Engineering Design as Disciplinary Discourse: An Exploration of Language Demands and Resources among Urban Elementary Students

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Engineering design is a social practice that has developed discipline-specific ways of "knowing, doing, talking, reading, and writing," or what Gee (1996) refers to as disciplinary Discourses. These specific ways of thinking and communicating make it possible for engineers to engage with each other in *reflective decision-making*, a cornerstone of engineering design (National Research Council, 2012). In the *planning* phase of engineering design in particular, engineers' disciplinary Discourses enable their reflective decision-making for proposing, evaluating, and choosing design proposals.

In the K-12 school context, the practice of collaborative engineering design has the capacity to be both "discourse enabling and discourse dependent" for students (Moje et al., 2001). In other words, engineering has the potential to support and elevate students' disciplinary language development, but at the same time it may demand language competencies that students are not typically asked to exhibit. In this paper, we explore the idea of young students' engineering design Discourse within two urban elementary schools, one in the eastern United States and one in the southern United States. Urban classrooms were chosen for this project in order to challenge the "deficit perspective" (Varelas et al., 2011) that is often used when studying urban students or urban education outcomes. This perspective can lead schools to focus on direct instruction of language forms and functions, rather than rich opportunities to use language to engage in practices. In this project we position engineering design as an opportunity for urban elementary school students to "do things with language" (Lee et al., 2013), and we adopt a "resources perspective" (Warren et al., 2001) to answer the question: *what discursive resources do urban elementary school students bring in response to the disciplinary discourse demands of engineering planning, and what challenges do they face in meeting those demands?*

Reflective Decision-Making in Elementary Engineering

Reflective decision making in any profession involves taking stock of what has happened, analyzing options, and moving forward (Schön, 1983). Reflective decision-making (RDM) is one of a number of social practices nested within, and essential to, the larger socially constructed practice of engineering design (Crismond & Adams, 2012; NRC, 2012; Wendell, 2014; Wendell, Wright, & Paugh, 2015). As a social *practice*, RDM occurs both within and across different language *events* (Bloome et al., 2004). When participating in engineering language events, elementary students act and react to each other in the context of a task assigned to them: collaboratively creating a functional artifact or process that solves a problem.

Here, we examine students' practices of reflective decision-making during the beginning of a typical engineering design cycle. That is, we focus on students' planning a solution to pursue. Reflective decision making during engineering planning involves at least three aspects: (1) the articulation of multiple design options, (2) the consideration of pros and cons of various design options, and (3) the intentional choice of a solution to pursue.

We consider these as aspects of RDM because each requires the engineering team to make a different decision or set of decisions. The decisions to be made during engineering planning are (1) what solutions should we consider? (2) what is the likelihood that the possible solutions will be successful?? and (3) which solution is most likely to solve the problem optimally?

It is important to clarify that these RDM aspects do not specify a linear sequence. Although the three aspects of RDM during planning (and the associated decisions to be made) appear to be chronological, they can occur in different orders and be repeated multiple times. They might also be carried out by multiple individuals at the same time, by the group collectively, or by different individuals on a team at different times. For example, one individual on an engineering team might propose one possible solution, another individual might weigh its pros and cons, a third individual might propose two more solutions, the second person might make a bid to pursue one of those, while the first person considers more pros and cons, and the third returns to the drawing board and proposes more solutions, and so on.

Conceptualization of Urban Elementary Students and Engineering Discourse

There are a few important things to say about the context in which we are "making an inquiry" into discourse (Bloome et al., 2004). We are looking for engineering reflective decision-making during small-group design tasks in elementary school classrooms. We are interested in how multiple modalities interact within oral language events and how students are co-constructing meaning to solve an engineering design problem. We are not examining tasks assigned individually to students but rather tasks where two or more students are expected to produce a design solution (or a plan for a design solution) collectively. Language events can feature different modes of communication including oral, written, graphical, and electronic modes. In this paper we are analyzing interactions primarily featuring oral discussion among elementary students (supported at times by adult interaction) enhanced by writing, drawing, electronic media, and contextualization cues (e.g., gestures, volume shifts, distancing).

The classrooms on which we focus are urban. For us, the term "urban classroom" signifies a racially heterogeneous public school classroom comprised of students who live in the city, have diverse cultural affiliations, often reside in homes where multiple languages are spoken, and predominantly come from low socioeconomic backgrounds. We locate our work in urban classrooms because much of the K-12 engineering popularized in the media takes place in more culturally homogeneous and more socioeconomically advantaged settings. We wish to illuminate the ways in which youth from urban communities engage in the talking, writing, thinking, and doing of engineering design (Moje et al., 2001) in order to broaden the available characterizations of kids doing engineering.

Intertextuality as a Tool for Discourse Analysis

Intertextuality is the juxtaposition of texts during the course of a language event (Bloome et al., 2004). It happens when someone proposes a connection from a current text to a prior or future one, and others participating in the language event take up that connection (Bloome et al., 2004; Varelas, Pappas, & Rife, 2006). Using ideas from Pappas, Varelas, and Rife (2006), who draw upon Wells (1990), we define "text" expansively to include not only written representations of meaning but also oral narratives and discussions, recounts of events, drawings and videos, online media, and shared hands-on explorations. Inspired by Pappas et al.'s typology of intertextuality in an urban elementary science classroom, we look for the relationship between language developed in classroom texts and the ideas created through activities in elementary school engineering.

Intertextuality, as a theoretical framework, presents an opportunity to highlight the potential value of what urban students bring to engineering from their homes and communities of practice. Because engineering design problem solving differs epistemologically from typical direct instruction school tasks, engineering may allow space for urban elementary students to bring resources to school that might not otherwise be valued. By utilizing an intertextual lens for examining the links that students make to and from the "texts" of engineering, researchers and teachers can be better positioned to identify those resources. Research shows that in urban classrooms in particular, children's home and community experiences tend to have unrecognized academic value (Bang et al., 2013; Hudicourt-Barnes, 2003); intertextuality may support researchers and educators in shifting perspectives on the usefulness of home and community connections.

We used the lens of intertextuality to investigate our research question, which we re-state here in three parts:

- What are disciplinary discourse demands for students to participate in engineering reflective decision-making? (By disciplinary discourse demands, we mean the language functions required to carry out the discipline of engineering and the reflective decision making nested within that discipline.)
- What resources do urban elementary students bring in response to those demands of reflective decision-making?
- What challenges do urban elementary students face in meeting the demands of reflective decision making?

Data Collection

Partnering with four elementary teachers in urban schools, we video recorded seven *Engineering is Elementary (EiE)* units at four different grade levels (water filters in 2nd grade, bridges in 3rd grade, circuits in 4th grade, and maglev vehicles, windmills, pollinators, and knee braces in 5th grade). The 2nd and 3rd grade teachers taught in the southern United States, and the 4th and 5th grade teachers taught in the northeastern United States. The student populations of the classrooms were culturally and racially diverse and had a high proportion (more than 50%) of students eligible for free or reduced lunch. Only students whose parents granted consent were included in data collection activities.

During each unit, we focused video recorders on two student groups chosen to provide variation in gender and ELL status. We also collected students' paper-and-pencil work on *EiE* handouts and images of their physical prototypes. After each unit, we reviewed the video footage and created a data set of video clips showing student-to-student interaction during the Imagine! and Plan! phases of the *EiE* units.

Analysis

After creating the video data set, we began microethnographic discourse analysis (Bloome et al., 2004; Snell, 2011) by identifying episodes of sustained student-to-student oral discourse that exhibited aspects of reflective decision making for engineering (for a discussion of these elements, see Wendell, Wright, & Paugh, 2015). The duration of an episode was defined by the length of time a student team remained focused on an activity or goal (Kittleson & Southerland, 2004). Sometimes this focus only lasted for two minutes; sometimes it was 20 minutes or even longer.

Next we conducted several rounds of inquiry into the reflective decision making episodes. The research team for these rounds consisted of two science and engineering education researchers and one literacy education researcher. To begin each round, the research team selected a video episode to review. Independently, research team members watched the episode and examined its transcript. Using open coding techniques, they made notes along three lines of analysis: intertextual links (Pappas, Varelas, & Rife, 2006), students' uptake of each other's ideas (Bahktin, 2; Jordan, 2014), and tiers of vocabulary (Beck & McKeown, 2002). The team then came together and discussed what these lines of analysis revealed about the students' engineering design discourse. Team members proposed claims about the language patterns demanded by the students' attempts at reflective decision-making and about the associated resources and challenges. The team looked for confirming and disconfirming evidence of the claims until consensus was reached on their validity. In this process of making claims and looking for confirming and disconfirming evidence, we followed the approach used by Cobb and colleagues in their design-based research on classroom microcultures (2001).

Findings

By using an intertextual lens to examine students' discourses during the planning phase of engineering design, we were able to identify not only the links students made from their design planning to other representations of meaning, but also the central text types that comprised those design planning conversations. As we looked for links students were connecting to prior or future texts, the *current* texts that students were co-constructing were brought into sharp relief. Across the video episodes, we found evidence of three common text types that students are expected to produce during engineering planning. It appears that with each aspect of reflective decision-making - i.e., each decision to be made – there is a set of language patterns demanded of elementary students as they work face to face to co-construct engineering design plans. Each set of language patterns serves a different purpose and therefore places different discourse demands on students. Likewise, students bring various resources and face various challenges in producing each set of language patterns or text type. Students are building language, building design ideas, and working to communicate those ideas to each other.

In our video data, three different text types with their own common language patterns emerged as students carried out different aspects of RDM during engineering planning: *design proposal* language to articulate multiple solutions to the stated problem; *design critique* language to evaluate pros and cons; and *design resolution* language to determine a solution to pursue. Below we attempt to characterize the demands, resources, and challenges associated with these three text types as they appeared among urban elementary students working on EiE design challenges.

(1) Discursive Patterns in Design Proposals

An early decision that engineering designers have to make is: what solutions should we consider to solve the design problem? The video data in our study show that when elementary students make this decision in a reflective way, they typically articulate multiple possible solutions by formulating several *design proposals*.

In engineering, a design proposal is a description of a hypothetical product or process that has the potential to meet the requirements of a design task. Design proposals are suggestions for what the engineering team should consider; they are not yet agreed-upon plans for what the team will pursue. To formulate a design proposal, one or more members of a design team describes the features of the hypothetical product or process and explains how those features will behave in order to solve the design problem or meet the task requirements. In other words, a design proposal specifies structures and functions (Gero & Kannengiesser, 2004). Depending on the nature of the engineering team and task and the stage of work, design proposals may be formal or informal. The language patterns associated with informal design proposals may be primarily oral in nature but may involve multiple modes of representation such as diagrams and physical materials. Design proposals are social constructions, which means that engineers have to develop shared understanding of the solutions under consideration. A design proposal is not simply one individual's description of a possible design solution. Rather, a design proposal emerges as a shared understanding in that individual's give-and-take with other team members about structures and functions. It is co-constructed by the presenter of the design idea and the team members to whom he or she is presenting.

Discourse Demands – As we examine students' attempts to produce design proposals, we find language patterns connected to the genres of "causal explanation" and "systems explanation," both of which seek to convey an analysis of how things came to be or how things work (Brisk, 2014). In Brisk's (2014) typology of explanations, causal explanation presents information in a temporal sequence by explaining what happens in terms of one step and then the next. When planning to solve an engineering problem, students can use a causal explanation to explain the cause-effect mechanism that would make a device function or to trace the series of reasoning steps that led to their idea. A systems explanation explains the relationships between components rather than conveying temporal sequence (Brisk, 2014). Students can use a systems explanation to articulate the elements of a possible design solution and to explain how they interact with each other. To generate a causal or systems explanation of a proposed design, students need to produce language about materials, structures, functions, and mechanisms. They need to create diagrams with legible drawings and labels and explain those diagrams with present-tense statements featuring technical names of materials and structures, passive voice, and text connectives like *because* (Brisk, 2014). Adjectival and adverbial phrases help to add details about the nouns that students are including in their design proposals (Brisk, 2014). To co-construct shared understanding of a design proposal through systems explanations, design team members also need to interpret diagrams, as well as ask clarification questions and questions to check for understanding.

Resources and Challenges – In the video data of students articulating multiple design options, we see common language patterns in their attempts to produce the design proposal text type. Without explicit instruction in how to do so, they draw upon several resources. We find evidence for three important intertextual resources: links to multimodal representations (diagrams, embodiment of design features, gestures), links to existing artifacts, and links to shared school events. We also see building blocks that help them build their engineering design language and their engineering design ideas: procedures to describe how they would put a prototype together, connector words such as *because*, *so*, and *then*, and metacognitive clauses like *I am saying* and *I was thinking.*

We also see challenges to accessing discursive resources necessary to develop design proposals with shared meaning. First, some students are challenged to find technical nouns, verbs, and text connectives that allow for the functions of various structures to be explained. Second, when a team member sketches out a possible solution and no one expresses questions or concern about that proposal, the team often moves on before the structure and function of the solution are fully explained. Because design proposals then go unvetted, lack of dissension among team members can pose a threat to the development of successful design proposal texts. The students' social codes may not allow for dissension, or students may not have tools for asking questions or explaining what aspects of another student's thinking they don't understand. Third, the presence of physical materials, while often supportive of students' idea generation (Crismond & Adams, 2012), can also hinder the oral articulation of the design proposal because when materials are available, students can point to and handle the items they want to include in a design artifact. They do not have to name any element explicitly.

Data from a fifth grade design team working on a miniature maglev train design problem illustrate some of these demands, resources, and challenges associated with design proposal language patterns. In In the following episode a team of three students is working on the "Plan!" task within Lesson 4 of the *EiE Designing Maglev Systems* unit. Each student has had a few minutes to sketch or write an individual plan for a magnetically levitating vehicle on the unit's "Imagine!" handout. Now they have been asked by the teacher to talk to each other and create a team plan. In a previous lesson they have explored the behavior of different kinds of magnets, and they know they will have styrofoam, tape, a cardboard box, and various other materials available for constructing their maglev systems.

As the three students come together, they begin to tell each other about their ideas for using these materials to make a miniature "train" that levitates. Then the teacher reminds the whole class that every team needs to produce a sketch of their collective plan. This announcement shifts the team's attention to the task of drawing, and here we see that one of the students, C, recognizes that he is proposing a distinct design idea from his teammates J and T. He calls for the team members to create separate design drawings because there are separate ideas under consideration.

1	J: Alright, so I'll draw it.
2	C: You and T can do it, and I'll do my own because you guys are saying that it should repel. I think that it should attract. So-
3	T: I'm not a person who's like an "artiste."

Even in this short interaction among the three students, we see a few interesting ways that the students are responding to the demand to produce design proposals. First, they acknowledge the importance of design drawings for communicating their ideas. Second, C works to construct shared meaning of the design proposals under consideration by describing what he sees as the key difference between his idea and his teammates: "you guys are saying that…" versus "I think that…" Third, T uses language to position herself as someone who should not be expected to produce a clear design sketch. Design drawings require "artistes," she implies.

The three students begin to draw, and while they do so, a researcher stops by and asks T what she is drawing (Figure 1). As T describes her design diagram, we see language indicating that she is making sense of her teammates' design proposals in order to inform her own idea-under-construction. She is also metacognitively aware of how her design ideas are coming into existence: notice her telling the researcher, “I was listening,” and “I was using.” She makes a link from C and J’s dialogue to her design proposal, and she uses multiple modes of representation (oral language, design drawing, the physical materials in the bag front of her) both to describe her maglev design and to explain why she thinks it will work. Finally, she makes a link to a future event: the test she will conduct to see if her “idea would actually work.”

4	T: Cuz I was listening to what J was saying, and I thought about it. And I was listening to what C was saying, as I was drawing it, cuz I was like, J, C was saying that maglev trains should have wheels. And I was thinking, why should it have wheels if it's powered by magnets? So I was thinking, the rails would repel, and the train would just like, levitate in the air, like not so much, but like, it would levitate. And then, I was using this to see like what I had to use, and what I would use to build my maglev train.
5	T: So I would use the long magnets, that were in the bag, like for the rails, and then, like, I would use the styrofoam, like the big piece of styrofoam that she had, and I would glue it together and like try to form it as a train. And see if the magnets would connect through the foam before I would glue it together, to see if my idea would actually work.

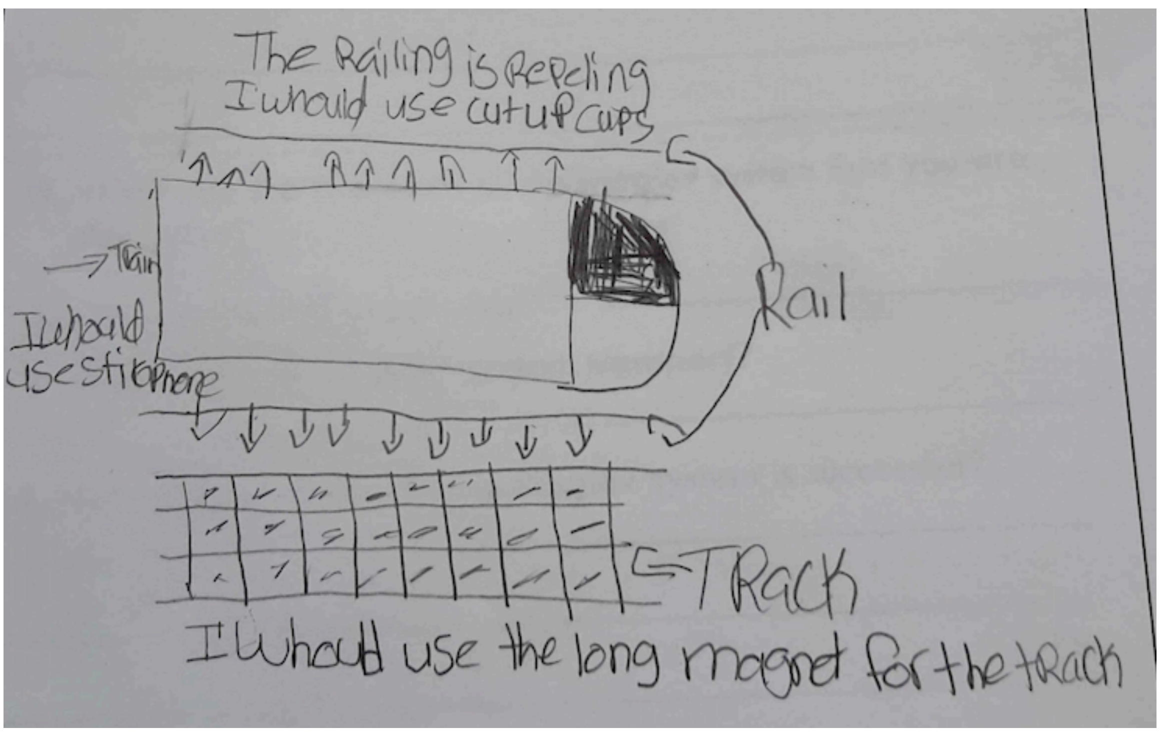

Figure 1. Maglev system design drawing created by T after listening to her teammates J and C discuss whether or not the train needed wheels

As T describes her design drawing with the researcher, J and C listen and then they interrupt their drawing and begin to talk to each other again. After about a minute, J thinks he has identified the crux of what C doesn’t understand about J’s maglev train idea. In the passage below, there are elements of the *design critique* text type, but in response to that critique, the students return to *design proposal* language as they refine their ideas. We use the passage below to illustrate that the text types do not appear linearly; in fact they can appear almost simultaneously as the students build their design plans. With this passage we also show two important intertextual links made within design proposal language. Specifically it includes a link to a design-drawing-in-process and a link to an existing community artifact (a subway station called Jackson Square). This passage also illustrates students' use of clarification questions to construct shared meaning of a design proposal. These questions press for more information and differ from critique questions, which are evaluative in nature.

6	J: (Talking to C) This is what I'm telling you here that you're not understanding (drawing on his paper). So, if I draw this, what I've drawn here, this little rectangle, it's the track basically. And it's like a big magnet. It's huge. And say this side is the north. This whole thing is a north pole. It's a north pole and then the train, in the bottom, this is the pole from the train. If they make it, the BIG one north, and north (labels parts of his drawing with "N"), then it's gonna repel against each other, causing the train to levitate above it, and, what you're saying is that if a person gets in between, the train would stop. That's what you're saying, right?
7	C: But if it doesn't have wheels, how's it gonna stop? It's a floating train, still going by repelling energy,
8	J: Yeah, that's what I'm telling you.
9	C: But then, it's going to keep going, keep going, keep going, no stopping.
10	J: Well I see what you mean. Let me tell you something here. THIS is what I mean.
11	C: No stopping, that's why I'm trying to say ATTRACT, because it's attracting, then when you keep rolling with the, with the – what's that thing called? The train thingamajigger. Then it's just gonna keep going. But if you have it attracting, it'd stop automatically.
12	J: Let me tell you how it would stop. SO the train's trying to go-o-o, let's say to Jackson Square over here and there's a train right there. A little bit before, when they're right at it, they would stop in the middle of it and they would have two sides still going but the train moves slower and then what would happen is both of them would shut off and it would go down, just like that. It would, like, the magnetic force, would like -
13	C: So repel and attract?
14	J: No. Like. The magnetic force would turn off basically, in the middle, so that it's still going but it's going a little bit slower. And it's descending, a little bit since.
15	Researcher: So you think for the train (inaudible)
16	C: (To J) Can you say a little more? I don't get that.

The above passage opens with J's acknowledgement that shared meaning has not yet been achieved. When he says, "This is what I'm telling you here that you're not understanding," he points out that C's interpretation of J's proposal differs from his intended meaning. To address this difference of interpretation, J links to his sketch and physically points to specific elements on it as he orally describes his design again. Unconvinced, C reiterates his critique of J's idea: because its magnets are set up only to repel each other, it has no mechanism for stopping. C insists it should have magnets set up to attract each other. J responds with a refinement of his idea – a continuation of his design proposal – and in his language he links to an artifact in the local community, the Jackson Square subway station. This link to a familiar landmark seems to be part of his attempt to make his design proposal more accessible to his teammate C.

While C and J draw upon several resources to construct design proposals with shared meaning, they also face challenges. C struggles to find the technical vocabulary that would help him point out the flaw he sees in J's idea, and he settles on "train thingamajigger." It is possible that this placeholder term could convey precise meaning among two students, but in this case it does not appear to communicate C's thinking to J and T. We also see J struggle to interpret C's statements as alternative design solutions rather than as misunderstandings of his own solution. J says, "This is what I mean," "This is what you're not understanding," when really C is trying to articulate a distinct design that involves attracting magnets for the train's propulsion and braking.

(2) Discursive Patterns in Design Critique

While or after proposing multiple possible solutions to the design problem, engineers have to analyze their feasibility and evaluate them against each other (Atman, Adams, et al. 2008). To do so they face another reflective decision-making task: What is the likelihood that the possible solutions will be successful? The text that supports this RDM task is the *design critique*. A design critique is a discussion of the strengths and weaknesses of a design solution – or an element of a design solution – relative to whether it will hinder or enable design criteria and constraints to be met. Design critiques often involve a claim that a design proposal, or specific aspects of that design, will or will not solve the design problem along with evidence to support that claim.

Discourse Demands – Among students' attempts to construct design critiques, we see language patterns connected to argumentation with evidence (McNeill, 2009; Zembal-Saul, McNeill, & Hershberger, 2012). Speakers assert a claim, attempt to offer evidence to support it, and provide reasoning to link the evidence and the claim. To generate these patterns of language, a design critique is like a design proposal in that it also includes precise language about materials, structures, functions, and mechanisms. To point out what will work well or poorly about a proposed solution, students have to be able to describe its features and their behaviors in language that their peers can understand. Technical vocabulary is useful for this descriptive function. Design critiques also require abstractions about which properties of materials or functions of structures will contribute to the design problem; these abstractions are often communicated in a formal register that emphasizes demonstrative pronouns (*this, that, these, those*) and connective prepositions (*because, so that*) and downplays first-person and second-person personal pronouns. Finally, design critique language patterns are connected to persuasive speech and writing (Brisk, 2014).

Resources and Challenges – The video data show particular intertextual links that serve as resources for students as they attempt to critique possible designs and justify their preferences. Students link from the design solution under consideration to earlier scientific investigations where they conducted trials of materials. They also link forward to anticipated performance of a potential design solution (i.e., what will happen when it is prototyped). Finally, they link to shared experiences tinkering with available materials.

To illustrate the language patterns of design critique, and students' resources for and challenges of accessing those language patterns, we highlight another team of fifth graders working on the "Plan!" task in Lesson 4 of the *EiE Catching the Wind* unit. The design challenge involves a miniature wind turbine that can lift a cup of weights when placed in front of a fan. The students have all sketched their own rotor and blade design in one square on an "Imagine!" handout divided into four quadrants. They have copied their teammates' sketches into the other three squares. When the following conversation takes place, the students have already discussed the different shapes of wind turbine blades that appear in their design sketches and are trying to achieve consensus on which shape to use. We use this excerpt to illustrate patterns in students' attempts to describe flaws in a design idea and argue with evidence about why or why not those flaws will prevent the idea from succeeding.

Because the students have recently studied different kinds of triangles in math class, they first focus on whether their various wind turbine blade proposals feature right triangles, isosceles triangles, equilateral triangles, or some other shape. Then each student stakes a claim for one shape. (Unfortunately the students appear to have adopted overly simplified archetypes for each kind of triangle; they believe isosceles triangles are always "long and skinny.") K cycles through all three kinds of triangles before settling on equilateral. A initiates arguments against each kind of triangle, but is not able to complete a thought before K or Y talks over him. Y expresses staunch opposition to K's idea that the wind turbine blades should be equilateral. She attempts to justify her opposition by describing what the wind turbine will look like "when it goes all the way around" if it is made of all equilateral triangles. She is linking to an anticipated performance of a design idea. Her concern seems to be that the equilateral triangles would necessarily be adjacent to each other and thus completely connected as if composing a circle. Y brings the resources of gesturing and physical embodiment to her design critique. Challenged to find the technical nouns and verbs to describe the shape she believes will be composed by the wind turbine blades ("ugh, I don't know how to say it"), she draws shapes in the air and arranges her arms and hands like the wind turbine blades to show her prediction for how they will behave. To Y, this predicted behavior of the equilateral triangle blades is a flaw of K's design. However, Y struggles to meet the demand of arguing with evidence for why this supposed flaw will hinder the performance of the wind turbine. Instead of connecting from the blade's shape to air flow and resistance, she makes a plea for her teammates to reason it out themselves: "If you think about it."

1	Y: I think it's a right triangle.
2	K: I think, I think a isoceles triangle.
3	J: Why do you think an isoceles triangle?
4	K: Uh,
5	A: I don't think it's, because, it's
6	K: (overlap) No, a right triangle!
7	A: It's too small, and
8	K: (overlap) No, a equilateral!
9	A: No, not eq-
10	Y: EquiLATeral? No, no, no, no, no.
11	K: It's equal on each side.

12	Y: Well, listen, when it goes all the way around, it's gonna look like it's all, like (draws circle in air with finger). It's gonna look like (then separates hands to show a circle shape), do you see my image? It's gonna look like a huge (spreading hands apart to make imaginary circle even bigger) like, ugh, I don't know how to say it. It's gonna look like it's all connected. It's gonna look like connected triangles in a circle. If you think about it.
13	K: If you space them out wide enough?
14	Y: I mean, but they're equilateral, so they're automatically just gonna connect. Connect, connect, connect, connect. (Uses thumb and forefinger of each hand to make a triangle shape and repeats that over and over while moving hands, as if to show a set of triangles with adjacent edges.)
15	J: So you're saying a right triangle would be better -
16	Y: Yeah.

Despite the Y's struggle to explain exactly why she views the equilateral triangle as a flawed design choice, K appears to be persuaded by Y's critique. After A finally gets a word in edgewise and proposes they use rectangle-shaped blades, K drops her triangle push and advocates for a parallelogram-shaped wind turbine blade. Again, Y disagrees in favor of a right triangle. This time, however, Y brings evidence to bear as she attempts to explain the reason for disagreeing. Her evidence includes an intertextual link (line 24) to the science investigation from Lesson 3 of the EiE unit, where the students explored the motion of sails on a nylon line. When reminded by A, however, that the equilateral sail was actually the "winner" in that sail investigation, Y shifts to a different mode of reasoning and uses the conditional "might be" to signal this shift (line 31). She suggests that the evidence from the sail investigation might not have implications for the wind turbine after all.

17	K: I think a parallelogram.
18	Y: I disagree to that. (looks at A, laughs in an embarassed way like she is surprised by her strong opinion) I can explain.
19	J: (overlaps) You think a parallelogram?
20	Y: (overlaps) I can explain why I -
21	K: Yeah because it's slanted, so, it's slanted (she is looking at Y, who is giving her a pointed look, and K stops in mid sentence, looking at Y)-
22	Y: That's how it always (inaudible)
23	J: Okay, we'll talk about that in a second, K. Y, you disagreed with A?
24	Y: I disagree with A comPLETEly, because I remember how we made sail boats, sail boats, and the squares that the people made, it went like, it didn't go as far as the triangles did. And the winner was actually the triangle. And it went pretty far.
25	J: So you're using your experience from that phase?
26	Y: Yeah.
27	J: And what shape triangle was the winner?
28	A: Right. No, wait, it was a equilateral.
29	Y: Yeah, it was an equilateral (says in somewhat defeated tone).

30	K: See, it was an equilateral!
31	Y: That doesn't mean the, you never know, the windmill, the windmill might be using a right triangle.

Undeterred by A's reminder that the right triangle did not "win" the sail investigation (line 28), Y makes two more intertextual links to argue in favor of it as a blade shape. As she links to a Google search for windmills (line 34) and her observations of actual windmills (line 36), her implication seems to be that because these resources did not feature blades shaped as parallelograms or equilateral triangles, those blade designs were unreasonable. "How are you gonna tell me?!" she says to K.

32	Y: I agree with a right triangle, too.
33	J: So you guys can all agree on triangles, except you are a right triangle?
34	Y: Cuz I've seen actual windmills, like, on Google the other day I searched for "windmills,"
35	K: (overlaps) I've seen on windmills two of the sides are the same length! And it's a (inaudible)
36	Y: I've seen like, on a table I've seen like a windmill. It was like an actual windmill, and it had like the little, um, right triangle (holds up arm and moves around liek the hand of a clock), like blades on them.
37	K: Nuh, uh!
38	Y: How are you gonna tell me?!
39	K: I seen like, wind turbines, and it's real skinny, and two sides are the same length.
40	A: (overlapping with K as he talks with J, he's not hearing K) Wait, you know those white windmills (talking just to J)?
41	J: Mm-hm. Wind turbines.
42	A: That you see on the highway.

(3) Discursive Patterns in Design Resolution

A third decision that faces engineering designers early in a design cycle is which proposal to pursue through the creation of a prototype (or a detailed mathematical and/or computer model). As they answer the question, "Which possible solution is most likely to solve the design problem optimally?", engineers working on a team must construct a third type of text: a design resolution. The language patterns for negotiating a design resolution are typically oral in nature and mediated by representations on paper and digital devices.

Discourse Demands – For a team of engineering designers, construction of a design resolution requires language of consensus building, positioning, appeasement, and negotiating, as well as turn taking, clarification questions, synthesis of ideas, and defending design choices. Interpersonal communication skills and positioning strategies help designers to modulate their statements to each other about how to move forward with one potentially optimal design solution. To achieve design resolution, student engineers need to be able to shift the mood of their statements to each other (for example, from the imperative command, "we should do this," to the interrogative question, "could we go ahead and do this?"). They also need to be able to deescalate (Brisk, 2014) from strong assertions with high strength (*should*) and medium strength (*will*) modals to more respectful suggestions achieved by low strength modals (*can, could*).

Resources and Challenges – In producing design resolutions, the elementary students in our study use a range of strategies that appear to be influenced by the social codes among the children, the norms of the classroom microculture, and the degree of divergence among individual students' design proposals. When individual proposals converge, students make intertextual links from one design drawing to another to point out similarities and assign jobs for the task of creating a collective group plan and prototype. When individual design proposals have distinct structures and functions or varying levels of feasibility pointed out by design critique, some students simply offer to try their teammates' ideas, while other students gently suggestion "mixing ideas" to create a collective design. However other students, often to adhere to a social code of competition, resolve to select one individual proposal as the team's solution and use aggressive modals and imperatives to convince their teammates to acquiesce. Still other students are guided by a social code that discourages dissension and therefore defer to the design proposal suggested the by the students with the highest social status.

A second grade episode from the *EiE Water Filters* unit highlights younger students' resources for design resolution in spite of a competitive social code that also presents barriers for accessing certain language patterns. In the passage below, three boys T, E, and D have a bin of water filter materials in the middle of their group of desks. They've been asked to draw their group plan before starting to assemble the materials. D had earlier reached for coffee filters from the materials bin while telling T and E about his design idea. They quickly rebuked him for touching the materials and took over the conversation to discuss their proposal for a water filter made only of sand and gravel.

1	T: We're doing sand and gravel.
2	E: Yeah, but it will be so gross.
3	T: Yeah, let's do sand and gravel.
4	E: Okay, let's draw it…. Come on. T, aren't you going to do it?
5	T: Yeah, first I'm thinking how we should draw it ((making a cutting motion with two of his fingers)). I mean we should start first.
6	D: Well, I'm going to use my idea.
7	T: Well, no (…)
8	E: Well, you can't use this ((referring to the coffee filter)), it will rip.
9	D: No it won't. (…)
10	E: If you put in a real one, it will rip.
11	D: I used that before, see it wouldn't rip on that ((pointing to previously tested filter within another group))
12	T: D, we're not meaning like that. We're meaning like this ((placing a finger into the cup of sand)).
13	E: They just know, they just don't know, D. They don't know that it'll rip.
14	D: Me -- me, and her ((pointing towards a student in another group)), and him ((pointing to the researcher)) did it before and it didn't rip. It just went through it. Right? ((Directed towards the researcher))
15	E: He doesn't remember, he doesn't remember.

16	D: Don’t you remember? ((Towards the researcher))
17	E: He doesn’t remember that well.
18	D: Did it -- rip //
19	E: // Dr. Wright doesn’t remember that well //
20	D: // He said no it didn’t rip, ha ha! I win!
21	E: Nah, uh. No you didn’t, we still have to vote.
22	D: Well then go over there and see him ((pointing towards the researcher who is video recording))
23	T: We’re doing sand and gravel though //
24	E: // Let’s vote.
25	D: You're just gonna pick his, aren’t you? ((Directed towards E))
26	E: I choose T’s.
27	D: I choose mine. I'm just going to choose mine .

In Line 1 of the excerpt above, T uses the present participle “We’re doing” to make a move toward design resolution. E agrees only hesitantly at first (line 2) but then expresses alignment with T by using the first-person plural construction “*let’s* draw it” (line 4). Their teammate D, however, does not concede to T’s move to settle on sand and gravel. Instead, he’s “going to use” his idea, the coffee filter. T and E try to defend their position by making an intertextual link to an anticipated performance of the coffee filter: “it will rip.” At this point in the boys’ attempt at design resolution, their discourse (lines 8 to 13) is based on expectations about properties and corresponding functions of the materials. D then proposes an intertextual link to a prior shared experience with the coffee filter, a test in which it did not rip. T and E do not take up this link immediately, so D appeals to one of the adults who was present for that test, the researcher operating the video recording equipment. At this point the boys’ social dynamics stand in tension with their attempts to come to a design resolution based on material properties and functions. Operating within a social code that values competition and winning, D can’t help but be delighted that the research agrees with him about the coffee filter. Immediately D cries (line 20), “ha ha! I win!” This shift in discursive tone and content seems to nudge E away from his focus on the performance of the coffee filter. His next design resolution move is to propose a vote (lines 21, 24). D anticipates his teammates’ preference for each other and continues to exhibit the tension of the social code of competition. If they are going to choose T’s design proposal, then he is “just going to choose mine” (line 27).

These three second-grade boys T, E, and D present an interesting case because, despite the strong implicit value of competition within the group, T and E explicitly reject Danny’s proposal based on their judgment that “it will rip.” The contention displayed in exploring the hypothetical outcome of the coffee filter may illustrate how design decisions are made based on the belief or non-belief in a property and function of specific aspects.

Conclusion

This study makes a contribution to the many open questions about the disciplinary practices that are associated with successful pre-college engineering. By identifying the discourse demands of reflective decision-making for engineering planning, and reporting on the resources urban elementary students bring to meet those demands, our goal is to uncover spaces where specific instructional supports can build upon student resources and create even more access to success and learning with engineering design.

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