Elementary Students Navigating the Demands of Giving Engineering Design Peer Feedback (Fundamental)

Ms. Fatima Rahman, Tufts University

STEM Education graduate student at Tufts University. Interests: Pre-college engineering design for under-represented minorities, Community-connected engineering design in pre-college classrooms

Chelsea Joy Andrews, Tufts University Center for Engineering Education and Outreach

Chelsea Andrews is a post-doctoral researcher at Tufts University and University of Massachusetts-Boston in STEM education. She received a B.S. from Texas A&M University in ocean engineering and an S.M. from MIT in civil and environmental engineering. Her current research includes investigating children's engagement in engineering design through in-depth case study analysis.

Dr. Kristen B. Wendell, Tufts University

Kristen Wendell is Assistant Professor of Mechanical Engineering and Adjunct Assistant Professor of Education at Tufts University. Her research efforts at at the Center for Engineering Education and Outreach focus on supporting discourse and design practices during K-12, teacher education, and college-level engineering learning experiences, and increasing access to engineering in the elementary school experience, especially in under-resourced schools. In 2016 she was a recipient of the U.S. Presidential Early Career Award for Scientists and Engineers (PECASE). https://engineering.tufts.edu/me/people/faculty/kristen-bethke-wendell

Nicole Alexandra Batrouny, Tufts University

PhD candidate in Mechanical Engineering at Tufts University. Interests: upper elementary engineering education, integrated science and engineering, collaboration in engineering, decision making in engineering.

Dr. Tejaswini S. Dalvi, Univeristy of Massachusetts, Boston

Elementary Students Navigating the Demands of Giving Engineering Design Peer Feedback (Fundamental)

Throughout the design process, practicing engineers seek out feedback on their design work to improve the quality of their design processes and solution. Feedback can be defined as information about how a process or product meets or strays from particular criteria (Butler, 1987), and it includes both feedback on function, often generated through physical testing or simulations, and feedback from clients, users, and other stakeholders (Darling & Dannels, 2003; Vinck, 2003). For engineering learners, the goals for engaging in the feedback process typically extend beyond simply improving designs, to refining learners' definition of the design problem, fostering creative tension among team members, and giving students an opportunity to learn from failure (Yilmaz & Daly, 2016).

A feedback approach that has been employed successfully across the K-16 spectrum is peer assessment, where equal-status learners "consider and specify the level, value, or quality of a product or performance" of their peers' work (Topping, 2009, p. 20-21). Across disciplines and ages, peer feedback has been shown to improve the quality of learning through increasing students' sense of ownership of their learning (Sivan, 2000), "trigger[ing] a deeper elaboration of the material" (Kollar & Fischer, 2010), and engaging students in the discourse practices of academic disciplines (Kafai & Muir Welsh, 2007; Wright, 2016). Importantly, these learning outcomes apply to both the assessors and the assessees, and educators can use the process of giving and receiving feedback to help students build empathy and metacognitive skills (Topping, 2003). However, it is important to note that engaging in a feedback process does not automatically mean that learning takes place (Kollar & Fischer, 2010), and providing useful feedback is challenging even for college students (Nilson, 2003).

In engineering learning environments, participation in the exchange of peer feedback can be a meaningful activity for students. In undergraduate engineering courses, peer assessment has been used to provide feedback on writing (e.g., Carlson, Berry, & Voltmer, 2005), presentations (e.g., Hersam, Luna, & Light, 2004), teamwork skills (McGourty & De Meuse, 2000; Ohland et al., 2005), and design solutions (Adams & Siddiqui, 2015; Yilmaz & Daly, 2016). At the pre-college level, researchers have begun to look at the ways in which design critique protocols influence students' design discourse and iterations (Jordan, 2014a; 2014b). Students have been found to make use of the suggestions given to them by other design groups and to engage in more substantive design discourse after receiving feedback, even negative critique.

While prior research in peer assessment points to it being a productive aspect of engineering instruction, there are still many open questions about how elementary students take up the process of giving and receiving feedback and how feedback experiences influence their engineering learning. College students have more fully developed capacities for social and emotional regulation than elementary students, so findings from undergraduate contexts do not necessarily shed light on how elementary students will navigate the demands of giving and

receiving feedback. In this paper, we report on a study of the ways in which elementary students approach generating engineering design feedback.

Theoretical Framework

Our work is grounded in the sociocultural perspective that learning engineering involves becoming a more proficient participant in a community of engineering design practitioners. This perspective is aligned with situated learning theory (Lave & Wenger, 1991), which would suggest that in order to learn how to give and receive engineering design feedback, students need to be placed in situations where feedback serves an authentic purpose for a design task.

The curriculum development project in which this study took place has an explicit goal of enabling underrepresented minority students to see engineering as a way to take action on problems that matter to their communities (Dalvi, Wendell, & Johnson, 2016). One way in which we are working toward this goal is by inviting community members to give feedback to students when they are defining the parameters of their engineering design problem. Another way we are supporting student engagement in engineering is by creating structured opportunities for them to give feedback on each other's design products and process, while attending to how well they are addressing the community's problem. We hope that as students participate in the feedback process, they develop conceptions of feedback and its purpose in collaborative engineering design. This paper focuses on student-to-student feedback during one of the new community-connected curriculum units for third grade.

The situated learning perspective informed the instructional choices we made as researchers co-facilitating the unit. We were committed to providing opportunities for students to participate meaningfully in the practices of engineering design. This commitment to meaningful participation meant that when planning for student-to-student feedback, we wanted the feedback to be productive for students' engineering design learning rather than simply an exercise in following a protocol. We chose to have the third-grade students engage in a peer-to-peer mid-design feedback session for a number of reasons: (1) student groups were not getting productive feedback from the limited physical testing they were conducting, (2) student groups were enamored with their own designs but could perhaps be more critical when taking on the role of "user" for another team's design, and (3) intentionally interacting with others' designs might give teams new ideas for iterations of their own designs. Thus, while we hoped that teams would use the feedback given to them by other teams to improve their own designs, we expected that the *process* of analyzing others' designs and generating feedback would be more productive than the actual written feedback itself.

In our analysis of student feedback processes, we also draw on the framework of cultural historical activity theory (Engestrom, 1999). We view the social practice of evaluating an engineering design and generating feedback as a complex activity system where learners' actions are influenced by existing tools (e.g., a feedback worksheet), norms (e.g., classroom rules), and community history (e.g., friend relationships among a group of children). To provide constructive and effective feedback, learners need to find a balance between these potentially competing activity system elements. For example, the social dynamics between the reviewer and reviewee, the goals and constraints of the project, and the design artifacts in question all influence the nature and content of given feedback. In order for students to learn how to navigate

the complexity inherent in feedback, they must be meaningfully engaged in the activity of giving feedback. While much research has focused on the effectiveness and accuracy of given feedback, there is little research on how students come to generate design feedback in specific contexts. In this paper we privilege the complex relationship between the act of generating feedback and the activity system within which it takes place.

In this paper, we develop a case study illustrating how one team of third graders handled the task of generating peer feedback during a community-connected engineering design unit. We are interested in deeply understanding the process students go through to generate feedback for their peers. To uncover how students participate in the process of generating peer feedback, this study addresses the research question, *How do elementary students navigate competing demands while collaboratively generating peer feedback on engineering designs?*

Study Context

This study is part of a larger grant-funded research project aimed at developing and studying community-connected, integrated science and engineering curriculum units that support diverse elementary students' science and engineering ideas, practices, and attitudes. The "playground design" unit in this study is for third-grade students. It is comprised of 10 one-hour lessons, including science inquiry lessons on forces, motion, and magnetism and an engineering design challenge focused on wheelchair-accessible playground structures. For the unit's design task, teams of three third graders designed, built, and tested small-scale, functional prototypes of accessible playground equipment on a 12-inch square foam platform. To emphasize that design should be functional, and not simply representational, each group was given a 4-inch tall model wheelchair to test their design with; an example of a "successful" design, a swing that accommodates a wheelchair, is shown in Figure 1. Teams documented their process in a digital design notebook on an iPad (Wendell, Andrews, & Paugh, 2019).

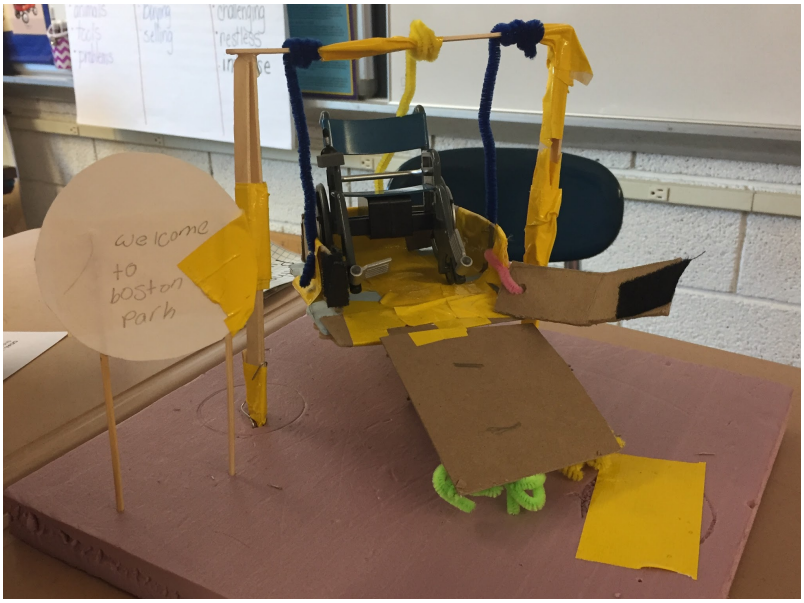

Figure 1: An example piece of playground equipment design created by one team, a swing that accommodates a model wheelchair, including a ramp (foreground) that allows the wheelchair to roll up onto the swing.

The focus episode of this study occurred during the eighth lesson, an hour-long feedback session, in which each of the eight design teams generated written feedback for two other groups. Students recorded feedback on a "Playground Design Feedback" form (Figures 2 and 3) developed by the research team for this enactment. To encourage students to consider the physical prototype (the "product") and documentation completed in the digital design notebook (the "process") equally, we devoted half of the form to each aspect. The form included a checklist of questions intended to prompt students to attend to the details of their peers' work and to avoid empty praise ("Good job!") or overly generic feedback ("It works."). Students chose "Yes," "No," or "Maybe" to answer each checklist question. The form had free response areas with prompts of "Something that impressed us" and "A suggestion for improvement" for both the physical prototype and the digital design notebook. Before students began conducting feedback with the form, the lesson began with a whole-class discussion about giving and receiving design feedback. Instructors modeled giving both specific praise and constructive criticism, and asked students to notice how they respectfully shared both kinds of feedback.

The lesson, co-taught by two members of the research team, was intended to encourage students to evaluate their peers' designs based on the four design criteria: accessibility, inclusivity, stability, and enjoyability.

The feedback form (Figures 2 and 3) used in this implementation of this unit is not a standard form used throughout the project; the nature and form of mid-design feedback is determined by the project team for each enactment of the curriculum. In some classes, student teams are paired up and discuss each other's designs face to face. In other classes, student teams give a share out of their designs in a larger group setting and other teams ask questions and give advice. In this class, prompted by the wide range of designs students had constructed and the presence of many English Language Learner (ELL) students who seemed less comfortable with oral discussions, we opted for written feedback that each team would generate without the other team present.

An initial draft of the feedback form included two free-response sections, "Something that impressed us" and "A suggestion for improvement," similar to a standard "gallery walk" approach (e.g., Kolodner et al., 2003), where students might be instructed to write feedback to each group. After reviewing field notes and photographs of in-progress design artifacts, the research team decided that for this class, we wanted to use the feedback session to further highlight the design task criteria, since we did not see much evidence of students attending to the criteria, despite frequent reminders. We considered simply listing the criteria on the form as a reminder, but eventually decided that to push students to consider each criteria in depth, it would be productive for student groups to consider and respond to each criteria separately (Figure 2, top). After conducting the analysis for this case study, we modified the form for a subsequent enactment of this unit: the checklist portion became a separate "self-assessment" form to be completed before student groups filled out the short written responses as a peer assessment.

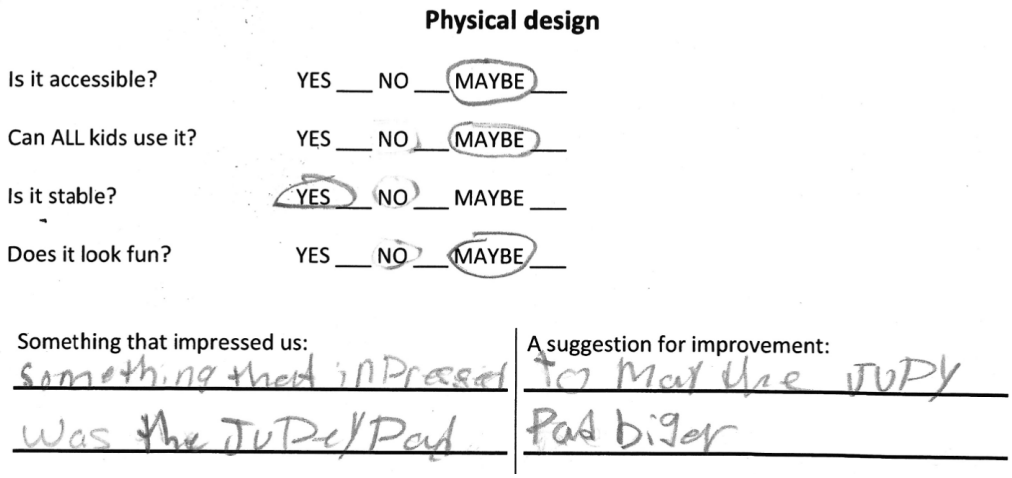

Figure 2. The first half of the peer feedback form focused on the physical design. This is the focus team's final version; initial erased responses are visible.

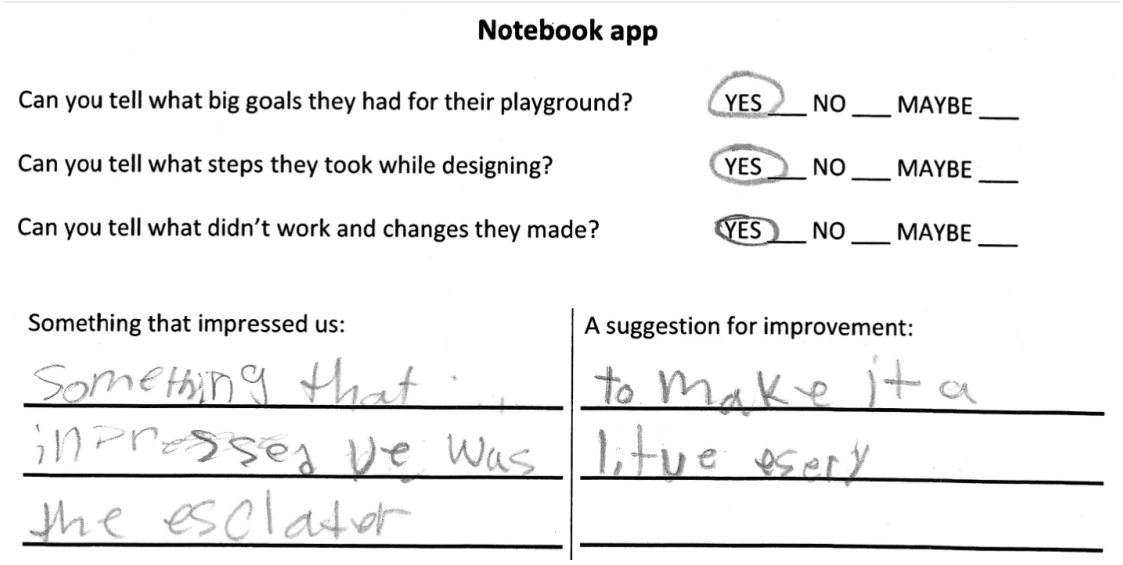

Figure 3. The second half of the peer feedback form focused on student design notebooks. This is the focus team's completed version.

Case Study Methodology

Drawing from descriptive case study methodology (Merriam, 1998) and interaction analysis (Jordan & Henderson, 1995), we explore one particular group's reasoning about the feedback forms as a way to understand the challenges that these students faced when giving peer feedback. We treat the case developed in this study as an extreme case (Yin, 2009; Flyvberg, 2006); it is not intended to be representative. As Flyvberg (2006) notes on selecting cases for study, "...the typical or average case is often not the richest in information. Atypical or extreme cases often reveal more information because they activate more actors and more basic mechanisms in the situation studied" (p. 229). The obvious disagreement between the students in this group is not typical; the sustained and intense nature of the disagreement is in fact what makes the challenges this group faced apparent and clear to us and available for study. We expect that the content of these disagreements are encountered by all students, but to a lesser degree than seen in this case.

While we focus on a single, extreme case in this study, that does not mean the findings that stem from this case are not generalizable. Instead of probabilistic generalization, we are interested in theoretical generalization, in using thick description (Geertz, 1973) to refine existing theories (Eisenhart, 2009). In case study research, "the search is not for abstract universals arrived at by statistical generalizations from a sample to a population, but for concrete universals arrived at by studying a specific case in great detail and then comparing it with other cases studied in great detail" (Erickson, 1986, p. 130).

Data Collection and Analysis Methods

Throughout the unit, researchers collected video data of two student groups, photos of student artifacts, and copies of the students' written work and digital design notebooks. This analysis focuses on one of the two followed student groups as they evaluated the first of two peer group playground designs. The episode is roughly 20 minutes long and includes video of the three students evaluating and giving feedback on another group's playground prototype and digital notebook. We chose this group and this episode because of the sustained and intense emotional disagreements that took place between the students; these disagreements attracted intervention from two teachers and left two of the three students close to tears.

We followed Jordan and Henderson's (1995) approach to interaction analysis. To begin the analysis, in research team meetings we reviewed field notes, artifacts, and portions of the video record from the feedback lesson including the video episodes for both of the focal groups. During this process, we prepared partial transcripts of student discourse and used memo writing to characterize the approaches and experiences of both focal groups as they worked to give feedback to two other groups' playground designs. The first author proposed particular dilemmas that the students seemed to be facing in deciding how to complete the feedback form. After this round of analysis, the focal group of Nate, Amanda, and Kevin (all names are pseudonyms) stood out as a extreme case illuminating the kinds of tensions that students have to navigate when asked to generate peer design feedback.

We chose to focus primarily on the nature of the concerns the students were raising around what to say in their feedback form. By doing so we were able to identify the different perspectives the students took when disagreeing with each other. We are less interested in attempting to identify causes for the disagreement; we expect the tensions were influenced by many elements of the activity system, including the design the students were analyzing, the existing social relationships between students in this team and with other teams, and the social and disciplinary norms present in this classroom. In this analysis we seek to make apparent the nature of the tensions that were specific to elementary students giving feedback.

Having selected a focal group for further analysis, we prepared a full transcript of their discourse during the feedback lesson. Again in research team meetings, we reviewed the video and transcript to determine whether the dilemmas proposed by the first author seemed to be important to the students themselves. We used discourse analysis techniques (Gee & Green, 1998) to review the students' conversation line by line looking for evidence that these dilemmas were repeatedly brought into their decision making process. Through this round of analysis, we

concluded that the data set supports characterization of two feedback-focused tensions, described in the Findings section below.

Findings

Two main tensions emerged in the focal group's discourse around what feedback to give to their peers: (1) whether to privilege being *honest* or being *kind* and (2) whether to critique the design artifact in its *current physical form* or to critique what the team *could potentially create* by the end of their final building day. Here, we give a general overview of how this group participated in the feedback day; below we look in detail at the emergence and development of the two feedback-focused tensions that dominated their discourse.

Overview of the episode

The focal group was comprised of three students: Nate, Kevin, and Amanda. All three were strong students who were confident in sharing and defending their own design ideas. They had a reputation for taking charge; the paraprofessional educator in this classroom described the group on this day as "three alphas." The three students also had frequent disagreements on the building days of this design challenge prior to this feedback day.

The focal group was assigned to review a playground design to consider whether the criteria set by the design challenge (accessibility, safety, fun and stability) was met by the model design. The reviewed design was created by a group of girls who, at the end of the previous building day, deconstructed their design artifact following an argument (Figure 4, note changes between images). As a result, there was very little of the design present for the focus group to review. The research team members, including the second author who facilitated this lesson, were unaware of how little of the design was available for the feedback session.

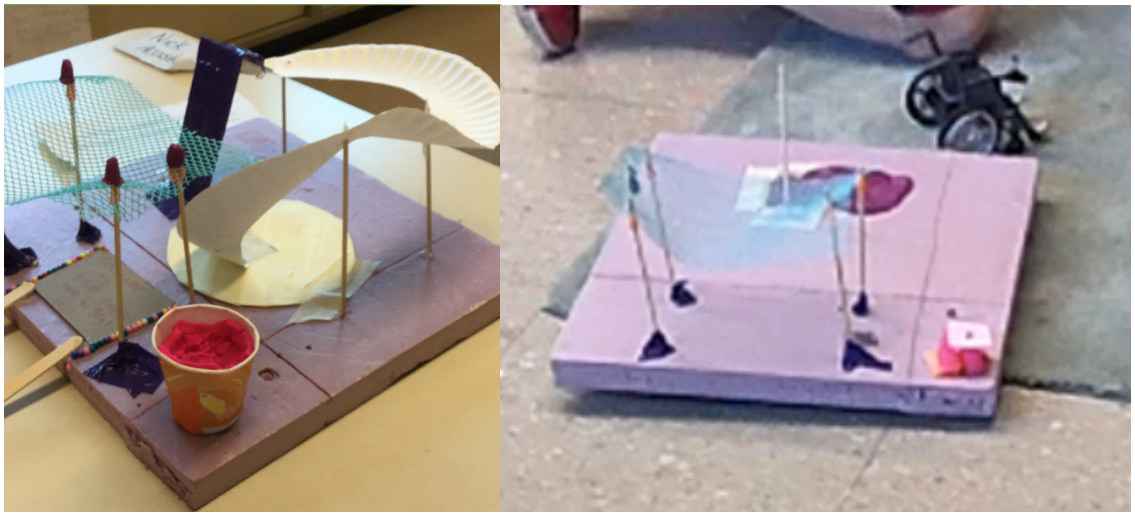

Figure 4. Photograph of the reviewed design the day before the feedback session, taken from the group's design notebook (Left) and photograph of the current state of that design Nate, Kevin, and Amanda provided feedback on during the feedback session (Right).

As might be expected, given that there were few fully constructed pieces on the target team's prototype, Nate, Kevin, and Amanda all expressed uncertainty about what the pieces represented in terms of a playground. For example, within the first few minutes of the students encountering and attempting to complete the feedback form, Amanda questioned Nate's statement that "the design is fun" by asking him "what the design even is." Nate then changed his response about the fun criterion. Kevin, too, said at first that the design was not accessible as, in his words, "there is nothing to access." Later in the feedback session, the students attempted to understand the prototype by asking the target group what their design was.

In addition to expressing uncertainty about what the prototype represented, the students also explicitly stated negative opinions about the design at various points during their feedback episode. This included statements that the design was "not good" (Nate), not fun (Amanda), and not impressive: "How is this impressive?" (Amanda). Kevin was most consistent in his critique of the design and stated that the design was not stable, fun, or accessible.

Despite the fact that all three students made negative comments about this design during the episode, they still argued about how to fill out the feedback sheet. Their fundamental disagreement was over how positive or negative their responses should be, particularly on the first half of the form, concerning the physical design (Figure 2). This argument became intense, with the students speaking loudly over each other, using accusatory language and tones, and displaying large dramatic gestures. Researchers and the classroom's paraprofessional who noticed the group's difficulties came by and sat with the group for short periods to both calm the students and help them sort through the disciplinary difficulties they were facing in productively evaluating the design and giving feedback. Despite the interventions by adults in the room, the students remained upset with each other: at one point Kevin appeared close to tears and took the paraprofessional's offer to go to the bathroom to regroup and later Amanda openly cried after Nate complained to a teacher about something she did.

This group's argument centered around what to write on the feedback form for the other team. From the very beginning, the teammates took opposing positions. For example, when discussing the first prompt, "Is it accessible?", Nate offered "it's decent" and Kevin countered, "No it's not! There is nothing to access!" Throughout the feedback session, Nate was consistent in his desire to not be, in his words, "rude." Kevin, on the other hand, was concerned with telling the "truth" about what they think of the other group's design. Amanda was more neutral at the beginning and took responsibility of writing the groups responses on the feedback form. However, Amanda later aligned herself more with Nate's position as she encountered difficulty in filling out the sheet. She argued that the group needed to focus on what the team *could* have made. Over the course of the argument, the group changed their initial circled answers to the first half of the form to more positive responses (that is, from two "no's" to a "maybe" and a "yes") and were more positive in their free response answers.

As mentioned above, we have identified two tensions that polarized the students and resulted in intense disagreements between the students. Below, we present and analyze each of the two tensions in turn, providing representative excerpts chronologically for each tension. (Note that the excerpts are presented chronologically within each section; some excerpts given for Tension 2 occurred between excerpts in the section for Tension 1).

Tension 1: Honest vs. kind feedback

We first present five excerpts from the feedback session that illustrate how students expressed and dealt with the tension of whether to tell the truth or to not be "rude." We present these excerpts chronologically and explore the emergence and development of the tension experienced by the students.

Excerpt 1: "You're being rude"

Within the first few minutes of arriving at the other team's design and beginning to fill out the feedback form, Nate accused his teammates of being "rude." As mentioned earlier, the students' initial reactions to the playground design were of uncertainty about what the design is and what in it they can critique. This uncertainty with the design itself caused Amanda and Kevin to laugh between each other when trying to respond to the question, "Does the design look fun?" While this laughter could be interpreted as nervous laughter stemming from their feeling awkward and uncomfortable with their task, it caused Nate to accuse his teammates of rudeness:

Amanda: *Does it look (laughing) fun?*
Kevin: *(laughing) No it does not.*
Amanda: *No (laughing).*
Nate: *[Looks at Amanda] You're being rude.*
*Note square brackets include the non-verbal actions of participants

This was the first of many times that Nate used the word "rude" during this episode. In this instance, Nate used the word "rude" to express his dislike of what he saw as his teammates' making fun of the target group's playground design. Here, Nate took the position that any laughter over someone else's design could be interpreted as an attempt to mock the design itself, and is therefore rude.

Excerpt 2: "Rude" feedback form responses

Throughout the feedback session, Nate accused his teammates of being "rude" in the way they talked about the other group's design, as when they laughed while discussing the design (Excerpt 1). It later became clear that Nate's definition of "rude" behavior extended beyond the way the design was discussed. The following excerpt comes just after Nate noticed how his teammates, particularly Amanda, filled out the multiple choice part of the feedback form. Nate objected to the responses Amanda had circled ("Maybe", "Maybe", "No", "No", to prompts in Figure 2) and asserted that they were "rude":

Nate: *[pointing to top of sheet] Why are you being so rude up here? That is rude*
Kevin: *No it's not we can write whatever we want*
--Brief conversation with students from the other group--
Amanda: *[Reading from sheet] Can you tell what steps they took while (pause) designing*
Nate: *[pointing at sheet] This is soo //rude]*

Kevin: *//Noo] //No we cannot]*
Nate: *//Why are you doing that]*
Nate: *[pointing at sheet] You guys are rude to them [reading from sheet] Maybe, maybe, no, no [Moves hand away from sheet] Heck.*

*Note that text enclosed between "//" and "]" denotes overlapping speech

Nate used the word "rude" three times to describe his teammates' responses to the first four multiple choice questions: "Why are you being so rude up here?", "This is soo rude," and "You guys are rude to them." To Nate, the responses-- two maybe's and two no's--were inherently "rude" as they communicated that the design failed to meet any of the design criteria. (Note the students later changed the two "no" responses to a "yes" and "maybe." Figure 2 shows the final responses.) Nate extended his critique of the responses by also accusing his teammates of acting rude towards the team who has made the design: "you guys are rude to them."

Nate's desire to have positive responses on the form is further illustrated in the following excerpt where Nate's objection to the earlier responses prompted his teammates to return to the questions, "Is it stable?" and "Does it look fun?"

Amanda: *Is it stable? //Yes]*
Kevin: *//Does] it look fun. No it does not.*
Amanda: *Maybe.*
Kevin: *[Looks up at Amanda] No it's not fun.*
Nate: *[Looks right at Kevin] Finally, some niceness.*

As the students read these questions aloud in order to elicit their teammates' opinions on them, Amanda changed the two "no" responses to a "yes" and a "maybe" (Figure 2). These revisions by Amanda caused Nate to remark that there was "finally some niceness." These two excerpts help make clear that Nate was primarily concerned with the overall tone of the feedback form, which to him needed to include more positive than negative responses.

We note that Nate's sole complaint in these excerpts was that his teammates were being "rude." He did not comment on whether he felt their responses were accurate reflections of the design. There may be multiple reasons why Nate was so focused on his teammates' apparent rudeness. For example, he may have viewed their behavior as so abhorrent that it needed to be addressed immediately, before he was willing to fully engage in the feedback task. In this interpretation, Nate's aversion to rude behavior may not be tightly linked to the actual feedback task. He may have felt that it is always improper to laugh at another classmate's work, even if the classmates will never know you laughed at them. Another interpretation could be that Nate felt that throughout the feedback process, it is important to consider the other team's feelings. That is, being nice is a critical part of evaluating another design and generating feedback. At this point in their discussion, it is not clear if Nate's focus on his teammates' "rude" behavior and responses (whether or not they are objectively "rude") was important to him for reasons specific to the feedback task-- because being "nice" is an important part of generating productive feedback--or if it was only important in a general sense--that there is never a reason to be "rude."

Similarly, at this point it is unclear if Kevin and Amanda see their behaviors and actions as being rude and think it is justified (for any reason), or if they do not interpret their actions as rude at all.

Excerpt 3: "Why is the option *no* there?"

The above excerpts show Nate's characterization of "rude" behavior and responses when giving feedback: being "rude" means laughing at the design and providing negative responses (an abundance of "no" and "maybe") on the feedback form. Kevin did not share Nate's concern and seems to be focused on answering the questions to accurately reflect his opinion of the design. Above, Kevin disagreed with Nate, stating that it does not "look fun" and that "we cannot" tell what steps they took while designing. In the following excerpt, Kevin gave part of his justification for selecting "no" on the feedback form.

Kevin:	*I was writing (pause), you won't let me do anything/ you're just writing whatever you want.*
Nate:	*[pointing at Kevin] Because you're being mean!*
Amanda:	*[Looks at researcher] Kevin keeps saying about their group and-*
Nate:	*(interrupting) // Because he is saying it's boring. You're saying it's boring]*
Kevin:	*(interrupting) // I am not saying anything]*
Amanda:	*// we're telling him to stop because he keeps saying it's boring and it's wrong and they don't like it. It's their design. He doesn't really know what it is.*
Kevin:	*This is a review. If they put the, if they put the option for the, if they put the option for no then why is it there? If we can't say no then why is the option no there?*
Nate:	*Because they're not, because they're just like, only if it's terrible. This is not terrible.*

By the time of this excerpt, with a researcher physically present in the group (after interpreting their yelling to mean they would benefit from an adult's presence), Amanda had aligned herself with Nate in criticizing Kevin's approach to the evaluation. Kevin complained that his opinions were not included in the form as he was not allowed to "do anything." Nate and Amanda attempted to justify excluding Kevin because he was "saying it's boring," a claim Kevin refuted.

Kevin invoked the authority of the form to make his argument for choosing "no" by pointing out that because "they" (those who created the form) included "no" as an option for teams to circle, teams should be able to choose the "option no" during their evaluation. Nate countered that the option "no" is "only if it's terrible," and this design, in his opinion, does not qualify as terrible. Perhaps, Nate believed that the option "no" represented a complete failure of a design to meet or potentially meet any of the requirements. Saying "no" could mean that a design is so bad that it cannot be improved upon to meet the criteria at all.

When Kevin argued "This is a review," he seemed to believe that his teammates viewed the design the same way he did (as not meeting the criteria), but they refused to fill out the form in a way that aligned with their view. Thus, he appealed to the task they were engaged in--a review--to argue that it was an appropriate time for them to point out deficiencies in the design.

It is unclear whether there was a true divergence in the way the three students viewed the design, or whether they all interpreted the design as not meeting any criteria but disagreed over how to fill out the form to reflect that interpretation. It is possible that Nate and Amanda were arguing for excluding Kevin and selecting more positive responses because they believed the design warranted it, but it is also possible that Nate and Amanda believed being nice (and/or being perceived as nice) was so important that they needed to identify (or, perhaps in Kevin's view, invent) some positive aspects of the design.

Excerpt 4: "Stop saying rude things"

In the previous excerpt, Nate and Amanda showed resistance to circling "no" on the form. They saw it as insensitive to the other group. In Amanda's words, "they (the students in the other group) don't like it." Amanda's and Nate's attempts to filter their responses on the feedback form soon extended to what they considered were acceptable things to say when reviewing a second group's design. The following excerpt is part of a larger discussion about the second team's idea to make an escalator, which was documented in their design notebook: "My other idea is to make a flat escalator so that the people that have a wheelchair won't need to do so much work" (Figure 5). There was nothing in the physical design on the feedback day that appears to correspond to the escalator idea, so Amanda, Nate, and Kevin evaluated the idea based solely on the documentation.

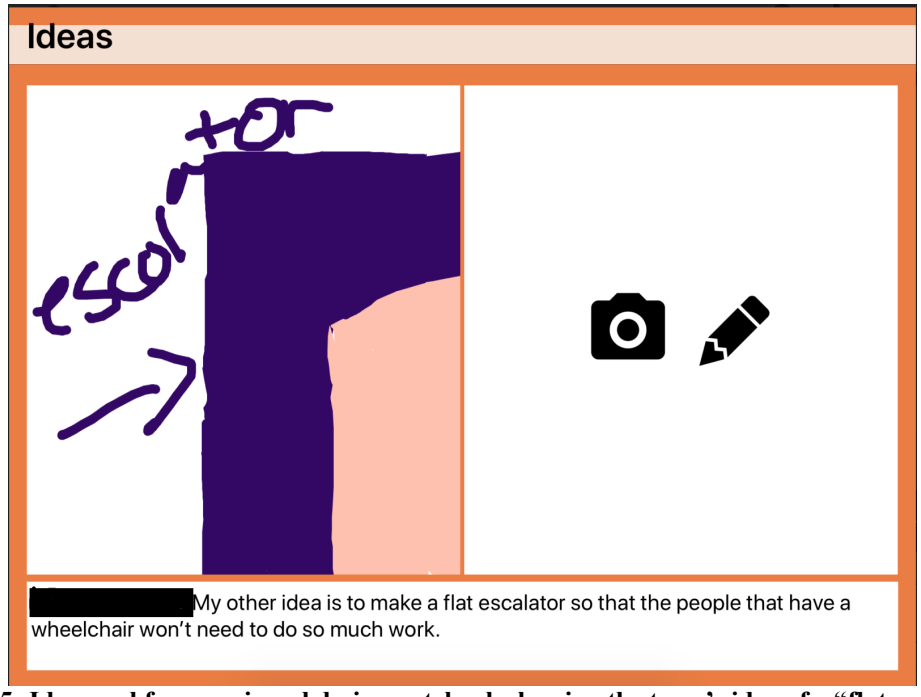

Figure 5: Idea card from reviewed design notebook showing the team's idea of a "flat escalator"

On the feedback form, in the section to give feedback on the documentation, Amanda responded to the free-response prompt of "A suggestion for improvement:" with "to make it a litue esery [little easier]" (Figure 3). Amanda implied that she approved of the escalator idea but conceded that it would be difficult to make. The following excerpt begins with the researcher making a move to draw attention back to the form and away from complaints about Kevin.

Researcher: *What did you write here [pointing to form]?*
Amanda: *[paraphrasing her response on the form, Figure 3] What if you make it a little bit easier - like because they tried to make like an escalator to like get them up to things*
Nate: *But that's good*
Kevin: *But how are they even supposed to get up the escalator?*
Nate: *By the escalator (inaudible)*
Kevin: *Yeah but it's like a full - it's a full [holds arm vertically]*
--Omitted: Researcher helps define 90 degree angle for Kevin--
Kevin: *Aaaa so this is like 90 degrees. This is 90 then how are they suppose to get up. Are they suppose to climb?*
Nate: *Nooo - the thing oooo [shakes head]*
Researcher: *So-*
Amanda: *Kevin stop saying rude things about their-*
Kevin: *I am not saying rude things.*
Nate: *You're saying then they can't get on that.*

After Amanda clarified her suggestion to the researcher, Nate immediately responded with, "But that's good," as if the escalator did not need improvement and therefore should not be referenced in that space. Kevin then argued that the escalator was not a good idea since it was vertical and therefore unusable by someone in a wheelchair. Nate and Amanda did not acknowledge Kevin's reasoning as a legitimate critique and characterized his line of reasoning as "rude." It is hard to tell if Nate and Amanda were suggesting that focusing on aspects of the design that seem non-functional is inappropriate, or if they were instead upset about the way Kevin was describing the design. Whether they were responding to the content or delivery of Kevin's points, instead of engaging in a discussion over the functionality of the escalator idea or what advice to give the other team, they used the accusation of "saying rude things" to shut down Kevin's responses.

On the other hand, Kevin never acknowledged that the tone he used, and the choice of phrasing, such as, "Are they supposed to climb?", could be interpreted as ridicule, and not an impassioned and frustrated plea for his teammates to accurately give feedback.

<u>Excerpt 5: Kevin advocates to "tell the truth"</u>

At this point, Kevin was very frustrated with Nate and Amanda and their constant accusations of rudeness, refusing to consider his (valid to him) points about the deficiencies of the design. The refusal of his teammates to include any negative feedback in their form led Kevin to raise a passionate objection to their approach, where he forcefully advocated that it is "better to tell the truth":

Kevin: *Guys you know it's actually better to tell the truth about what you think about it and not just lie.*
Amanda: *// We're not lying!]*
Nate: *// We're not lying!] Jinx.*
Kevin: *Well you won't let me do anything.*

Amanda:	*Kevin we're not lying we just told you to do stuff and you're saying rude - you're saying rude things about them.*
Nate:	*Why are you being rude? (gesturing with palms up towards paper or model)*
Kevin:	*If this is an option then why won't you let (inaudible)*
Nate:	*[Looking in researcher's direction] Why are you being rude?*
Amanda:	*Because we don't think no. Because we don't-*
Nate:	*How about we put this so they won't get mad?*
Kevin:	*So yes yes yes to everything. Oh no (inaudible)*
Nate:	*That's not yes yes yes yes yes!*
Kevin:	*You just want them to think everything is perfect!*

Kevin voiced what he thought was problematic about his teammates' approach to privilege the "niceness" of their responses and reluctance to saying "no" on the form. He argued that by refraining from saying "no" and preventing him from including his opinions, his teammates were being dishonest in the form about what they actually thought. He exaggerated that his teammates wanted to say "yes" to everything and wanted the other team to think that everything was "perfect." His teammates disagreed with Kevin's assessment of their responses. Nate and Amanda responded in two different ways to Kevin's accusations: Nate emphasized that they needed to express their responses so that the other students didn't "get mad" at them, while Amanda insisted that the decision to not say "no" was reflective of what they actually thought: "Because we don't think no. Because we don't."

Tension 2: Analyze current vs. potential design

In this section we explore the second tension this team experiences as they generate feedback, between critiquing what is currently constructed versus what we will call in this study the potential design. The potential design includes considerations around (1) what is possible for the group to make, and (2) what the idea behind the design is (that is yet to be expressed). This tension of current versus potential design emerges as the students move to the part of the feedback form that focuses on critiquing the design notebooks (Figure 3). In what follows we discuss three excerpts that illustrate the two main considerations raised by the students.

Excerpt 6: Could they have made the escalator?

The following excerpt occured right after the students move to the second half of the feedback form and focus on the question, "Can you tell what didn't work and changes they made?" It begins with Amanda referring to an Ideas card on the other group's digital design notebook. She asked her teammates if they think the other group actually made the "escalator" that is included as an idea in the notebook (Figure 5), which prompted the team to mention for the first time that the design may be incomplete.

Amanda:	*[looks down at iPad] Do you think they made - do you really think that they made (pause) *that* (points to iPad screen, looks up at Kevin)*
Kevin:	*[Looks down at iPad] Escalator?!*
Nate:	*//Yes they did]*

Amanda: *//No, they didn't. They didn't]*
Nate: *No, they are probably still working on it*
Kevin: *They can't make that escalator*
Nate: *They can, they don't have time*

In his three turns of talk, Nate's responses to Amanda's question evolved from "yes they did," to "they are probably still working on it," to "They can, they don't have time." The way Nate so quickly attempted three different arguments to counter Kevin and Amanda's criticisms of the design gives the appearance that Nate was grasping at straws to come up with anything to defend the other team's work. However, Nate did raise two valid points: (1) this is a mid-design feedback session, so the designers may still be working on some parts of the design, and (2) there is an externally imposed time constraint on the challenge, which limits what the team is able to create. When Kevin claimed, "They can't make that escalator," he could have been considering the limited time, the limited construction materials, or the other team's construction skills. Thus, Kevin may have been critiquing the students' inability to do the design task within the given constraints.

Here the students experienced a tension in giving feedback on the design notebook: should they evaluate what they think can be practically done (Kevin's position) or what the group can potentially do (Nate's position)?

Excerpt 7: Critiquing the current design or a potential future design

This excerpt also illustrates Nate's and Amanda's stance that it is important to view the design process as ongoing and leave room for doubt before negatively judging an idea. The conversation happened after the researcher encouraged the three students to consider how the other group had recorded information in their notebook. (Note this conversation happens between Excerpts 4 and 5).

Nate: *I don't think they even finished yet so Kevin*
Researcher: *Ohhh, okay but the parts they do have*
Nate: *Like we still have one more day. We have one more day to do it so they probably didn't finish [looks at Kevin]*
--Amanda does some out loud thinking about the design notebook--
Nate: *What if tomorrow it's awesome?*

In this excerpt, Nate argued against Kevin being critical about the design (Excerpt 4) since the group still had one more day to work on their design. Despite the researcher's comment to focus on what parts of the design the group had made, Nate insisted that negative judgement be suspended as the group "probably didn't finish." His concern for what the group could potentially accomplish on the final building day was reflected in his next comment, "What if tomorrow it's awesome?" In these turns, Nate further developed his stance that his team should hesitate to give negative feedback because the design they're reviewing was still in progress. The tension between judging a design as it currently stands and what it could become after more time to design is understandable and likely common during mid-design feedback sessions.

Excerpt 8: Ideas in their mind

The following excerpt is from a conversation immediately Excerpt 5, when Kevin accused his teammates of lying by circling "yes" on the form. Here, Amanda presented another reason for not being critical of the other groups design, that they do not know what the other group is thinking:

Kevin:	*You just want them to think everything is perfect*
Amanda:	*Is it accessible? Maybe cause //we don't know what they're building yet. We haven't seen their finished design so we don't know what they are building]*
Nate:	*//How about you stop being rude. How about you stop thinking this is (inaudible) [looks at Kevin]]*
Nate:	*Yeah if we knew what they were building then you could*
Amanda:	*So maybe it is accessible we don't know what they are building. They have their own creative stuff in their mind of //what they are going to build and we]*
Nate:	*//What if they think ours is bo...] Would you like if they thought ours was boring. Would you like that?*

Amanda claimed that the group does not know enough about what the other group was building to be critical of the design. She argued that since they did not know "what they [the other group] are building" there was a possibility it was accessible and hence their answer should reflect that uncertainty (be a "maybe" instead of a "no"). Amanda also invoked the other team's potential ideas that may not have been expressed: "They have their own creative stuff in their mind." While it may be worthwhile to give a team the benefit of the doubt while generating feedback, it is easy to see how this argument could quickly become a slippery slope: if teams need to take into account the "creative stuff in their mind," of which there is no documented evidence, can teams ever give any negative feedback? Nate was aligned with Amanda, but for a different reason: he did not want to hurt the feelings of the other group ("would you like that?").

Table 1: Summary of dilemmas related to the two tensions

Tension	Related Dilemmas
1. Honest vs. Kind	• What does it mean to be "rude" when giving feedback? (Excerpts 1, 2, 4) • When is it acceptable to negatively critique a design when a criteria is not met? (Excerpt 3) • Is it dishonest to withhold negative criticisms about another group's design in the interest of being kind? (Excerpt 5)
2. Current vs. Potential Design	• Should feedback privilege what has already been physically expressed, or what designers may be able to do by the end of the designing time? (Excerpts 6, 7) • Should feedback consider only physically expressed ideas or take into account that not all ideas may have been properly expressed, understood, or executed? (Excerpts 7, 8)

Discussion

We treat Kevin, Amanda, and Nate's case as an extreme case (Yin, 2009) that can help researchers and practitioners better understand the demands of engaging students in generating feedback in engineering. The intense disagreements between this focal team while giving mid-design feedback helps make explicit some of the underlying tensions that elementary student might experience during the peer feedback process. This team in particular struggled with the perception that they must choose between being honest and being kind and between evaluating the current design and its future potential form. We argue that the dilemmas posed by the two tensions are valuable to the students' developing understandings of what it means to give feedback.

Tension 1: Honest vs. kind feedback

The first tension experienced by this team, a perceived forced choice between being honest and not being "rude," provided an opportunity for these students to evaluate and revise their responses on the feedback form in light of how it would come across to the receiving team. This process of constant reflection provided opportunities for the team to wrestle with dilemmas (Table 1) that are important to the practice of generating good feedback.

Of course, while Amanda, Nate, and Kevin experienced a tension between honesty and kindness during this feedback session, they are not two ends of a spectrum--good feedback should incorporate both elements. That is, this team does not need to choose between these goals, but ideally should find a way to present honest feedback in a way that is not "rude," such that the receiving team is open to the feedback.

The desire to not give negative feedback to peers, expressed by both Nate and Amanda, is common, even at the undergraduate level (Nilson, 2010). Nate's insistence on his team not being rude demonstrates "empathetic concern" for the feelings of the other team, the students whose design they are evaluating. "Empathetic concern" in feedback has been shown to increase the likelihood that the recipient responds positively to it (Yong, 2017). We see the students' concern for the social repercussions of their feedback form as valuable to their developing understandings of how to give good feedback. At the same time, Nate's unwavering desire to not appear rude at times prevents his team from having substantive discussions about the functionality of the design under consideration. Kevin consistently brings up issues with the design and is nearly always met with claims of rudeness, rather than a healthy debate.

The other side of the perceived tension, supported by Kevin, is honesty. Honesty, in Kevin's view, involves letting other teams know when their design does not meet the established criteria, by circling "no" when appropriate on the feedback form.

Generating good feedback involves giving an accurate assessment of the other team's product and doing so in an empathetic way, to ensure that the other team is willing to listen to the feedback. Thus, these issues are a productive debate for a student team. However, this group does not seek to understand each other's positions well enough to negotiate between them; instead they accuse each other of being "rude" or "lying". This group appears to need support for

effective group collaboration. In particular, they would likely benefit from learning how to engage in "heedful interrelating," attending to how one's actions affect functioning of a group when working on a joint task and sensitivity to the task at hand (Jordan & Daniel, 2010). Two aspects of heedful interrelating in particular that would likely be productive for this group are: "Avoid assuming what group members are thinking" and "Ask others to clarify or probe at their ideas" (Jordan & Daniel, 2010). By seeking to understand and acknowledging the merits of each other's positions they could have realized that the two positions were not at odds and shifted to attempting to meet both goals simultaneously by generating feedback that was both honest and kind.

Even though these students were not completely successful in dealing with the tension between being honest or kind, their efforts to empathize with the other group, be mindful of their own responses, and wrestle with their own beliefs about the design indicate the potential of students to engage in deeper reasoning around the challenges of giving feedback in real life.

Tension 2: Analyze current vs. potential design

The second tension that emerged for the students -- evaluating the current vs. a potential design -- was closely linked to the first tension, being kind vs. being honest. As Amanda and Nate were so deeply invested in generating feedback they deemed to be not "rude," they needed to identify positive aspects of the design, or at least justifications for why the design did not appear to satisfy the criteria. As a result, Amanda and Nate focused on the potential design, what the design could be in the future or the design that the creators imagined but were not able to successfully express.

Giving good feedback in engineering often includes taking into account feasibility of a design, intentions of designers, and challenges and affordances of a model's realization in real life. We see the students' considerations of the potential of the design as valuable to their learning to give good feedback.

In this study, the students raised competing concerns that stemmed from differing perspectives on what to privilege when giving feedback. While the students struggled to negotiate their different perspectives when evaluating the design, the concerns they raised are productive beginnings for deeper engagement with the decision making process of giving feedback. The failure of these students to productively balance the tensions of giving feedback may be attributed to their difficulties in collaborating. Learning to balance varying perspectives around what to consider when critiquing designs in particular contexts is an important part of giving good feedback. Engaging students in the *process* of balancing these perspectives provides opportunities for students to develop deeper understandings about the complexity of giving feedback; students may learn to situate their feedback within the social, temporal, and physical aspects of the design in question.

Limitations

This case study considers only one specific design task, which resulted in solutions that were overall more representational than functional. It is reasonable to expect that certain design tasks

might be more likely to lead to certain tensions while teams are generating feedback. For example, another tension that may arise in a different context include criteria trade-offs where students may argue which criteria is more important to the critique of a design. We chose in this study to focus on the tensions themselves that this team faced, and not on how or why these tensions arose. For example, while we expect that the particularities of the feedback form given to students affected how they generated feedback and the resulting discussions, we are not interested in assigning causality to any particular variable in the case and instead look holistically at the context in which the students are engaging in the feedback process. We did not attempt to account for all of the affective and social dynamics at play. For example, it is possible that some of the students in this team have more social capital in the class, and that as a result their arguments carried more weight.

Conclusion

We argue that even though the students struggled to deal with the tensions they experienced while giving mid-design feedback to their peers, the tensions presented opportunities to develop deeper understandings about the process of generating feedback. These included understandings about balancing empathy with honesty and balancing evaluation based on the current status of a design and its potential future form. We take the stance that students do not always need to be sheltered from experiencing frustrations as they can be productive (Jaber & Hammer, 2016b) for students' developing understandings of how to give good feedback. However, more research is needed to understand how best to facilitate student encounters with the tensions of giving feedback in engineering. Future research could focus on how best to facilitate collaboration between students when engaging in joint critique of engineering designs.

We have used the extreme case of Amanda, Kevin, and Nate to analyze two tensions experienced by elementary students while giving engineering design feedback. We anticipate that other tensions will arise in other contexts with different social dynamics and different engineering design artifacts, and more research is needed to characterize additional tensions. Such work would refine this study's implications about the support elementary engineering students need to generate useful but empathetic feedback, make sense of prompts for different kinds of feedback, and navigate the social and emotional challenges of giving good feedback.

Acknowledgements

This work was supported by National Science Foundation grant number 1657218. We are grateful to the collaborating classroom teachers and student participants. We acknowledge the support of the Tufts University Center for Engineering Education and Outreach.

References

Adams, R. S., & Siddiqui, J. A. (Eds.). (2015). *Analyzing design review conversations*. West Lafayette, Indiana: Purdue University Press.

Butler, R. (1987). Task-involving and ego-involving properties of evaluation: Effects of different feedback conditions on motivational perceptions, interest, and performance. *Journal of educational psychology*, *79*(4), 474.

Carlson, P.A., F. C. Berry and D. Voltmer, (2005). *Proceedings Frontiers in Education 35th Annual Conference*: Incorporating student peer-review into an introduction to engineering design course. Indianapolis, IN, pp. F2C-20.

Dalvi, T., Wendell, K. B., & Johnson, J. (2016). Community-based engineering: Experiences from a 2nd grade urban classroom. *Young Children, 71*(5), 8-15.

Darling, A. L., & Dannels, D. P. (2003). Practicing engineers talk about the importance of talk: A report on the role of oral communication in the workplace. *Communication Education, 52*(1), 1–16.

Eisenhart, M. (2009). Generalization from qualitative inquiry. In Generalizing from educational research (pp. 61-76). Routledge.

Engestrom, Y. (1999). Activity theory and individual and social transformation. In Y. Engestrom, R. Miettinen & R.-L. Punamaki (Eds.), *Perspectives on activity theory*. (pp. 19-38). Cambridge: Cambridge University Press.

Erickson, F. (1986). Qualitative methods. In M. Wittrock (Ed.), Handbook of research on teaching (pp. 119–161). New York: Macmillan.

Flyvbjerg, B. (2006). Five Misunderstandings About Case-Study Research. Qualitative Inquiry, 12(2), 219–245

Gee, J. P., & Green, J. L. (1998). Chapter 4: Discourse analysis, learning, and social practice: A methodological study. *Review of research in education*, 23(1), 119-169.

Geertz, C. (1973). The interpretation of cultures (Vol. 5019). Basic books.

Hersam, M. C., Luna, M. and Light, G. (2004), Implementation of Interdisciplinary Group Learning and Peer Assessment in a Nanotechnology Engineering Course. *Journal of Engineering Education*, 93, 49-57.

Jaber, L. Z. & Hammer, D (2016a). Learning to Feel Like a Scientist. *Science Education,* 100(2), 189 -220.

Jaber, L. Z., & Hammer, D. (2016b). Engaging in science: A feeling for the discipline. *Journal of the Learning Sciences*, *25*(2), 156-202.

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The Journal of the learning sciences*, 4(1), 39-103.

Jordan, M. E. (2014a). Exploring how design critique processes shape fifth graders' peer interaction in collaborative engineering projects: 121st ASEE Annual Conference and Exposition. American Society for Engineering Education.

Jordan, M. E. (2014b). *Influence of public design critiques on fifth graders collaborative engineering design work.* Boulder, CO: International Society of the Learning Sciences.

Jordan M. E. & Austin B. S. (2013). Communication in Creative Collaborations: The Challenges of Uncertainty and Desire Related to Task, Identity, and Relational Goals. *Communication Education*, 62 (2), 210-232.

Jordan, M. E. & Daniel, S. R. (2010) Heedful Interrelating in the Academic Discourse of Collaborative Groups. *The Journal of Classroom Interaction*. 45(2), 4-19.

Jordan, M. E., & McDaniel Jr, R. R. (2014). Managing uncertainty during collaborative problem solving in elementary school teams: The role of peer influence in robotics engineering activity. *Journal of the Learning Sciences*, *23*(4), 490-536.

Kafai, Y. B., & Muir Welsh, K. A., (2007). Evaluating students' multimedia science design projects in the elementary classroom. In R. Pintó and D. Couso (Eds.), *Contributions from Science Education Research*, pp. 435-449. Springer.

Kollar, I., & Fischer, F. (2010). Peer assessment as collaborative learning: A cognitive perspective. *Learning and Instruction*, *20*(4), 344-348.

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., S. Puntambekar, & M. Ryan, (2003). Problem-Based Learning meets Case-Based Reasoning in the middle-school science classroom: putting Learning by Design(TM) into practice. *Journal of the Learning Sciences*, 12(4), 495–547. http://doi.org/10.1207/S15327809JLS1204_2

Lave, J., Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Linda B. Nilson (2003) Improving Student Peer Feedback. *College Teaching*, 51(1), 34-38.

Merriam, S. B. (1998). Qualitative research and case study applications in education.

Nilson, Linda B. (2003). Improving Student Peer Feedback. *College Teaching*, 51(1), 34-38.

Ohland, M. W., Layton, R. A., Loughry, M. L. and Yuhasz, A. G. (2005), Effects of Behavioral Anchors on Peer Evaluation Reliability. *Journal of Engineering Education*, 94(3), 319-326.

Sivan, A., (2000) "The Implementation of Peer Assessment: An Action Research Approach," *Assessment in Education: Principles, Policy & Practice*, 7(2), 193-213.

Topping K. (2003) Self and Peer Assessment in School and University: Reliability, Validity and Utility. In: Segers M., Dochy F., Cascallar E. (eds) Optimising New Modes of Assessment: In Search of Qualities and Standards. Innovation and Change in Professional Education, vol 1. Springer, Dordrecht

Topping, K.J., (2009) Peer Assessment. *Theory Into Practice*, 48(1), 20-27.

Vinck, D. (2003). Everyday engineering: An ethnography of design and innovation. MIT Press, 13-27.

Wendell, K. B., Andrews, C. J., & Paugh, P. (2019, Online Early View). Supporting knowledge construction in elementary engineering design. *Science Education*.

Wright, C. G. (2016). Constructing a collaborative critique-learning environment for exploring science through improvisational performance. *Urban Education*.

Yilmaz, S., & Daly, S. R. (2016). Feedback in concept development: Comparing design disciplines. *Design Studies*, 45, 137-158.

Yin, R. K. (2009). Case study research: Design and methods. Sage publications.

Young, S. F., Richard, E. M., Moukarzel, G. R., Steelman, L. A. & Gentry, W. A. (2017). How empathic concern helps leaders in providing negative feedback: A two-study examination. *Journal of occupational and organizational psychology*, 90 (4), 535-558.

McGourty, J., & DeMeuse, K. P. (2000). *The Team Developer: A Skill Building and Feedback Program. NY: Wiley.*