, "I think you should scoot it down there" was coded as an idea; however, it was used in a direct way because it was accompanied by an attempt to take the object away from the other student. Mark's statement, "Don't connect those. Let me try it" indicates that he (a) does not agree with the tasks being attempted by the other student, and (b) prefers to work on it himself.

Disaggregation of speech acts (displayed in Figure 5) resulted in a finding that Mark used direct requests more frequently than the other group members, supporting the notion that he preferred to control the design process. Charles, on the other hand, used almost as many interrogations (21) as he did direct requests (30), indicating that he deferred to other members of the group on occasion (for example, using "Is that right?" on 11.11).

The overall group dynamics of the boys group was characterized by overt and covert hierarchies that seem to have been motivated by perceptions of competence. These differences emerged despite similarities in knowledge as measured by open prompt pre- and post-test scores (SD pre=0.57, SD post=0.5). Mark, the student who tended to dominate verbal dialogue throughout the sessions, reminded the group on 10.28 that someone previously called him a "genius." Perhaps he used this perceived attribute to justify his many attempts to maintain or take control over the design process. The other students expressed dissatisfaction with this perceived inequity, calling him a "work hog" (Charles, 10.28). To garner more control over the process, Tate used the justification, "I know how to do it, but they won't let me do it" (Tate, 10.28), indicating that the inequity was not due to ability, but to fairness. This begs the question: If Tate believed he was not competent, would he have instead inhibited his desire to tinker? Thus, instead of group-orientation, it is possible that self- and other-orientation is due to a higher value being placed on the final product than the group process being equitable for all involved. Attempts to utilize their own ideas or take control over the design process may not have been motivated by power, but based on the logic that the "better" idea will improve the group's end product. Male-dominated groups placing a higher value on the task at hand over group processes is consistent with research on adults participating in decision-making groups (Johnson & Schulman, 1989). Despite these hierarchies, the group demonstrated gains above average for the program on the open prompt test (mean gain was 4.25 compared to 3.47 overall). The pre-test mean for the boys group was 1.33 out of 10 (the same as the girls group), and the post-test mean was 5.67, the highest of the four groups.

*Group 3: Mixed*

Group 3 was made up of three girls and one boy: Craig, a vivacious seventh-grade boy with "multiple personalities," Lizzie, a confident and decisive seventh grader, Heidi, a seventh grader who appeared to be friends with Lizzie, and Sally, a sixth grader who sometimes floated to other groups. The overall dynamic of this slightly older group was lighthearted, fun, and silly. Craig produced that most verbal speech, with his dialogue making up 71 percent of the utterances transcribed.
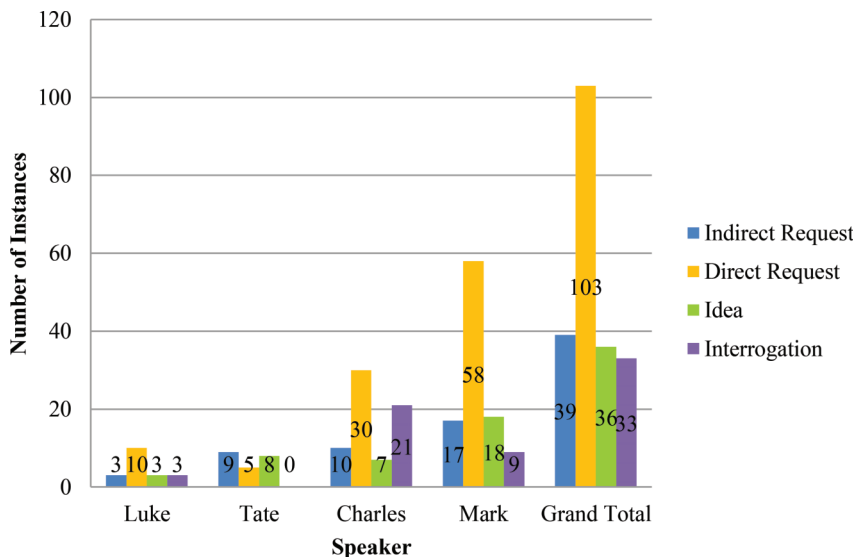
*Figure 5*. Boys group 2. Processual speech acts by speaker.

Craig's subject orientation for Group 3 was similar to that of Mark and Charles in the boys group (see Table 7). His preference was towards other- and self-orientation, although his proportion of group-oriented speech was slightly larger (21 percent) than that of Mark and Charles (15.4 percent). Over time, his percentage of other-oriented speech decreased, whereas his self-oriented speech increased, and his group-oriented speech stayed consistent. Girls demonstrated similar overall subject percentages; however, the percentage of group-oriented subjects decreased throughout the sessions, from 25 percent on 10.14 to 11 percent on 11.4. Percentage of other-oriented speech also increased over time for the girls, perhaps as they adjusted to Craig's style of speech.

Other-orientation seemed to change reciprocally; as Craig increased his other-oriented speech, it decreased for girls and vice versa. This is most likely due to the reciprocal nature of self and other subject orientation. When one speaker uses other-orientation (for example, "you didn't wrap it correctly"), it necessitates a self-oriented response (for example, the defensive, "Yes, I did"). This pattern of *you/me* is at the expense of a group, collaborative perspective, and identity. This pattern was common in Group 3, with Craig beginning with a *you* statement, and the girls responding with an *I* statement (for example, "Are you doing it right?"). See Figure 6 for subject orientation counts by speaker.

The accusatory tone of self- and other-oriented speech was directed towards Craig as well. Girls used other-oriented speech to accuse Craig of mishandling a task or object. In the following excerpt, Heidi accuses Craig of mishandling the device and he responds in a defensive manner.

*The group has assembled their gravity light; however, each time Craig tests it using a water bottle, the motor falls off.*

Table 7

*Mixed group 3 − self, other, and group subject orientation by gender over time.*

| Date | Self | | Other | | Group | |
|---|---|---|---|---|---|---|
| | **Craig** | **Girls** | **Craig** | **Girls** | **Craig** | **Girls** |
| 10.14 | 66% | 38% | 17% | 38% | 17% | 25% |
| 10.28 | 46% | 60% | 32% | 30% | 21% | 10% |
| 11.4 | 36% | 53% | 40% | 37% | 24% | 11% |
| Overall | 45% | 47% | 34% | 33% | 21% | 20% |

*Note*. 10.21 was omitted from this table due to low utterance counts, though counts were utilized in the overall percentage.

**Heidi**: You're breaking it.
**Craig**: I'm not breaking it, I'm dropping the bottle like we're supposed to. Exactly, what am I supposed to do, slow it down? You guys don't even make sense. (11.4)

In this example, Craig responds to an accusatory remark by both defending his actions, and making an assertion that the girls don't know what they are talking about. This type of speech comes across as somewhat competitive, similar to the style observed in the all-boys group.

An examination of Craig's processual speech acts indicated that he utilized interrogations to drive the group process. The proportion of interrogations used by Craig was almost double that of the girls (41 percent versus 23 percent). See Table 8 for the percentage of processual speech acts utilized by both boys and girls over time. Accusatory, "known response" questions were utilized almost exclusively by Craig. For example, on 10.14 Craig asked Sally, "Did you sand ENOUGH?" implying that he believed she did not sand enough. This type of interrogation can serve as a relay mechanism, directing the group process and keeping the other members on task. In addition to being an interrogation, these statements are other-oriented,
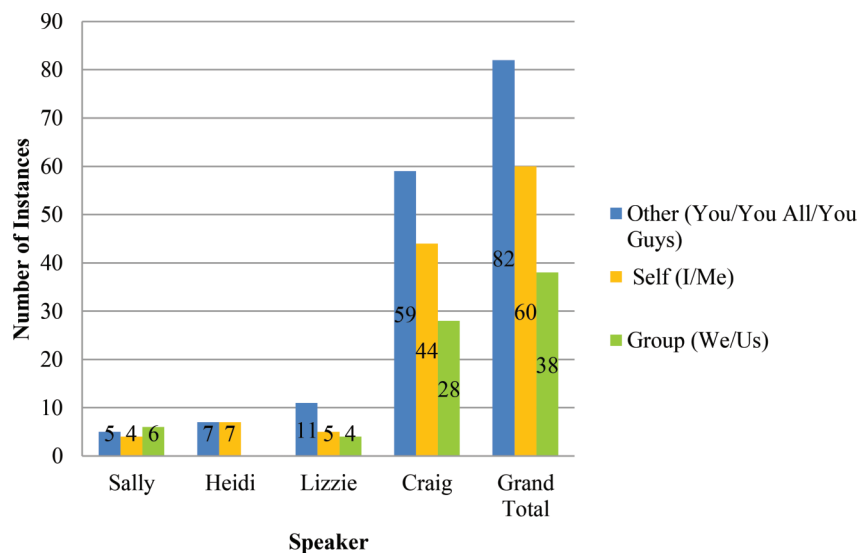
*Figure 6.* Mixed group 3. Self, other, and group subject orientation by speaker.

as described above. The following excerpt is a prime example:

> *The group is about to test their gravity light again. The ribbon needs to be re-wrapped around the spool each time they test it. Heidi typically takes on the role of "ribbon wrapper." Lizzie and Craig just handed the spool to Heidi and she is working on wrapping it.*

**Craig:** Are you doing it right?
**Heidi:** Uhh ... I am doing it right.
**Craig:** But I was checking girl.
[Heidi mumbles something]
**Craig:** ... [Holding the object] I'm not freaking you out. I'm helping.

In this example, Craig checks Heidi's work in an evaluative manner, although Heidi had wrapped the ribbon for the group multiple times. Unfortunately, we were unable to hear Heidi's comment, but we can ascertain that it was interpreted by Craig as "You are freaking me out." Craig dismissed this comment and instead asserted that he was "helping." This indicates that Craig saw his evaluative role as beneficial for the group.

Craig also used open-ended "unknown response" questions to solicit information from the group (for example, "What did we do when it worked really good?" 10.14). As a result, girls in Group 3 had a higher percentage of speech acts relating to ideas than Craig did (33 percent versus 16 percent).

Second to interrogations, Craig most frequently used indirect requests in the group process (see Figure 7). For example, on 11.4 Craig said to Lizzie, "OK, we have to get the multimeter." Following this "hint," Lizzie picked up the multimeter and began to look at its directions for use. Craig also used self-deprecation and complements to ask the girls

Table 8
*Mixed group 3 − speech acts over time.*

| Date | Indirect Request | | Direct Request | | Idea | | Interrogation | |
|---|---|---|---|---|---|---|---|---|
| | M | F | M | F | M | F | M | F |
| 10.14 | 26% | 12% | 16% | 18% | 21% | 24% | 37% | 47% |
| 10.28 | 38% | 14% | 25% | 43% | 13% | 43% | 25% | 0% |
| 11.4 | 16% | 17% | 22% | 33% | 14% | 42% | 49% | 8% |
| Overall | 23% | 15% | 20% | 28% | 16% | 33% | 41% | 23% |

*Note.* 10.21 was omitted from this table due to low utterance counts, though counts were utilized in the overall percentage

to do something in a non-threatening manner, for example, "OK, Lizzie, your expertise is needed" and "I am mentally challenged most of the time." This interactional style was unique to Craig, who combined interactional styles demonstrated in both the girls-only group and the boys-only group. Craig's voluble and directive style was similar to that utilized by some in the boys-only group; however, the indirect style was similar to that used in the girls-only group. Craig's style may have also reflected an actual deficit in content knowledge, as Craig's post-test score was between 5 and 3 points lower than Heidi and Lizzie, respectively. The pre-test mean for this group was 0.5 out of 10 points, and the post-test mean was 4.25, brought down by Craig's post-test score of 1 point.

When we examined request style for girls in Group 3, we found that they more frequently made direct (28 percent) rather than indirect requests (15 percent), as opposed to Craig, who favored a more suggestive style. Many of these direct requests were aimed at Craig, insisting he do something different or stop doing something altogether (for example, "Shut up!"). Lizzie and Heidi also advocated for their position within the group. The following example demonstrates how they asserted themselves in a way that
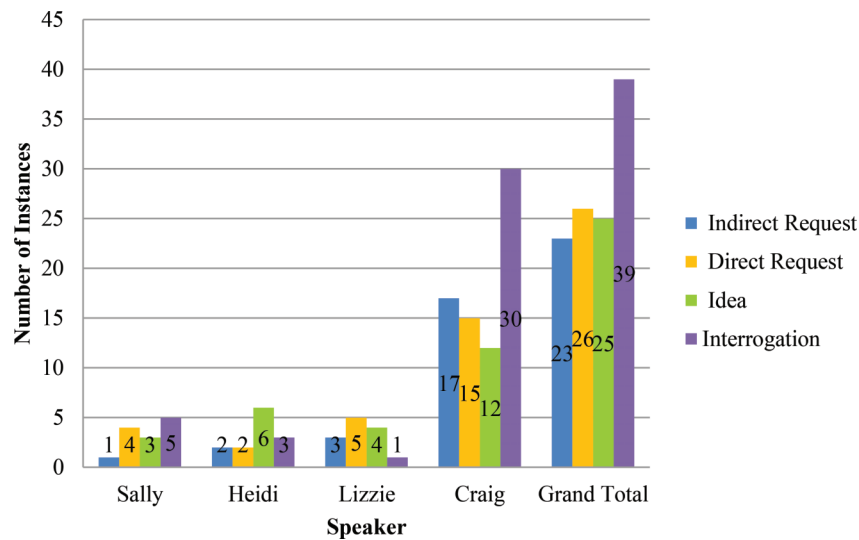
*Figure 7*. Mixed group 3. Processual speech acts by speaker.

reaffirmed a somewhat "expert" status that Craig occasionally affirmed.

*Sally and Craig are working on coiling copper wire around a tube with a magnet in it, but aren't seeing any voltage coming from it yet. Lizzie and Heidi are talking quietly for several minutes while the others work. Lizzie did make one suggestion previously, but it was not acknowledged.*

**Craig**: You're not doing anything [to Lizzie].
**Lizzie**: We were ... [puts her hands out like she wants to try and wrap the coil].
**Craig**: Well you shoulda said something.
**Heidi**: Well I'm like, 'Why don't you do this?' and you are like 'baam baam' [shaking the tube in an exaggerated manner as if making fun of him].
**Craig**: Well you apparently didn't say it out loud.
[Lizzie takes the tube and unwraps some of the copper wire.]
[Lizzie mumbles something about it being done incorrectly.]
**Craig**: Yeah, I messed up terribly. (10.14)

In this occasion, Craig acknowledges Lizzie and Heidi's lack of participation. After explaining that they tried to help, they make fun of the work that was being conducted by others, implying that it was not high quality (using exaggerated gestures and a high vocal pitch). When Lizzie did get the device, Craig sought approval from her, implying that he viewed her as "the knowledgeable one." This dialogue demonstrates that Lizzie was not afraid to assert herself when she thought she was being unheard by the other group members. This simply might reflect her audacious personality and/or an elevated comfort level with her peers. Indeed, Craig and Lizzie had attended Studio

STEM together since its inception. They were the only original members of Studio STEM still attending at "North." Perhaps this facilitated Lizzie's ability to stand up to Craig.

This group example is compelling because it demonstrates how both boys and girls can adjust their interactional style over time when working together. Craig utilized indirect techniques that were common in the girls-only group, whereas Lizzie and Heidi utilized direct, more competitive styles that were common in the boys group. Despite a gap in content knowledge, Craig took an evaluative role with the girls in his group, delegating tasks and determining the value and merit of design tasks conducted by other group members. Despite an overall quietude, the girls were able to maintain an "expert" role within the group. Thus, as opposed to the boys-only group, Group 3's dynamic favored delegation, with each member taking a particular role based on his or her "expertise." Tonso's ethnographic study demonstrated how the "expert" role is not always one that garners the most group power. In a small group of college engineering students, despite one female's demonstrated skill over the other male group members, her work was frequently evaluated and critiqued (2006). Our finding, in conjunction with Tonso's work, falls in opposition to older research that found boys developed positions of power within small groups because of perceptions that boys were more competent (Lockheed, Harris, & Nemceff, 1983).

*Group 4: Mixed*

Group 4 was made up of four students originally: Albert, an energetic 11-year-old who seemed to "push his teammates' buttons," Penny and Meredith, who appeared to be friends, and Candy, a less confident, quieter girl who left the group after a few sessions to team up with Tate from Group 2.

The overall group dynamic appeared more strained, and less lighthearted than in Group 3, demonstrated by frequent gestural cues such as eye rolls, vocal inflection, and sighs.

The corresponding interactions between the boy (Albert) and the two to three girls in his group deviated markedly from those observed in Group 3. We captured more dialogue from Albert than the three other girls combined, but the proportion was more equitable than Craig's in Group 3. Albert's speech comprised 53 percent of all group utterances compared to Craig's 71 percent in Group 3. It should be noted, however, that the overall utterance counts were lower in this group than the other three groups, with a little over half of the overall utterances than Group 3.

Albert most commonly displayed a self-orientation in his speech, which differed from Craig (Group 3), who used other-orientation more frequently. Examples of "I" statements used by Albert were "I did it" or "Can I show you?" as he made attempts to garner time tinkering with the design object. The girls reciprocated with other-oriented speech directed at Albert. See Table 9 for percentages of self-, other-, and group-orientation by gender. This *I/You* dynamic is similar to that observed in Group 3; however, Albert tended to act regardless of whether permission was granted by the other group members. Thus, his attempts were more likely to be interpreted by other group members as self instead of group advocating. A common sequence of events was that Albert would make a design change, and the girls would refute it while displaying gestural cues that signified annoyance. Thus, the girls would sometimes begin interactions with other-oriented speech in response to Albert's physical gestures, for example, "Albert! You're turning the cup around! Stop!" (11.11). These gestural moves may have signified a difference in processual values: Albert, preferring to try design changes first, and the girls preferring to reach group consensus first before making design changes. This value difference is reflected by previous findings that within groups, men place preference on accomplishing tasks, whereas women place preference on the group collaborative process (Johnson & Shulman, 1989).

The girls in Group 4 did not orient themselves in a homogeneous manner. As seen in Figure 8, Penny and Meredith used other-oriented speech more than Candy, who participated very little in the group overall. Similar to Tate in the boys-only group, the few subject-oriented

Table 9
*Self, other, and group subject orientation by gender.*

|  | Self | | Other | | Group | |
|---|---|---|---|---|---|---|
| Gender | M | F | M | F | M | F |
| Overall | 54% | 30% | 27% | 64% | 19% | 7% |

*Note.* low overall utterance counts necessitated an overall comparison instead of disaggregations by gender and date.

utterances observed from Candy were self-oriented, during which she made attempts to insert herself into the group process (e.g., "Can I take a large?" on 10.21). She also utilized gestures in an attempt to join the group process, as described further below.

Additionally, the total count of other-oriented speech made by girls (28) closely matched the self-oriented speech made by Albert (32), evidence of a reciprocal *You/I* group gender dynamic. Also of note was Albert's higher proportion of group-oriented utterances (19 percent) compared to the girls (7 percent). In fact, only three group-oriented subjects were counted for all three of the girls in the group. Perhaps this indicates that the girls did not wish to associate Albert with the group, despite his desire to do so. An example of this dynamic is displayed below:

*The group is attempting to stabilize the cups on their windmill generator, and is trying to determine the best way to do so.*

**Albert**: I know what will help. Can I see it for a second? We could rubber band them.
[The girls put the device on the table and Albert tries to put a rubber band on.]
**Albert**: Tape it like this.
**Penny**: What does that do? That does absolutely nothing.
**Albert**: I'm gonna do it like that. (11.11)

In this excerpt, Penny does not think Albert's idea is working, but he responds to her with the assertion that he is still "gonna do it like that," implying that he is choosing to ignore her remark. Both reaction types serve as barriers to the collaborative process: Penny, by dismissing Albert's contribution, and Albert, by refusing to accommodate to the girls' request. These reactions can be interpreted as "power plays," as each member of the group advocates for themselves at the expense of others in the group.

Processual speech acts differed slightly by gender. Both genders displayed a preference for direct speech acts, followed by indirect speech acts, although Albert used a higher proportion of both. Girls, on the other hand, displayed more frequent interrogations, with twice the proportion of interrogations than Albert. See Table 10 for specific percentages.

The aforementioned example includes both indirect and direct forms of request. Albert asks, "Can I see it for a second?" which serves as an indirect request for the object (he does in fact, take the object as a result). He then says, "Tape it like this," which serves to direct the girls to secure his design idea. Examples of girls using directives also include the utterance, "Albert! You're turning the cup around! Stop!" (11.11). In this case, one of the girls uses the directive "Stop!" to get Albert to refrain from a perceived design error. See Figure 9 for a breakdown of processual speech acts by type for each group member.
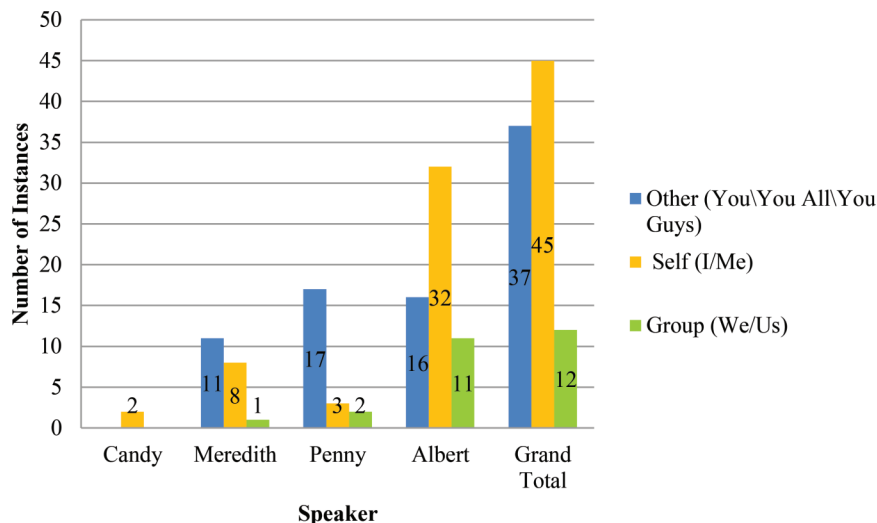
*Figure 8.* Mixed group 4. Self, other, and group subject orientation by speaker.

As mentioned previously, a characteristic of this group was that the design process (idea generation, trial and error) was expressed in more of a physical rather than verbal manner, as was present in the boys-only group. In fact, Albert made physical attempts to take the design object on 13 occasions, seven of which were unsuccessful. Penny and Meredith seemed to take on a "defensive" stance in reaction to Albert. The girls physically attempted to take the design object from Albert, succeeding seven of eight times. In these instances, no words were used to describe the group design process; instead the group process was conducted through "tinkering." The following dialogue provides an example of this physical speech in conjunction with the accusatory forms of communication we outlined previously.

*The group is attempting to attach a motor to their gear train. In order to do so, the group will need to attach more gears to the device.*

**Albert:** Can I show you? Can I show you?
[Candy is now inserting the gear onto the dowel. Albert looks up at the camera with a quick glance. The device looks like a car with a black frame and four pink gears for wheels. The other two girls are sitting passively.]
[Candy rolls the device back and forth like a car. Meredith, watching this, puts her hand out and takes it away and brings it towards herself.]
**Meredith:** [Sarcastically] It's not a car!
**Albert:** But if you connect the – can I show you my idea? [Albert puts his hands up to his head on either side of his head, as if frustrated.]
**Meredith:** I think what you're supposed to do … [to Penny, ignoring Albert]
[Meredith pulls off one of the gears, almost banging Penny in the head.]
**Albert:** Did you hit her? [Laughing].

Table 10
*Processual speech acts by gender.*

|  | **Indirect Request** | | **Direct Request** | | **Idea** | | **Interrogation** | |
|---|---|---|---|---|---|---|---|---|
| Gender | M | F | M | F | M | F | M | F |
| Overall | 23% | 17% | 48% | 40% | 15% | 13% | 15% | 30% |

*Note*. low overall utterance counts necessitated an overall comparison instead of disaggregations by gender and date.

[Candy is looking at a different black frame, and studying it with a gear. Meredith is holding the device.]
**Albert:** Now use this [holding out a yellow clip].
[Meredith takes the clip and tries to put it on the dowel.]
**Albert:** Here, I know how to do it.
[Meredith does not give the device to Albert. He rises up out of his seat, standing at the table, and peering closer at the device.]
**Albert:** Here.
[He reaches out and grabs the device.]
**Albert:** I'm going to put some on now.

In this excerpt, Albert makes several attempts to garner the attention of Penny and Meredith. When his attempts are ignored, he instead resorts to a gestural act (grabbing the device). A previous case study conducted on a boy–girl pair in the same afterschool program (Griffin et al., 2015) indicated that "tinkering gaps" did shift the balance of power to favor the boy. In this example, however, although Albert did succeed in getting the design object, there was a sense that Penny and Meredith did not want him to make suggestions or actual changes to the gear train. Thus, although Albert may have held "physical" power, the girls may have held more respect.

Also of note were the gestural micro-aggressions directed towards Candy from Penny and Meredith. Similar to Bonnie in the all-girls group, the other two girls took the

gear train away from her, accompanied by the words, "It's not a car!" This move served as a way of communicating to Candy, "You don't know how to do it. You don't deserve to tinker with the gear train." This is reminiscent of the interaction we previously discussed during which Tate advocated for more time tinkering with the design object. Instead of reacting to this gestural move in an oppositional way like Tate, Candy instead did nothing. It is unclear whether gender, self-efficacy, or both played a role in this reactive difference. A second example of Candy making an unsuccessful attempt to join the group was when she attempted to offer a tool to the other group members on 10.21. She attempted to offer help three times in the video, and each time she was not acknowledged. Candy later decided to leave her group, perhaps as a result. She joined up with Tate, and we observed them working together for the remainder of the sessions. Allowing a pair of students to form a new group appeared to provide these two students with more design time.

To determine whether the dynamics of Group 4 were in reaction to Albert's physical style, we examined videos of Penny and Meredith tinkering with a hand crank generator before Albert joined the group. This gave us the opportunity to ascertain whether the addition of Albert shifted the processual style of the group, or whether it was present for the entirety of the sessions. The following excerpt indicates that the girls did indeed act differently prior to Albert's arrival:

*The girls are trying to connect a hand crank generator to an LED to make it light up. So far, the LED is not lighting up. The girls try to connect the red and black alligator clips to the LED light.*

**Penny:** So maybe the black on black.
**Mentor:** Okay, you think so? Try it.

**Instructor:** You've got to hold the black one because it doesn't have a good connection. So you have to hold it on the metal parts. Just squeeze it together.
**Penny:** It's not … It's not … It's too big to get it to clip.
**Meredith:** Can I see this? [Asking for something.]
**Penny**: I might be able to get the red one on.
**Mentor:** Uhh, yeah, try it.
**Penny:** I can get the red one on, but not the black one.
**Mentor:** Try it together. Come on teamwork – have someone hold one wire…

In this excerpt, the mentor and instructor are trying to tell the girls exactly what they need to do to get the LED to work. When one of the girls decides she wants to try something, she asks "Can I see this?" instead of using a direct imperative such as "give me that." Although this is a short clip, it is in contrast to behavior exhibited when Albert joined their group. Meredith became more assertive in her role once Albert became part of the group, overtly expressing aggression towards him.

Similar to the dynamic found in Group 3, both boys and girls in Group 4 seemed to modify their interactional style in reaction to the other members of the group. A notable finding from Group 4 was that Albert's attempts to garner power were rarely effective. Albert made many attempts to control the design process, using *I* statements, directives, and attempts to take control over the design object. The girls, however, did not respond positively to these attempts, and thus Albert was not able to gain full directorial control over the others. Despite overt frustration present in this group, the students all gained between 4 and 5 points on the open prompt pre- and post-test. The pre-test mean was 1.2 out of 10 points, and the post-test mean was 5.4. This demonstrates that accusatory and competitive group interactional styles do not always impede learning. Research has demonstrated that girls are indeed competent and capable of learning engineering
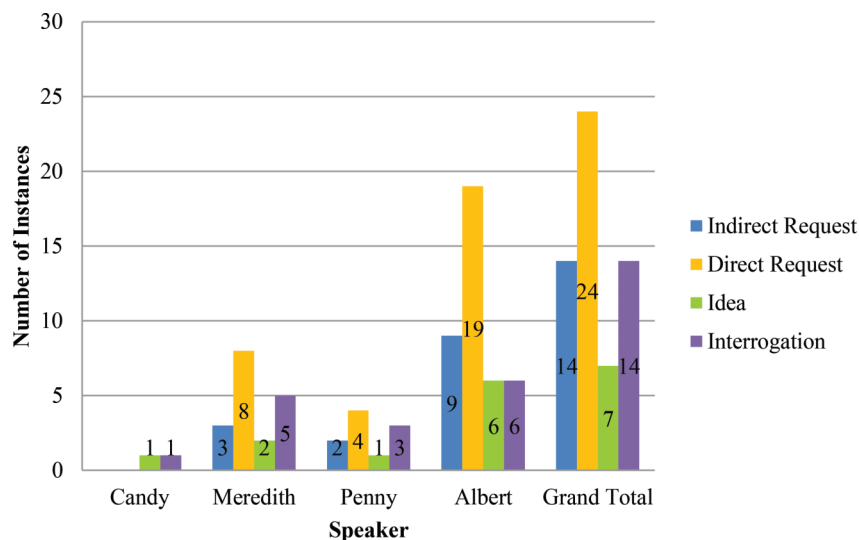


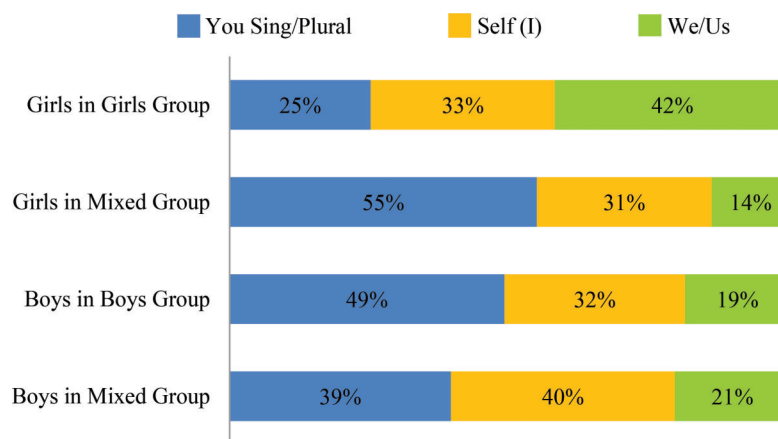*Figure 9.* Mixed group 4. Processual speech acts by type.

*Figure 10.* Subject orientation by gender and group type.

concepts (Shettle et al., 2007); thus, knowledge gains for girls may not be enough to garner their interest and confidence in design-based engineering tasks.

*Group Comparison*

Several findings emerged from across group gender comparisons. The group-oriented, indirect interactional style exhibited by the girls-only group was unique. As seen in Figure 10, girls in the single-gender group had double the group-oriented speech (42 percent) than all other groups (14–21 percent). Thus, students in the girls-only group outwardly displayed the most solidarity while interacting with one another. Girls in mixed-gender groups, however, had the lowest percentage of group-oriented speech (14 percent), and the highest proportion of other-oriented speech (55 percent). Similarly, processual speech acts used in the girls-only group were primarily indirect (28 percent, see Figure 10). Out of all gender/group combinations, this was the highest proportion of indirect speech acts observed. Girls in mixed-gender groups, however, had the lowest proportion of indirect speech acts (16 percent). This indicates that girls may change their interactional style to be less collaborative and solidarity focused, and more competitive in mixed-gender groups in order to advocate for control over the design process or the design object itself. This considerable difference provides evidence that girls in mixed-gender groups "overcompensate" in their efforts to gain power beyond what might be necessary for boys in a boys-only group.

Similarly, boys in the single-gender group used more other-oriented speech (49 percent) than boys in the mixed-gender groups (39 percent). They also used a slightly higher percentage of group-oriented speech (21 percent) than both boys in single-gender groups (19 percent) and girls in mixed-gender groups (14 percent). Indirect processual speech acts were more common for boys in mixed-gender groups (23 percent) than boys in single-gender groups (18 percent). Reciprocally, directives were

utilized by boys almost half as frequently in mixed-gender groups (30 percent) compared to boys in single-gender groups (49 percent). See Figure 11 for a graph depicting the proportion of processual speech acts by group type and gender. Boys in mixed-gender groups also displayed the highest proportion of self-oriented speech as they attempted to advocate for control over the design process. The *You/I* interactional dynamic was consistent in both mixed-gender groups, as accusations and imperatives were frequently countered with self-oriented defensive statements. This contributed to more outward gestures of frustration in both mixed-gender groups, consistent with the interactional characteristics of the single-gender boys group. The difference in group collaborative dynamics between the boys-only groups and the mixed-gender groups was slight compared to the difference between the girls-only group and the mixed-gender groups. This suggests that girls adjust their interactional style to a greater extent than boys when participating in a mixed-gender group.

We also noticed the presence of micro-aggressions towards less involved members of each group. All four groups had large variation in participation across individual students, with a token excluded student who failed to interact at the same level as others. The most poignant instances of exclusion involved Tate in the boys-only group and Candy in Group 4. Both students made unacknowledged attempts to interact with others during the group design process. Tate overtly expressed his desire to participate and solicited the teacher's help. Although in this case the teacher did intervene, we did not see any other instance of instructor intervention addressing these forms of micro-aggression. These two students eventually left their original groups, and ended up working together. Although we do not have any video of this new "group," it appears as if the two excluded students worked together for the remainder of the sessions.

The theoretical frame we utilized suggests that members of both genders act based on cultural expectations normative in broader society. Engineering has traditionally
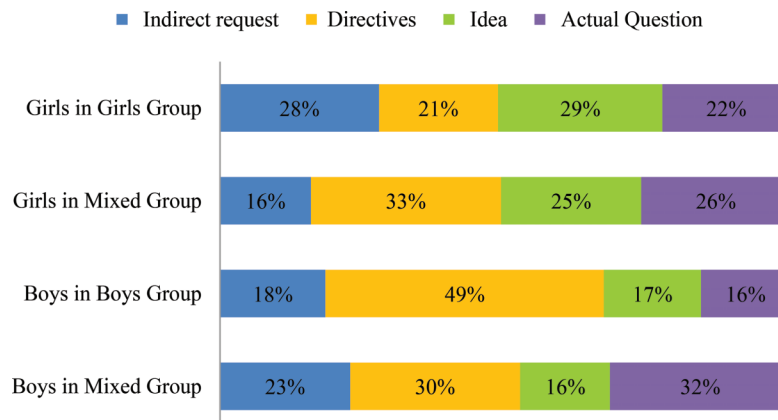
*Figure 11.* Processual speech acts by gender and group type.

been male dominated, and we reviewed research that supported the dominance of male cultural norms in engineering "culture." We summarize some of these findings below:

*Male Gender Socio-Cultural Norms and Values*

- Value technological and mathematical competence and rational thinking (Hacker, 1981)
- Perception that engineering success is contingent on acquisition of organizational power (McIlwee & Robinson, 1992)
- Disapproval of weakness or admission of mistakes in others (Wolfe & Powell, 2009)
- Focus on tasks instead of group processes (Johnson & Schulman, 1989)

The group dynamics exhibited by males in the boys-only group seems to fit with traditionally "male" values as outlined through earlier research. The boys worked in a more hierarchical manner and made overt attempts to gain control of the design process. They seemed to place value on the qualities of the design product and required tasks at the expense of group unity and solidarity.

Acting in contrast to the boys-only group, the girls-only group exhibited behaviors consistent with female gender norms. We outline several of these below:

*Female Gender Socio-Cultural Norms and Values*

- Emotional or relational thinking and social complexity (Hacker, 1981)
- Nurturing, people-oriented, wish to benefit society (Eccles, 2006)
- Collaboration instead of competition (Baron-Cohen, 2002; Seymour, 1995)
- Dislike of aggressive, self-promotion (Wolfe and Powell, 2009)

The primarily indirect, group-oriented style exhibited by girls in Group 1 fits with the traditionally "feminine"

prioritization of group process over the end product, as outlined in earlier gender research. Lower-than-average post-test content knowledge gains for this group support this assertion (see Figure 12). The outwardly displayed solidarity-focused speech fits with the societal expectation that women should be collaborative. To be clear however, aggression was still present in the girls-only group, just less overt than in the boys-only group.

When girls and boys interacted in mixed-gender groups, even though the boys were outnumbered $2-3$ to 1, the majority of the group speech was produced by the male group members in both groups (only 36 percent of coded utterances were spoken by girls). This is consistent with previous research, indicating that girls tend to participate less in small groups (Hansen, Walker, & Flom, 1995). In addition, as we outlined above, the differences in interactional style were greater for girls in mixed-gender groups (compared to single-gender groups) than for boys. From a socio-cultural perspective, the girls in the single-gender groups were creating their own group norms. The girls in mixed-gender groups either went along with the processual structure initiated by the male group member (as in Group 3), or rejected his attempts to dominate the process (as in Group 4). The fact that boys in each mixed-gender group dominated both frequency and volume of speech may explain why girls felt the need to respond to them in either of these manners. Thus, mixed-gender groups appeared to generate more overt frustration than single-gender groups.

Although the boys-only and mixed-gender groups were marked by overt gestural displays of frustration, learning gains were consistent across the three groups (see Figure 12). In fact, despite overt efforts to secure solidarity, the girls group was the only group that did not make significant pre- to post-test gains. Paired *t*-tests for each group indicated significant gains ($p < 0.05$) for Groups 2–4, whereas there was no gain for Group 1 ($p = 0.42$). While three groups made gains of an average of 4 points, the girls group only made an average gain of 1 point. Thus, despite the conflict-laden experience of working in a
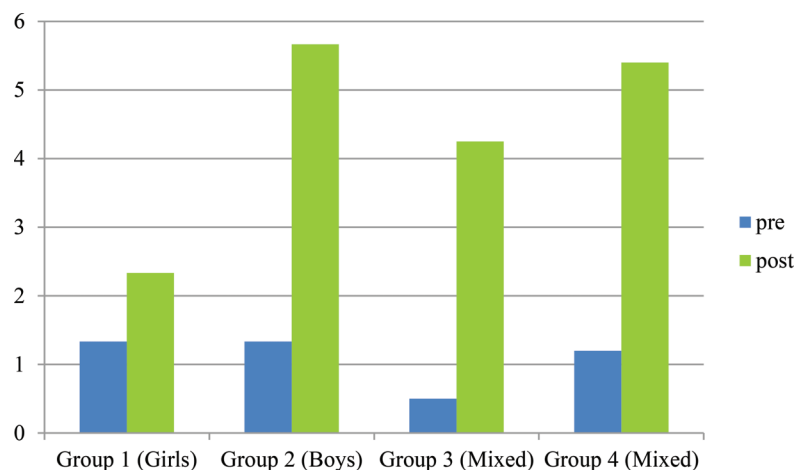
*Figure 12.* Mean content test gains per group.

mixed-gender group, girls may learn more when paired with boys. Although boys in the boys-only group demonstrated the highest post-test scores, they demonstrated the most competitive group interactional style, necessitating teacher intervention. Thus, members of each gender are positioned to learn from one another when working in collaborative, mixed-gender teams. Results support the notion that adjustments made in these mixed-gender groups may be greater for their female members.

### Discussion and Recommendations

Our descriptive and cultural examination of collaborative gender dynamics is the first of its kind conducted on middle school students in informal, design-based learning contexts. We discovered micro-inequities that were present across groups, and we analyzed our descriptive results using both the group context and broader cultural norms. Similar to college-aged students in Tonso's ethnographic study (1996), interactional styles of boys in mixed-gender groups varied, and thus dynamics of these groups were not consistent. Our finding that the interactional styles of girls differed more when they were participating in mixed-gender groups fit with the assertion that engineering is not accepting of female styles of interaction. It was significant to see that these differences were present as early as sixth grade, the age at which many students are beginning to experience group work. This emphasizes the importance of future examinations of these differences. Middle school potentially serves as "ground zero" for women beginning to either steer towards or away from engineering, and it is becoming increasingly imperative that group equity be pursued. Potential solutions fall within one of two categories: (a) group composition or (b) teamwork protocols.

In regard to group composition, our results support the finding that mixed-gender groups promote learning for all involved. Reducing the number of students in each group, however, may have potential for alleviating group inequties.

Our findings cause us to wonder whether typical choice in classrooms of four students per group is ideal. Perhaps groups of two would work best for some students, if materials are available for such small group sizes. We saw evidence of strong collaboration between two students at a time, but four was always problematic. Perhaps youth at this age, just beginning to engage in group work, should be given expressed permission to change groups when the desire for more interaction with the materials arises.

On the other hand, while some youth may prefer to work alone or in pairs, there needs to be a balance between this desire and the need to learn to work in groups. For one thing, it is not reasonable to supply every child with his or her own set of materials, but more importantly, learning to work as a team is vital to future success. Working in teams is important for design-based activities because the goal is not a grade or a completed project, but a functioning design, and the multiple perspectives are key for successful designs. Finelli, Bergom, and Mesa (2011) outlined recommendations for effective engineering teams in post-secondary education, stressing the need to have instructors assign teams that are heterogeneous in terms of level of abilities and perspectives (Johnson, Johnson, & Smith, 2007). Although all middle school students may not be prepared to work on such teams, they will need to learn these skills eventually. Thus, instructors may need to differentiate for students based on whether they are prepared and interested in working in a group larger than two. This delicate balance between giving students support that promotes self-efficacy and challenging them to work in diverse environments is essential.

The results also have implications for Studio STEM teamwork protocols. Finelli et al. (2011) recommend that instructors provide adequate support for the development of functional teams, including supports prior to group work (teambuilding activities, norm setting) and supports during and after teamwork (adequate monitoring, team processing, and peer evaluations). Thus, perhaps these supports should be infused into the program design,

essentially adding a socio-emotional component to the program. Another consideration would be to provide the students with engineering role models (male and female) who understand the currently dominant male presence in engineering, and who are explicitly taught to allow both boys and girls to struggle with the materials, resist the urge to jump in and fix problems, and prevent negative experiences by noticing and remediating micro-aggressions if/when they occur. Many researchers blame engineering gender inequities on a lack of female role models (e.g., Latu, Mast, Lammers, & Bombari, 2013); however, if the male-dominated "culture of engineering" is to be remedied, perhaps having male "allies" in these roles is just as important.

We encourage future researchers to apply our methods to programs that utilize some of the aforementioned group structural or teamwork supports. This research could critically examine how these supports create equity for both boys and girls participating in informal design-based engineering group work. Additionally, it would be beneficial to study the impact of instructor and mentor training in the area of middle school interactional gender dynamics. This exploratory study lays the groundwork for future research by providing methods for documenting, framing, and interrogating group dialogue that is often nuanced, complex, and reflexive in nature.

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