Function, Fairness, and Feelings in Elementary Students' Engineering Design Groupwork

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Abstract

Youth who are learning engineering while participating in design teams are also learning to manage conflict. Engineering design teams regularly anticipate, encounter, and resolve disagreements about which tasks to pursue, which processes to utilize, and interpersonal interactions. Managing conflict while making design decisions is integral to engaging in and learning engineering in groups. Through phenomenographic analysis of interviews with 73 fourth- and fifth-grade students, this paper explores the ways in which these students experience and manage conflict in engineering design groupwork. Students describe the strategies and reasoning they employ to resolve task, process, and relationship conflict. When resolving conflict to make design decisions, these students consider the function of design solutions, the fairness of the group's work process, and the feelings of group members. Youths' experiences with and management of conflict have implications for their affective engagement, equitable participation, and persistence in engineering learning.

Keywords: teamwork, conflict, design practice, elementary school, student experience, student perspective, interviews

Introduction

Learning engineering design includes learning to navigate disagreement to make decisions with a team. Elementary students who are learning engineering design by participating in design teams also experience and manage conflict; they anticipate, encounter, and resolve disagreements concerning which tasks to pursue, which processes to utilize, and interpersonal relationships. We can envision that the ways in which students interpret and manage conflict interact with the ways in which they make decisions with their teams, what they learn about what it means to do engineering, and their satisfaction with engaging in engineering. Although children's experiences with conflict are likely to be consequential to their participation and persistence in engineering, elementary students' perceptions of their experiences with conflict in engineering groupwork are underexplored.

This study builds understanding of elementary students' perspectives of their experiences of design-related conflict within engineering groupwork. Through interviews with students, I explore the nature of the conflicts students experience, the strategies students use to resolve conflict to make design decisions, and students' rationales for using these decision-making strategies. I argue that these students manage conflict by attending to the function of proposed solutions, the fairness of proposed solutions and procedures, and the feelings of team members. These students' descriptions of their experiences with conflict in engineering design groupwork suggest that conflict management has implications for students' participation, persistence, and progress in engineering learning.

Background

Learning Engineering through Participating in Design Teams

When elementary students participate in engineering activities, they frequently do so in groups or teams, meaning two or more students work together toward a shared outcome. While youth certainly can and do learn engineering individually and independently, educators have been encouraged to structure elementary students' participation in engineering as design teamwork (National Academy of Engineering, 2004; National Research Council, 2009; National Science Foundation, 1995; Next Generation Science Standards Lead States, 2013a). As an educational approach, collaborative teamwork or cooperative groupwork can support students to learn engineering. In engineering and in a variety of disciplines, people learn effectively when they work in concert with other people (National Academies of Sciences, Engineering, and Medicine, 2018; National Research Council, 2000). Additionally, students make progress in a discipline when they participate in practices comparable to authentic practices of that discipline or profession (National Academies of Sciences, Engineering, and Medicine, 2018; National Research Council, 2000). It is reasonable to believe that student participation in engineering design teams replicates a common structure of professional engineering and could advance students' engineering learning. At the same time, it is important to keep in mind that elementary students participate in engineering to learn engineering, not to become professional engineers. Engaging in teamwork may teach aspiring engineers to become skilled engineers, but study is needed to understand the nuances of what elementary students learn while they participate in engineering design teams.

Managing Conflict Is Disciplinary Activity

Teamwork is common in professional engineering design. Ethnographies of engineers and engineering firms indicate that although professional engineers may work individually on a component of a system or object, work groups come together physically or virtually to integrate components and share expertise (Bucciarelli, 1994; Trevelyan, 2010; Vinck, 2003). Collaborative decision-making and conflict management are inherent in engineering design. Decision-making is a disciplinary practice of engineering; teams of engineers make many design-related decisions while envisioning, evaluating, or selecting possible solutions to a design problem (Dym, 1994; Ullman, 2018). In professional engineering, decision-making can be conceptualized as team members generating and evaluating a variety of solution proposals and selecting one proposal to pursue (Ullman, 2018). In this model, team members collectively reflect on the actual or anticipated performance and risks of each proposal and agree to advance the best performing or most promising solution (mediated by the team's assessment of risks) (Ullman, 2018). During the decision-making process, team members regularly disagree and resolve disagreements, or experience and resolve conflict (Dym, 1994). Teams may experience conflict while attempting to make decisions during the conceptualization (Dym, 1994), evaluation (Vincenti, 1990), or selection of proposals (Ullman, 2018). Experiencing and resolving conflict are essential to collaborative decision-making, thus managing conflict is a disciplinary activity integral to the disciplinary practice of decision-making.

Characterizing Conflict in Engineering Teamwork

The word *conflict* itself is contended and has various definitions and connotations; here I use *conflict* to describe situations in which participants perceive incompatibility in activities or actions (Deutsch, 1973). This definition of conflict distinguishes it from other characterizations

of conflict as perceived incompatibility in goals (c.f., Bartos & Wehr, 2002; Rubin, Pruitt, & Kim, 1994). I assert that broadly speaking, engineering team members share a common goal of creating or improving a product or process, thus conflict as *incompatibility in activities or actions*, but not goals, is most suitable to describe engineering design team conflict. I draw from Jehn's (1997, 2014) typology of workplace intragroup conflict to characterize design team conflict. In this typology, *task conflict* is rooted in disagreement about what a group is trying to accomplish, *process conflict* is rooted in disagreement about how a group will accomplish a task, and *relationship conflict* is rooted in differences in personal values (e.g., political beliefs) or dislike of teammates. Here, I modify *relationship conflict* to include conflict rooted in disagreement about how group members should treat each other. That is, my conception of relationship conflict includes conflict rooted in disagreement about norms of intragroup or interpersonal interaction. Engineering design teamwork offers ample opportunities for team members to experience conflict about task decisions (what to design), process decisions (how to design), and relationships (how team members treat one another).

Influence of Conflict on Team Members

In workplace settings, there is evidence that conflict variably interacts with team productivity, at times enhancing productivity and at times hindering it (De Wit et al., 2012; O'Neill et al., 2013; Rispens, 2014). Workplace conflict is negatively associated with team members' satisfaction with their teamwork and with their overall work experience (De Dreu & Weingart, 2003; Giebels & Janssen, 2005; Jehn, 1995, 1997). We might expect analogous dynamics for students who experience conflict during groupwork; we would expect conflict to interact with students' productivity and satisfaction. By *students' productivity,* I mean students' learning through participation in engineering activities (Engle & Conant, 2002; Lave & Wenger,

1991); while productivity in an engineering workplace context signifies advancing an employer's goals, productivity in an engineering education context signifies advancing students' learning. With respect to productivity in K-16 learning experiences, evidence suggests that conflict influences disciplinary engagement (Engle & Conant, 2002; Johnson et al., 1976; Koretsky et al., 2014) and interacts with equitable and authentic participation in a discipline (Wright et al., 2018), which indicates that conflict in groupwork is consequential to students' learning.

By *students' satisfaction*, I mean students' affective interpretation of their engineering groupwork experience as pleasant. In workplace settings, satisfaction with teamwork experiences may mediate employees' participation in teamwork and is associated with overall job satisfaction and employee retention; team members who experience higher levels of conflict are less satisfied with their job and more likely to leave their job (De Dreu & Beersma, 2005; De Dreu & Weingart, 2003; Giebels & Janssen, 2005; Guerra et al., 2005; Jehn, 1995, 1997). In a school setting, satisfaction is likely to mediate students' participation and persistence in a discipline. Conflict interacts with students' affective experiences within a learning environment (Carlsson-Paige & Levin, 1992) and emotions entwine with learning (Baker et al., 2013; Jaber & Hammer, 2016a, 2016b). Students' affective experiences in a discipline may influence their sense of belonging in or affinity toward a discipline (Baker et al., 2013), which in turn may influence their future participation or persistence in that discipline (Marra et al., 2012). Thus, children's affective experiences with conflict in engineering teamwork are likely to impact their current and future participation in engineering.

As engineering education expands in K-12 settings and because teamwork is recommended as an engineering learning structure (ABET, 2018; National Academy of Engineering, 2004; National Research Council, 2009; National Science Foundation, 1995; Next

Generation Science Standards Lead States, 2013a), elementary students are participating in engineering design groupwork and thus are managing conflict in the context of design-related decision-making. Like professional engineers, student designers navigate intragroup interactions and make design-related decisions, and it is reasonable to anticipate that elementary students may experience similar types of conflict as do professional engineers. However, it is not clear that children perceive and manage conflict in the same ways adults do. There is evidence that children resolve conflict in different ways than adults do and that young children may bring a particularly productive stance to conflict resolution (Carlsson-Paige & Levin, 1992). Children may find some types of conflict more or less notable than do adults, may attend to different features of conflict than do adults, or may work toward different outcomes than do adults (Carlsson-Paige & Levin, 1992). Although it is likely that youths' experiences of conflict in engineering design learning share features with youths' experiences of conflict in other contexts, it is also possible that engineering offers a distinct disciplinary context for navigating conflict. To date, the ways in which young learners experience and manage conflict in engineering groupwork are underexplored.

Students' Experiences of Conflict in Engineering Teamwork

Professional engineering design teamwork is a social endeavor (Bucciarelli, 1994) and team members must navigate complex interactions among multiple stakeholders who each bring their own expertise, expectations, and emotions to the team. We can envision that elementary students variously interact with or attend to multiple features when making design decisions with a team. In engineering groupwork, elementary students have been observed to attend to a solution proposal or artifact, classroom norms, peer relationships, and their own emotions. At some moments, students may attend to a solution proposal or artifact through evaluating and

optimizing solution performance (McCormick & Hammer, 2016; Rahman, Andrews, Wendell, Batrouny, & Dalvi, 2019; Roth, 1995, 1996; Wendell et al., 2017). At other moments, students may prioritize classroom norms, including teachers' expectations for student presentations (McCormick, 2015; McCormick & Hammer, 2016) or social harmony (Wright et al., 2018). At times, students may attend to peer relationships, taking into account peer status (Cohen & Lotan, 1995), uncertainty about peer relationships, (Jordan & McDaniel, 2014), or the affective impact of design critique on peers (Rahman et al., 2019). At other times, students may prioritize their own emotions or psychological safety and seek to save face (Jordan & Babrow, 2013) or avoid risk (Wright et al., 2018). Although students have been observed to attend to a variety of aspects of collaborative decision-making, there has been little direct study of students' experiences with conflict in design teams. Additionally, there has been little study of elementary students' perspectives on engineering design teamwork or general groupwork; existing research tends to draw from naturalistic observation or participant observation of group activities (e.g., Jordan & Babrow, 2013; Jordan & McDaniel, 2014; McCormick & Hammer, 2016; Roth, 1995, 1996, 1997; Watkins, Spencer, & Hammer, 2014; Wendell et al., 2017). Below, I outline the small pool of studies which have explored students' perspectives on engineering teamwork and general groupwork.

Elementary students' perspectives on conflict in engineering teamwork were explored by Wright and colleagues (2018) through interviews with minoritized students in urban schools. These students explained that they avoided debating the merits of solution proposals because teachers treated this type of conflict as disruptive behavior. In these classrooms, engaging in conflict was risky to and eschewed by students (Wright et al., 2018). Additionally, conflict avoidance entwined with students' identities as engineers and students; the students minimized

conflict in order to maintain their standing as "good" engineering students (Wright et al., 2018). These findings indicate that intragroup conflict can be salient to elementary students, may influence their participation in engineering, and may intersect with their engineering identities.

We can also look to research on students' perspectives on general groupwork for clues about students' perspectives on conflict. Florez and McCaslin (2008) elicited students' conceptions of the nature of groupwork by asking third-, fourth-, and fifth-grade students to write stories describing a picture of three children sitting at desks in a group. While this study did not directly ask students about their personal experiences with groupwork, it is reasonable to imagine that the students' descriptions of the picture reflected their own experiences with groupwork. These stories suggested that these students perceived groupwork as a pleasant means to complete academic work. Mulryan's (1994) interviews of fifth- and sixth-grade students suggested that these students perceived mathematics groupwork as an enjoyable way to get help, complete work correctly, and get to know other students. Surveys and interviews of sixth-, seventh-, and eighth-grade students indicate that some middle school students see groupwork as an enjoyable way to complete academic work, learn more about a subject, or build social connections, while other middle school students see groupwork as interfering with completing work or hindering learning (Slesinski, 1998; Tan et al., 2005).

The above studies were situated in general (Florez & McCaslin, 2008), mathematics (Mulryan, 1994), science (Slesinski, 1998), or geography (Tan et al., 2005) group learning contexts. In all of these contexts, researchers reported a student focus on groupwork as a means for individuals to achieve correct answers on schoolwork or exams. These studies explored students' perspectives on groupwork and focused on students' conceptions of the nature and purpose of groupwork, and to a limited extent, students' perceptions of the influence of

groupwork on their own learning and students' social and affective experiences associated with groupwork. Conflict did not emerge as a significant theme in these studies; the absence of conflict may be an artifact of what researchers chose to report, may indicate that students chose to highlight other aspects of their experiences, or may indicate that conflict was unremarkable in these groupwork contexts. Engineering design may offer a distinct context for experiencing groupwork, as engineering design work is characterized by developing a collective product, rather than an individual product, and by developing a satisfactory solution to an ill-structured problem, rather than by ascertaining a canonically accepted answer to a strictly-defined question (Petroski, 1996). In these ways, collaborative engineering design may afford students additional ways of negotiating decisions, framing conflict, and resolving conflict. In this study, I build on the work that suggests conflict may be salient to elementary students in engineering learning contexts (e.g., Wright et al., 2018) to explore what students describe as notable about conflict and the ways in which students describe managing conflict in engineering design.

Observations of classroom activity (e.g., Jordan & McDaniel, 2014; Mangiante et al., 2020; Roth, 1995; Wendell et al., 2017) and interviews with educators (e.g., Mangiante & Moore, 2019) have provided thick descriptions of students' interactions in engineering design teams and educators' perspectives of classroom conflict. Researchers have begun to explore how elementary *students* perceive conflict in engineering and the ways in which students interpret their own conflict management and decision-making (e.g., Wright et al., 2018). I build on the existing literature by including elementary students' perspectives on conflict, conflict management, and decision-making in engineering teamwork. I seek to understand students' interpretations of their own experiences because integrating students' perspectives into the design of learning environments supports student learning. Therefore, in designing this study, I

considered two research questions through a lens of student reflection: *How do these students experience design-related conflict?* and *How do these students manage design-related conflict?* In this paper I strive to amplify student voices, so to answer the questions above, I attend to students' descriptions of their own experiences, or how these students describe conflict as notable in their experiences of engineering design groupwork, the ways in which students describe the nature of their experiences of conflict, how these students describe their experiences of resolving conflict to reach a design decision, and what these students describe taking into account when managing conflict to reach a design decision.

Methods

Methodological Approach

In this study, I sought to understand the various ways in which elementary students experienced design decision-related conflict during engineering design groupwork and to distill this variety of student experiences into a small number of coherent themes. Therefore, I took a phenomenographic approach to data collection and analysis. Phenomenographers aim to understand the range of human experiences with or understandings of one phenomenon (Marton, 1981). Phenomenography captures the variable nature of human experience: not only might one student experience engineering design groupwork differently than another student, one student might experience engineering design groupwork differently at different moments or in varying contexts. I analyzed interviews with 73 fourth- and fifth-grade students and identified themes in their descriptions of their engineering groupwork experiences. Each theme represents the experiences of some, but not necessarily all students and each student's experiences may be represented in one or more themes.

Study Context and Participants

This study was grounded in an outreach program in which pairs of university students, or *engineering ambassadors*, facilitated elementary students' in-school participation in engineering design projects for one hour per week for sixteen weeks. Fourth- and fifth-grade students solved design challenges while working in groups of two to four students. These students represented eight inclusive classrooms in four economically, ethnically, and linguistically diverse suburban schools in the northeastern United States. I report the gender and racial identities of participants to be transparent about who is included in this study, as silence about gender and race of study participants contributes to biased assumptions and interpretations in research (Pawley, 2017). As reported on study intake forms, 39 girls and 34 boys participated in this study; no one selected non-binary gender options. Thirty-eight percent of participants identified as White, 25% identified as Hispanic or Latinx, 10% identified as Black or African American, 8% identified as Asian, fewer than 5% of participants identified as American Indian, Alaskan Native, Native Hawaiian, Pacific Islander, or Multiracial, and 14% of participants did not state a racial identification. All names in this work are pseudonyms which respect the gender of the students. To respect the range and ethnicities of the students, I included a range of culturally-connected names in the set of pseudonyms; however, to support students' confidentiality, I assigned pseudonyms randomly.

Classroom Activity Structure

The students in this program primarily worked in small, heterogeneous groups to design one artifact together. The outreach program provided opportunities for students to experience design-related conflict; student teams were encouraged to consider multiple possible solutions in each design challenge. However, also implicit in the structure of the program was an expectation

that each student team would eventually select one design solution to pursue and elaborate upon; therefore, it was reasonable to expect that students might disagree and experience conflict. While observing the program and reviewing the video recordings, I had noticed that at times, teammates disagreed (sometimes vociferously) about which design ideas to pursue, how to select a solution to pursue, or how to organize the group's work on an agreed-upon solution.

In this work, I group these eight classrooms because in a broad sense, they participated in the same outreach program. However, the engineering design activities varied from room to room. Six different pairs of outreach ambassadors facilitated the activities, and each classroom participated in a range of engineering design projects selected by the ambassadors in collaboration with the classroom teachers. Projects were completed in one to four class sessions. In general, students used familiar craft materials to envision and build solutions to challenges. For example, two classrooms used two class sessions to create model houses that could withstand simulated hurricanes and earthquakes. These students used cardboard, plastics, elastics, and fasteners to build their model homes. At times, the projects introduced students to computer-aided design software. For example, two classrooms used Tinkercad software to create 3D models of rockets over three class sessions.

Students had varied experiences with engineering during this study and prior to it. Engineering was included in the state curriculum framework for these students, and schools and teachers had varying flexibility to choose how to teach engineering. The teachers of four of the classrooms described other craft material-based engineering design projects they typically facilitated with their classes. Many of the fifth-grade students, representing five of the eight focal classrooms, had participated in this outreach program in the prior school year.

Data Collection

Mid-way through the school year, six members of the research team conducted individual semi-structured interviews with 73 students. None of the interviewers were the outreach ambassadors. One of the interviewers (the author) was known to all of the students from the research consent process and from video data collection. Two of the interviewers were known to some of the students from video data collection. Three of the interviewers met students for the first time at these mid-year interviews. In the 15- to 45-minute interviews, students discussed their experiences, interests, and aspirations with respect to the outreach program and engineering. The interviewers made video and audio recordings of the interviews.

From these interviews, I focused on students' responses to questions about their groupwork experiences in the outreach program. Interviewers generally asked the following questions in the order listed below:

- Sometimes in [this engineering program], you worked on teams with other people; what was that teamwork part of engineering like for you?
- Can you tell me what makes a good group experience for you?
- Is there anything you really like about working in a group?
- Is there anything you really don't like about working in a group?
- Can you tell me about a time when working with a team helped you solve a problem better?
- Was there ever a time when you think you could have done better if you were working by yourself?
- Were there ever times on your team when you and your teammates disagreed about what to make or how to make it?

- What did you do when you and your teammates had different ideas?

The first four questions were intended to elicit students' general perceptions of their groupwork experiences. The latter four questions were intended to elicit students' perceptions of their experiences with decision-making in groups and with conflict. I chose to ask students about *disagreement* and *different ideas* rather than *conflict* to promote an expansive range of responses related to conflict, as colloquially, the word *conflict* connotes a fight or an emotionally intense argument and does not encompass milder disagreement (e.g., Lee, Huh, & Reigeluth, 2015). I asked about students' general perceptions before asking about disagreement to facilitate detecting the salience of conflict to students and to avoid cueing responses that only focused on conflict.

Data Analysis

Professional transcriptionists transcribed the interviews. I reviewed the original video and audio recordings to attend to paralinguistic features, to resolve ambiguity in the transcripts, and to better understand the texture of students' responses. While the students appeared equally forthcoming across the interviews, variations in the students' relationships with the interviewers and the fluid nature of semi-structured interviews point to a thematic, rather than statistical, approach to analysis. I reviewed the transcripts several times and conducted five coding passes to identify themes in the data. In every coding pass, I reviewed all transcripts of students' responses to the eight focal interview questions. In each coding pass, I focused on a different theme, tagged relevant responses, and generated preliminary codes and categories. I wrote memos to record and guide my interpretation of student responses and I reviewed the transcripts to refine the codes and categories (Braun & Clarke, 2006; Strauss & Corbin, 1990). To check my interpretation of the data, I engaged in peer debriefing (Lincoln & Guba, 1985); I reviewed the memos and

original data with colleagues with backgrounds in engineering, education, and engineering education and refined my analysis in concert with their feedback. After I achieved stability in the thematic analysis, I compared student responses across themes and again checked my interpretation with colleagues.

Each coding pass focused on one component of these students' experiences with conflict and decision-making in engineering design groupwork. The first coding pass addressed the extent to which conflict was salient to these students. Although I believed that I had observed students engaged in conflict during groupwork, I wanted to know if conflict was significant to the students themselves. To identify the salience of conflict to these students, I tagged student responses that mentioned or described conflict. I noted if students mentioned conflict when directly asked about disagreement and when asked more open questions about their general experience with engineering groupwork. I tallied how many students mentioned conflict, mentioned an absence of conflict (e.g., saying "No, not really" in response to "Were there ever times on your team when you and your teammates disagreed about what to make or how to make it?") or did not discuss conflict. This coding pass probed the extent to which students found conflict notable enough to describe to interviewers - first as part of their general description of their engineering groupwork experience and then when asked directly about their experience with conflict.

The second coding pass addressed the nature of these students' design-related conflicts. In this coding pass, I explored which kinds of conflicts students described. I tagged students' descriptions of intragroup disagreements and categorized these disagreements as *task, process, relationship,* or *other* conflict based on students' descriptions of the substance of their disagreements and Jehn's (1997, 2014) typology of conflict. Initially, I assigned codes based on

Jehn's definitions of conflict types and used the code *other conflict* to mark conflicts which did not align with Jehn's typology. Ultimately, I utilized Jehn's definitions of task and process conflict and I expanded her definition of relationship conflict to include conflict rooted in ways of interacting with teammates. Expanding the definition of relationship conflict allowed me to re-classify disagreements which I had originally coded as *other conflict* as *relationship conflict*.

The third coding pass addressed the ways in which these students associated conflict with satisfaction or dissatisfaction. First, I focused on students' responses to the questions about what they liked and didn't like about engineering teamwork. When students said they liked or did not like engineering teamwork *because* they disagreed, argued, or fought with teammates, I marked those responses as associating conflict with satisfaction (if students said they liked groupwork because they disagreed with teammates or because they liked arguing) or dissatisfaction (if students said they disliked groupwork because they disagreed with teammates or because they disliked arguing). In addition, I re-examined students' descriptions of the presence and absence of conflict and noted any satisfaction, pleasure, dissatisfaction, or displeasure that was embedded in or suggested by those descriptions. For example, I considered the student statement "Me and [my partner] worked good together, so we never really argued about anything" to be an example of associating satisfaction with the *absence* of conflict. Finally, to understand what students found satisfying or unsatisfying about conflict, I grouped students' descriptions of conflict into themes of advantages and disadvantages of intragroup conflict.

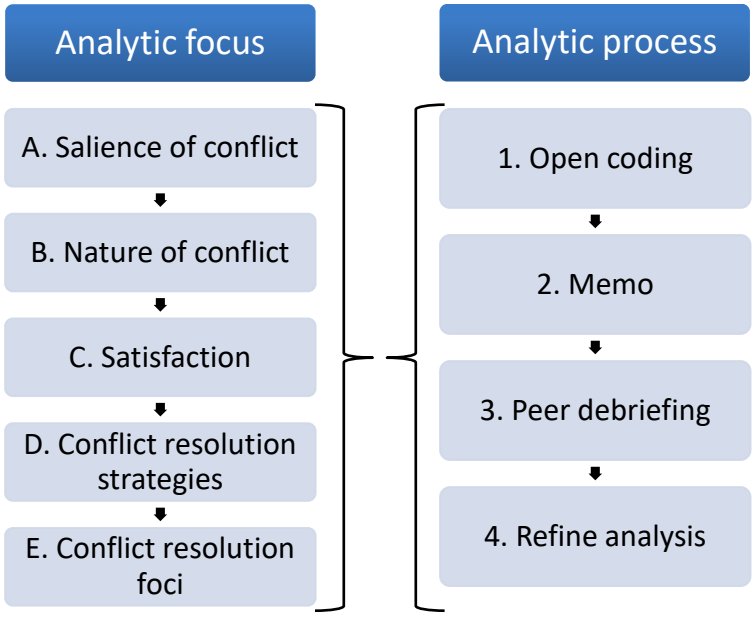
The fourth coding pass addressed the ways in which students resolved design-related conflicts. I tagged students' descriptions of conflict resolution, I noted themes in students' approaches to resolving conflicts to make design decisions, and I created categories of conflict resolution strategies. To create these categories, I drew from students' responses and from

existing descriptions of youths' engineering decision-making and design strategies. Specifically, the category *choosing through reasoned comparison* of solution ideas reflects core ideas of reflective decision-making (Wendell et al., 2017) and informed designing (Crismond & Adams, 2012) and *combining ideas* has been described as a design problem-solving strategy that minimizes risks to classroom relationships (Wright et al., 2018). Four additional categories (*generating a new idea, selecting a solution through a game of chance, voting to select a solution,* and *agreeing with a teammate*) emerged from the data.

In the fifth coding pass, I focused on what students attended to when managing conflict to reach a design decision. I re-examined students' descriptions of conflict resolution and I tagged moments when students stated reasons for choosing a conflict resolution strategy. I grouped students' reasons into themes based on the primary emphasis underlying each student's explanation for choosing a particular strategy. These decision-making foci included attention to the function of the design, the fairness of the group's process, and the feelings of team members.

Figure 1

Analytic Approach



Limitations

Although the interviewers attempted to position the students as experts who were sharing knowledge of their own experiences, it is possible that students were not always forthcoming with interviewers. Students may have taken up the interview as an evaluation of their well-liked engineering ambassadors and spoken positively to ensure the ambassadors' return to the students' classroom the next semester. To mitigate this possibility, the interview was structured so evaluative questions focused on the program, rather than the ambassadors. It is also possible that students felt obligated to uphold standards of politeness by speaking positively rather than critically. To moderate this possibility, the interviewers invited criticism of the outreach program by asking the students to share any suggestions for improvement.

Students' responses to interview questions varied in depth. The questions about students' groupwork experiences fell at the end of a longer interview and at times students may have lost energy for answering questions. Interviewers varied in the extent to which they probed students' responses, at times because interviewers were responding to students' (dis)interest in continuing, at times because interviewers chose to pursue other responses in greater depth, and at times because the interviews were interrupted by other happenings in the school.

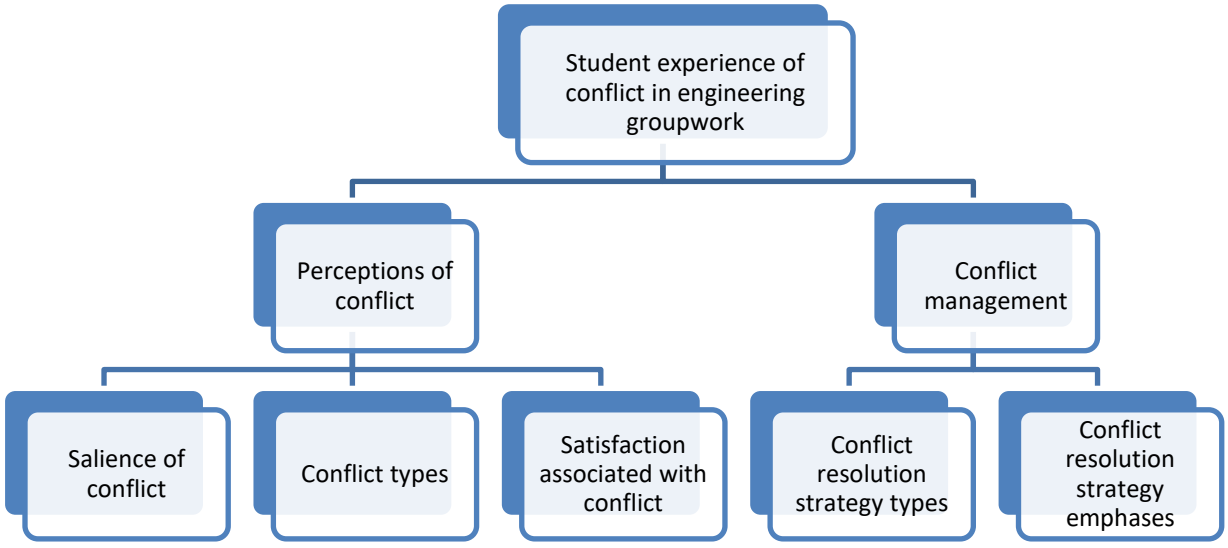
Students volunteered information about the ways in which they perceived groupwork interacting with their participation in engineering design. I believe that students described the groupwork moments that were most noteworthy to them, but I cannot ascertain if those moments were memorable because they were typical, exceptional, or simply most recent in time. I believe that the range of moments described by students represents a range of student experiences and that the moments students chose to describe were significant to them and thus are worth working to understand.

Findings

I present student-described perceptions of conflict and student-described conflict management strategies. Students' perceptions of conflict include the salience of conflict to students, the types of conflict students experience, and the satisfaction students associate with conflict. Students' descriptions of conflict management strategies include the types of strategies they employ to resolve conflict and the decision-making emphasis of each conflict resolution strategy. Figure 2, below, provides a map of the findings as related to each other within the broad theme of understanding students' experiences with conflict in engineering groupwork.

Figure 2

Overview of Findings



Student Perceptions of Conflict in Engineering Design Groupwork

Salience of Conflict

Before unpacking the ways in which students experienced intragroup conflict, it was important to establish if students perceived conflict to be noteworthy in their engineering experiences. Conflict might have been a notable part of these students' participation in

engineering groupwork or it might have been insignificant to these students. In response to questions that asked generally about students' experience with engineering design groupwork – but not specifically about conflict – just over half of students (38 of 73 students) described disagreement as part of their engineering experience. This observation – that students brought conflict to the attention of interviewers when describing their general experiences with engineering groupwork – suggests that conflict was noteworthy to many of the students in this study. Additionally, the majority of students (66 students) described experiencing conflict in engineering groupwork when asked specifically about disagreement in engineering groupwork or generally about their engineering experience. Two students said they never disagreed with their teammates. The five students who did not mention conflict were not asked specifically about disagreement (and did not describe conflict when asked generally about their engineering groupwork experiences). Overall, students' responses suggest that many of the participating students experienced and noticed conflict during engineering groupwork.

Types of Conflict

These students described task, process, and relationship conflicts, or conflicts about what to design, how to design, and how group members treated one another. Students' descriptions of the conflicts they experienced generally aligned with Jehn's (1997, 2014) typology of workplace intragroup conflict. Students' descriptions of conflict mapped closely onto Jehn's conception of task and process conflict, and less closely to her conception of relationship conflict. Students described disagreements about what the group should design and why the group should pursue a particular design solution; these descriptions echo Jehn's conception of *task conflict* as disagreement about the content of what a group is trying to accomplish. Students described disagreements about how the group should design, including how to organize or distribute work

(or who in the group should do what); these descriptions match Jehn's conception of *process conflict* as disagreement over the means to accomplish a task or the logistics of scheduling and distributing work. Students also described disagreements about how group members should treat each other. At times these descriptions mapped onto Jehn's conception of *relationship conflict* as mutual interpersonal dislike, but students did not describe conflict that could be ascribed to Jehn's other sources of relationship conflict, namely political or religious differences. Rather, students described conflicts that appeared to be rooted in differences of groupwork norms or students' expectations of how teammates should interact with each other. Figure 3, below, includes sample student statements illustrating each conflict type.

Figure 3

Types of Conflict

Conflict Type	**Examples**
Task: What to design	Antonio: My teammate wanted to have sort of a flattish top, but in like a circle-like building, and I wanted to have a pointy roof because then the water and snow and stuff - this is the natural disaster project - it would just fall off the edge of the building. Diane: In the rocket group Karina thought we should make it [the rocket] lighter. Me and Leslie thought we should make it heavier. Madeline: The car - me and my partner had totally different ideas of what we were going to do.
Process: How to design	Brandon: If I tried to do something usually people would scream at me or not scream but say I was doing it wrong. Mayim: When we were building houses [with a limited supply budget], me and my partner had really different ideas on it, because my partner just wanted to keep buying stuff and adding it on. And then I just wanted to work with what we had and save our money. And so that didn't really work out in the end.
Relationship: How to treat teammates	Hedy: When I don't particularly wanna be with someone, it's a little bit harder, 'cause I really wanna boss them around. Kermit: Sometimes…we were working on something and we both didn't like the way we were working with each other. So we would fight and say, "No, I don't like this," "No, I like this."

Satisfaction Associated with Conflict

Studies of workplace teams indicate that intragroup conflict is negatively correlated (but not causally linked) with team members' satisfaction with their team and with their overall work or learning experience (De Dreu & Weingart, 2003; Jehn, 1995, 1997). The relationship of intragroup conflict to elementary students' satisfaction is less well understood. In this study, interviewers asked students to describe their overall experience with engineering teamwork as

well as what they liked and disliked about *engineering teamwork*. Interviewers did not specifically ask what students liked and disliked about *intragroup conflict*. Therefore, students' responses tended to reflect the ways in which students called out conflict as an appealing or unappealing feature of engineering teamwork, rather than the ways in which students experienced conflict itself as appealing or unappealing.

When students mentioned conflict in response to the general questions about their experiences with teamwork or in response to the specific question about their experiences with disagreement, they tended to associate conflict with dissatisfaction rather than satisfaction. Students occasionally mentioned conflict when they were describing what they liked about engineering groupwork. More often, students mentioned conflict when they were describing what they disliked about engineering groupwork. When students talked about their experiences with conflict, they tended to describe what they disliked about those experiences, rather than describing what they liked about those experiences.

Satisfying Experiences with Conflict.

At times, students indicated a sense of satisfaction associated with experiences of conflict. These students described disagreement over proposed design solutions and indicated that they perceived peers' disagreement as helpful critique which led to higher quality solutions. Kermit described a time he and his partner envisioned conflicting solutions and chose to pursue his partner's more promising idea. "[My partner] helped – he shows me the thing that I did is…not that good. It won't work….So I agree with his idea….One mind is just by itself. Two minds together is much stronger than one mind." In addition, one student overtly stated that she enjoyed arguing; Frances said, "I like when we argue 'cause it helps me in getting a head start for being a lawyer," then smiled and added, "So I just let [my teammates] argue and then I try to

fix it." When asked to clarify what she liked about arguing, Frances confirmed that she enjoyed resolving disagreements.

Unsatisfying Experiences with Conflict.

Generally, students described experiences with conflict as unsatisfactory or unpleasant. These students identified three drawbacks of conflict in engineering groupwork: *task inequity, idea obstruction,* and *emotional strain*. Students pointed to perceived *task inequity,* or an unfair distribution of work. Students who identified *task inequity* stated that they did more than their fair share of the work or that they did tasks that they disliked while a peer did the more appealing tasks. Students also described *idea obstruction*; these students explained that conflict prevented them from being able to pursue ideas they wished to explore. Finally, students identified *emotional strain* as a drawback of conflict. These students described disagreement with groupmates as leading to unpleasant emotions or as a possible challenge to friendships. Figure 4, below, elaborates on these themes of drawbacks of conflict and includes sample student statements illustrating each theme.

Figure 4

Students' Descriptions of Drawbacks of Conflict in Engineering Groupwork

Drawback	**Example**
Task inequity: Work is distributed inequitably in the group or a group member dislikes the nature of the tasks they perform.	Kelly: Some people are sometimes not doing anything. They don't want to do it and they just do nothing. Hope: I really wanted to help and tie the strings and things. But sometimes I couldn't because I only cut the tape and give it to them and just watch them do it.
Idea obstruction: Peers hinder an individual's ability to pursue their own envisioned solution.	Nina: Everyone's like, "No, no, we should use this different idea," "No, this different idea," "No, this different idea." And then it's really annoying because then I don't get to use my idea which I know will work. Willa: The part I didn't like is that sometimes [your groupmates] want to do what they want, but you want to do what you want. Then you don't really get time to do it.
Emotional strain: Disagreement with peers leads to unpleasant emotions or perceived risk to relationships.	Eddie: What I didn't like was a lot of the times we would argue over which idea was the best. Tamara: Sometimes people fight, they're fighting over the idea….They said to choose, and I didn't really want to…because I didn't want to hurt anyone's feelings.

Conflict Resolution Strategies

The fourth coding pass aimed to unpack the ways in which students resolved design-related conflicts. Students described six strategies for coming to agreement about a design decision: *choosing through reasoned comparison, combining ideas, generating a new idea, selecting a solution through a game of chance, voting to select a solution,* and *agreeing with a teammate.* In *reasoned comparison*, students described choosing a solution to pursue by comparing proposed solutions, weighing the functional advantages and disadvantages of those solutions, and selecting the most promising or best performing solution. Some students explicitly

mentioned comparing the results of tests, while other students talked about comparing hypothetical advantages and disadvantages of yet-untested proposals. All student responses in this category referenced the performance or anticipated performance of a solution. When students described *combining ideas*, they talked about integrating solution ideas or parts of solution ideas from more than one person on a team. Within this theme of combining ideas, some students described this process as additive; they talked about putting together groupmates' ideas. Other students who described combining ideas mentioned compromise or subtraction. These students talked about removing an idea or part of an idea; they described processes of modifying solution ideas, giving up a solution idea, or giving up part of a solution idea to come to agreement.

When describing *generating a new idea*, students said that they abandoned all of the disputed solution proposals and proposed a new idea. This new idea could come from within the team or could be an idea generated by another group. Students described *selecting a solution through a game of chance*, explaining that they had used the game "rock-paper-scissors" to pick a solution (implying that the winner of this game would pick which solution to pursue). Students stated they used *voting* to choose which idea to pursue; the idea which received the most votes from group members would become the idea to advance. Finally, some students explained that they reached consensus by deciding to *agree* with their groupmates' preferred action or solution proposal. These students appeared to be attending to relationships within the group, implying that agreeing with a partner maintained amicable relationships in the group and could lead to partners reciprocating in the future. Figure 5, below, includes definitions of each decision-making strategy and includes sample student statements illustrating each strategy.

Figure 5

Conflict Resolution Strategies

Strategy	**Example**
Choose through reasoned comparison: Group members compare design ideas. They weigh the functional advantages and disadvantages of a solution based on test results or compare the likelihood of success of different potential solutions.	Odin: Well, we tried both of them [initial solutions] and the simple one worked better so we all agreed that we should do that.
Combine ideas: The group uses varied ideas or parts of ideas from multiple team members. Students may describe adding ideas together or giving up parts of ideas to reach a compromise with peers.	Cyrus: So [my partner] wanted to do this idea, but I wanted to do another one. So I said, "Why don't we just put both of them together?"
Generate a new idea: Students put aside their original conflicting or disputed ideas and select a novel solution that all teammates agree to pursue. The new idea may be generated within the group or inspired by the work of another group.	Olivia: We left those [disputed] ideas alone and we thinked of another one that all of us could agree on.
Select one idea by chance: The winner of a game of chance selects the idea to pursue.	Miriam: So then after that, we worked our problems too — we just rock-paper-scissors too, and the other person won.
Vote for an idea: The group selects which idea to pursue by a majority vote.	Octavia: We actually voted. Yeah, it's only three people, an odd number. So whoever won, won.
Agree with a teammate: The group elects to agree with one group member's preference.	Basil: Just breathe and if you wanna make the person wanna help you, to go agree with them.

Emphases in Conflict Management

The final coding pass was intended to highlight what students attended to when managing conflict. Students variously described decision-making strategies which emphasized one of three themes: *function* of a design solution, *fairness* of the group process, and *feelings* of group

members. Most frequently, students described strategies which focused on the performance or *function* of the design solution. At times, students described strategies which emphasized the decision process, particularly students' sense of *fairness* in the group. At other times, students described strategies which addressed relational tensions among group members, or *feelings* in the group. These foci are not necessarily mutually exclusive, but rather represent the dominant stance expressed in students' conflict management strategies. Figure 6, below, includes definitions of each decision-making rationale and student statements exemplifying each theme.

Figure 6

Emphases of Decision-Making Strategies

Conflict Resolution Emphasis	**Example**
Function: Consider how well a solution has performed or how well it is anticipated to perform and make a decision focused on a mutually acceptable performance.	Bonnie: Then we just do the one that we think will work and take it out of our minds and just put it in front of us. Fabiola: Well, what we did was we tested all the ideas we had and the one that really worked we did that one …We tried a lot of things, and we put more and more ideas on it. … Well, we used the things that really worked on the previous one [rocket iteration] and we took that on the previous ones and we put it together. Then, we started using a few new ones, new materials, and then we're like, "This should be our final one, because a few of these ones were the ones that made our rocket go as far as we really need it to."
Fairness: Consider how much each group member has contributed or will contribute to the solution and make a decision focused on a mutually acceptable distribution of contributions.	Bella: We came to an agreement to add a little bit of everybody's creativity 'cause it was our project that we were all making….But then we're like, "But if we're doing one idea everybody's not really included in it because we're just using one person's idea." So we kinda talked it out and did like, "Maybe we can add a little bit of everything in this one project 'cause we're all making this project together." …We all agreed on it and we all worked together to make it everybody's. A little piece of everybody's creativity in one project is kinda hard but wasn't. Cole: He got some of what he wanted but I got some of what I want.
Feelings: Consider how each group member feels or will feel about the decision and make a decision focused on group members' emotions.	Bethany: And if you include everyone's idea, it could make everyone like, happy. Kermit: [The combined solution] would look more neat and fun to add because [the engineering program] is mostly about doing stuff with people what makes you feel good and building with other people.

Discussion

Students' Perceptions of Conflict in Engineering Design Groupwork

Salience and Types of Conflict

Conflict rooted in incompatible actions in elementary students' groupwork has been underexplored in the literature to date. Conflict in elementary classrooms has frequently been conceptualized as cognitive controversy or as physical violence rather than as disagreement within groupwork. The literature on conflict in elementary classrooms has largely focused on structuring classrooms to promote conceptual conflict or argumentation (e.g., Johnson et al., 1976; Osborne et al., 2004; Wilson-Lopez et al., 2020; Windschitl et al., 2012; Zembal-Saul et al., 2013) or to promote peaceable schools and prevent violence stemming from incompatible goals in social interactions (e.g., Carlsson-Paige & Levin, 1992; Johnson & Johnson, 2002; Levin, 2003, 2012; O'Reilley, 1984). To contextualize students' engineering design groupwork conflicts, I turn to workplace conflict literature, which has focused on the prevalence, significance, and types of conflict in work teams.

Intragroup conflict was present for and noteworthy to the students in this study; nearly every student noticed and described experiencing intragroup design-related conflict. These students described experiencing three types of conflict which generally corresponded with the types of intragroup conflict observed in professional workplaces (Jehn, 1997, 2014). Similar to adults in work settings, these youth described experiencing task conflict (disagreement about what a group is trying to accomplish) and process conflict (disagreement about how a group will accomplish a task). However, these youths' descriptions of relationship conflict diverged from descriptions of relationship conflict in workplace settings. In workplace contexts, relationship conflict is typically conceptualized as arising from dislike of teammates or from differences in

personal values (such as political beliefs) and interests (such as hobbies) (Jehn, 1997, 2014). In this study, relationship conflict emerged from disagreement about norms of intragroup or interpersonal interaction. Students described disagreements about how team members should treat one another during the group activity; while these disagreements might have been rooted in differences in personal values associated with intragroup interactions, unlike adults, students' relationship conflicts were not rooted in political values, personal interests, or dislike of peers.

The groupwork context may explain this variance in descriptions of relationship conflict. Groupwork by elementary students in an engineering classroom could give rise to conflicts that differ from those which emerge in professional workplaces. Workplace conflict studies principally have been conducted in large companies, and similarities in these workplace contexts may have limited our understanding of team conflict (Conlon & Jehn, 2019). Recent studies suggest that varied work contexts may give rise to varied types of conflict and researchers have proposed additions to Jehn's (1997) conflict typology. For example, culinary arts students may experience temporal conflict, or disagreement about when tasks should be completed, when student teams attempt to prepare food under strict time constraints (Mohammed et al., 2017). Conlon and Jehn identify financial, political activism, and drug conflicts within punk music bands, and they ascribe these conflicts to the distinctive context in which these musicians work. These two studies point to pressures specific to particular work contexts and suggest that variety in context may give rise to variety in conflict.

Children learning in classrooms experience different contextual influences than do adults in workplaces, and thus it is likely that children learning engineering in classrooms experience conflict differently than do adults in corporations. Additionally, it is possible that engineering groupwork could present children with different pressures than might groupwork in another

discipline. For example, the pressures to create diverse solutions and working artifacts in an engineering classroom might lead toward a different type of conflict than might the pressures to develop shared understanding of phenomena, patterns, and relationships in a science or mathematics classroom. Future work could explore the nuances and possible additional types of conflict in elementary students' engineering groupwork.

Satisfaction

Students' satisfaction with their engineering groupwork experience is likely to influence their current and future participation in engineering endeavors. Enjoyment and other positive affective experiences are strongly correlated with students' disciplinary participation, sense of competence, interest, identity, and persistence (Ainley & Ainley, 2011; Baker et al., 2013; Eccles, 2005; Elliot & Dweck, 2005; Hidi & Renninger, 2006; King et al., 2015). Youth who have positive groupwork experiences participate more in groupwork in the moment (Linnenbrink-Garcia et al., 2011) and youth who experience sustained, satisfying groupwork express a positive outlook toward future participation in groupwork (Edwards & Jones, 1999; Florez & McCaslin, 2008; Gillies, 2003). Conversely, students who have unpleasant experiences are likely to avoid similar future experiences (Elliot & Dweck, 2005) and students who have unpleasant experiences in engineering study are more likely to turn away from engineering (Godwin & Potvin, 2017; Marra et al., 2012). Conflict is often, but not always, associated with negative emotions (Troth et al., 2014). Students in this study generally described their experiences with conflict as unpleasant or unsatisfactory, and it is possible that these students' experiences of intragroup conflict could adversely impact their relationship with engineering.

However, there is opportunity for students to experience conflict as satisfying or energizing, rather than unsettling or unpleasant. Just as students doing engineering, science, or

mathematics can find debate, uncertainty, or sensemaking exciting and productive (Cobb et al., 2011; Danielak et al., 2014; Engle & Conant, 2002; Jaber & Hammer, 2016a, 2016b; Radoff et al., 2019; Watkins et al., 2018), elementary students could experience design-related conflict as a satisfying element of engineering, particularly if their classrooms supported engaging in conflict as a disciplinary norm. A growing body of research highlights a relationship among students' epistemologies, students' emotions, and the disciplinary norms of classrooms (Gupta et al., 2018; Radoff et al., 2019) and between classroom-supported disciplinary norms and students' epistemologies (Carlone et al., 2011; Cobb et al., 2011; Engle & Conant, 2002). Future work could explore ways in which classrooms could promote conflict as an important, productive, and satisfying part of learning engineering design.

One step toward re-framing intragroup conflict as desirable is understanding what students find undesirable about conflict. In this study, students identified task inequity, idea obstruction, and emotional strain as drawbacks of conflict in engineering groupwork. These drawbacks of engineering groupwork emerged from conflict which loosely maps onto the *relationship conflict* identified in workplace team conflict literature. In workplace settings, relationship conflict jeopardizes productive teamwork (Jehn, 1995, 2014; Rispens, 2014). In this study, these three drawbacks of groupwork may have been rooted in interpersonal conflict, but in addition to jeopardizing teamwork, these manifestations of conflict may also have jeopardized personal relationships. *Emotional strain* in particular could result from damage or anticipated damage to relationships, and students described moderating their decision-making to avoid this strain. Future work could explore ways to reduce students' stress about disagreeing with groupmates.

Task inequity is frequently cited as sources of tension in groupwork literature; studies in high school, university, and workplace settings describe group members' unhappiness with peers who shirk work (often referred to as social loafing), take prime tasks for themselves and delegate less desirable tasks to teammates, or ignore teammates' contributions (Chiriac & Granström, 2012; Karau & Williams, 1993; Lee et al., 2015; Tonso, 2006). In university settings, task inequity has been theorized to contribute to inequitable participation, influence engineering identity, and contribute to inequitable future opportunities for engineering students (Tonso, 2006). It is possible that elementary students could experience similar consequences to their learning; future study could explore the impacts of task inequity on equitable participation and identity formation for elementary students who are learning engineering.

Task inequity is described as a tension in a variety of disciplines (Karau & Williams, 1993; Lee et al., 2015; Tonso, 2006), but *idea obstruction* may be more specific to or prevalent in engineering groupwork. We can imagine that in some disciplines, an idea that is not initially taken up by a group could be revisited. However, in engineering design, the group often makes a physical commitment to prototype an artifact which then narrows the group's attention (e.g., Dym, 1994), and that commitment may preclude revisiting earlier, discarded ideas. In the engineering outreach experiences of this study, students had limited time to participate in engineering challenges. Once an idea was ignored or cast aside by group members, time constraints would make it unlikely for that idea to be able to be revisited and realized as a design artifact.

Idea obstruction may have arisen when students were not afforded sufficient time or material resources to pursue multiple ideas. In a similar setting, educators might consider providing more time and more materials so students could explore and prototype many possible

design solutions. Idea obstruction might also be particularly noticeable to students in this engineering context because they physically built an artifact based on an idea that their group had imagined. The physical artifact might provide a tangible reminder of whose ideas were promoted and whose ideas were passed over. In another context, a student might be less attached to their individual idea; in a group activity of creating a final presentation or report, the group's set of imagined manifestations of their final product might have less potential for variation in solutions and be less personally significant.

In detailing what students identified as drawbacks of conflict, I am not arguing that students should never experience conflict in engineering design groupwork. Rather, I suggest that educators could consider which conflicts might be productive for students to work through and which conflicts might detract unduly from students' overall engineering experiences. Additionally, I suggest that educators could consider ways to support the development of epistemologies that embrace conflict as satisfying rather than stressful.

Students' Management of Design-Related Conflict

Dominant conceptions of decision-making by professional engineering teams emphasize reflection on solution performance and foreground a focus on the function of solution options. A norm of professional engineering design is that a design team aims to create an optimal or satisfactory solution for a problem (e.g., Dym, 1994; Vincenti, 1990). In a professional engineering design process, we would expect engineers to generate multiple solution possibilities, to compare these possible solutions to each other, and to assess their performance or potential performance in light of criteria and constraints (Dym, 1994; Ullman, 2018). Engineering educators, expecting students to move toward expert design practices, might also anticipate and desire that students would resolve design disagreements through comparing

solutions and selecting the best performing or most promising solution to pursue (e.g., Crismond & Adams, 2012).

While it is sound pedagogical practice to encourage learners to participate in and make progress in the practice of reflective decision-making (Wendell et al., 2017) and the supporting activity of comparing solutions (Crismond & Adams, 2012), there is reason to unpack students' decision-making strategies and emphases. Understanding the ways in which students resolve design-related conflict and make design decisions not only builds our understanding of the ways in which students enact engineering design, it allows us to interrogate the expectation that reflection on solution performance is the only way or the best way to make decisions. This study suggests that when students manage design conflict to make design decisions, students not only consider the function of solution options, but also consider the feelings of team members and the fairness of the decision-making process. The breadth of students' conflict-resolution emphases and decision-making activities offers an opportunity to expansively envision possible ways of learning and doing engineering.

Conflict management strategies

It is reasonable to anticipate that elementary students can and will engage in reflective decision-making. Research indicates that elementary students can and do reflect on solution performance to inform their design choices; researchers have observed elementary students utilizing test evidence to inform iteration and improvement (Mangiante et al., 2020; Wendell et al., 2017). The present study aligns with prior studies' findings that elementary students may compare test results to choose among incompatible solution options; in this study, many students described resolving design-related conflict through *choosing through reasoned comparison*,

which involves comparing possible solutions and selecting an option to pursue based on the performance or anticipated performance of the possible solutions.

However, employing this strategy necessitates that group members 1) prioritize satisfactory or optimal solution performance, 2) possess sufficient experience or information to assess or predict the performance of various solution options, and 3) participate in a learning environment conducive to debating solution options. Although many students in this study compared solutions to resolve disagreement, many more students utilized other strategies to resolve disagreement about designs. To unpack these students' selections of strategies, I turn to these students' descriptions of their experiences with design-related conflict and to prior studies of children's engineering design experiences. I first consider the broad contextual influence of learning environments, then students' access to information that would facilitate evaluating solution performance, and finally students' priorities in decision-making.

In order for students to debate engineering solution options, students must participate in a learning environment which supports students to disagree and to resolve conflict. That is, disagreement about and debate of solution options must be a norm of the discipline as performed in the classroom. Researchers have called for students to engage in disagreement and debate in classrooms in general, arguing that a classroom which cultivates *constructive controversy* or *collaborative argumentation* supports students to co-construct knowledge and sense-make in a variety of disciplines (Andriessen & Baker, 2014; Johnson et al., 1976; Johnson & Johnson, 1994).

However, disagreement and debate are not necessarily available to all students. Classrooms may be structured to promote argumentation (rooted in Toulmin), in which students construct a claim based on evidence and reasoning (Next Generation Lead States, 2013b;

Toulmin, 1958, 2003), but not dialogic argumentation or debate, in which students interact with and critique peers' arguments (Osborne & Patterson, 2011). Additionally, students may hesitate to engage in debate when it is framed as a competition (Berland & Reiser, 2011) or as a display of knowledge (Berland & Hammer, 2012a; Berland & Hammer, 2012b) rather than as a means of co-constructing knowledge. Students may refrain from debate when the topic under discussion is emotionally charged or challenges their personal identities (Goldberg et al., 2011). Participating in debate can be eschewed by students as personally risky; elementary students have described avoiding debating possible engineering solutions in order to avoid being seen as fighting or causing trouble in class (Wright et al., 2018). These studies point toward attending to the interactions of debate and the multiple facets of youths' identities. In particular, Wright and colleagues' interviews with Black youth illuminate the importance of attending to disparate impacts on minoritized students of inequitable access to the discourse of design conflict. It is beyond the scope of the current study to unpack individual students' access to design conflict discourse, but it is incumbent upon us to acknowledge and abate possible constraints on participation in conflict discourse by youth who are members of groups that have historically been marginalized in schools and in engineering.

In order for students to compare engineering solution options, students must have means to assess or anticipate the performance of possible solutions. Although the materials utilized in the design challenges in this study were familiar or somewhat familiar to students, students may have been using them in novel ways and under time constraints, which could have made it difficult for students to predict or evaluate how the materials and solutions might behave. It is also possible that students in this study were not familiar with structures for comparing solutions. Many classrooms in this study, like many K-12 classrooms in the United States, did not

deliberately scaffold comparing solutions (Wilson-Lopez et al., 2020). It is beyond the scope of this study to thoroughly unpack the resources students brought to each design challenge, what *did* support many of these students to compare solutions, and what *might have* supported additional students to assess or anticipate solution performance. However, if educators wish to encourage students to compare solutions, future work could investigate ways in which educators could ensure that students have sufficient experience and information to assess and predict solution performance. This support might take the form of increased contact with materials to build familiarity and inform predictions about performance based on known characteristics. Support might take the form of scaffolded decision matrices, house of quality matrices, or other tools that promote comparing solution performance. Support could also take the form of explicitly naming, describing, and coaching reflection upon and comparison of solutions.

For students to compare solutions, group members must prioritize satisfactory or optimal solution performance. This study offers some insight into students' priorities in decision-making and suggests that some of these students may have prioritized something other than solution performance when resolving design-related conflict. Among the students in this study, it is likely that some students prioritized conflict mitigation or conflict avoidance (rather than solution performance) when making design decisions. These students may have employed a design decision-making strategy that minimized conflict, such as *combining ideas, generating a new idea, selecting a solution through a game of chance, voting to select a solution,* or *agreeing with a teammate.*

Students could have varied reasons for valuing the reduction of conflict or absence of conflict; they might perceive conflict as unpleasant or unsafe. In Wright and colleagues' work (2018), students described conflict as unsafe; these students avoided conflict because

participating in debate put them at risk of being perceived as troublemakers and being punished in the classroom or at home. Students may also avoid conflict that threatens their identities or sense of competence (Elliot & Dweck, 2005; Goldberg et al., 2011; Wright et al., 2018).

Participants in this study, however, described conflict as unpleasant, rather than unsafe. In this study, most students identified conflict as affectively unpleasant or contributing to dissatisfaction. While students identified three sources of dissatisfaction, here I focus on two – idea obstruction and emotional strain – as possibly influencing students' prioritization of minimizing conflict. It is reasonable for students to act in ways that minimize their discomfort with conflict or maximize their enjoyment of engineering groupwork and we can imagine that students might combine solutions in order to prevent idea obstruction and facilitate the realization of their own idea. We can also imagine that students might combine ideas, select a solution through a game of chance, or agree with a teammate or capitulate to avoid messy feelings and risks to friendships. In other classroom contexts, students have been observed to take relationships with peers into account when engaging in conflict, argumentation, and groupwork in general. Elementary students attend to relational uncertainty while learning engineering in groups (Jordan & McDaniel, 2014) and university students attend to and attempt to mitigate relational tension while solving physics problems in groups (Sohr et al., 2018). More specific to conflict and argumentation, other studies suggest that elementary students consider peers' feelings when evaluating peers' claims in science (Jaber & Hammer, 2016a) and when evaluating peers' builds in engineering (Rahman et al., 2019). Students attend to their own emotions and those of peers in a variety of groupwork contexts; it is not surprising that students consider feelings and friendships when managing design-related conflict and decision-making in engineering groupwork.

Conflict management emphases

Many students in this study described resolving disagreement through comparing solutions and focusing on function. However, many more students described taking into account not only function, but also teammates' feelings and a sense of fairness. In this study, the most frequently described decision-making strategy was *combining* the ideas of multiple team members. Students' explanations for why they chose to combine the ideas of team members indicated that at least some students employed this strategy because they were prioritizing group members' feelings or a norm of fairness (and supporting that fairness by ensuring that some idea from everyone in the group was used). Similarly, students' rationales for *generating a new idea, selecting a solution through a game of chance, voting to select a solution,* and *agreeing with a teammate* appeared to be grounded in attention to teammates' feelings or fairness within the group. In professional engineering teams, team members consider functional tradeoffs when making design decisions (e.g., Dym, 1994; Ullman, 2018). In the context of these elementary students' design process, perhaps the tradeoffs students consider not only include functional factors, but also involve feelings and fairness.

These youths' attention to feelings and fairness in engineering design groupwork offer an opportunity to re-envision participation in engineering learning and professional practice. It may be that professional engineers typically focus on function or solution performance to resolve conflicts and advance design decision-making. It is productive for youth who are learning engineering to consider how well various solutions will perform. At the same time, youth who attend to feelings and fairness are also attending to the well-being of the group, which is consequential for team members' participation in engineering. By attending to feelings, students support positive emotional experiences with conflict and with engineering design. By attending

to fairness, students are attending to participatory equity (Shah & Lewis, 2019) or relational equity (Boaler, 2006a, 2006b, 2008) and opening opportunities for peers to contribute and to value teammates' contributions. Students who give weight to feelings and fairness to resolve design-related conflict offer a model of engineering learning and practice which supports equitable participation, promotes satisfaction, and strengthens an affinity toward continued participation in engineering.

Future Work

These students' descriptions of their engineering groupwork experiences present two opportunities for designers and facilitators of engineering learning experiences. First, educators could support sustained and equitable participation in engineering learning by bolstering students' existing attention to feelings and fairness in design groupwork. Second, educators and researchers could design engineering learning environments with an eye toward promoting satisfaction with conflict and supporting students to associate positive emotions with conflict.

Conclusion

Learning to manage conflict is critical to learning engineering design with a team, and the ways in which students experience conflict are consequential to their learning. In order to optimally support children to participate in engineering, designers and facilitators of learning experiences need to understand the ways in which youth may perceive and manage conflict in design teams. This study adds to our understanding of how students experience design-related conflict and the ways in which students resolve conflict to make design decisions. Students' affective experiences with conflict in engineering design teams and students' conflict management strategies have implications for students' current and future participation in engineering.

In this study, elementary students participating in engineering design teams managed conflict and made design decisions by variously attending to the function of design ideas, the fairness of the group's work process, and the feelings of group members. Although decision-making in professional engineering may be weighted toward evaluating function, function may not always be students' priority. Prioritizing fairness or feelings may support students to have positive affective experiences with engineering design, which may in turn, support their disciplinary participation and persistence.

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