Board 110: Elementary Students' Disciplinary Talk in a Classroom with an Explicit Engineering Decision-making Scaffold (Work in Progress)

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While engineering grows as a part of elementary education, important questions arise about the skills and practices we ask of students. Though the engineering design challenge is widely used as a structure for doing engineering in educational settings [1], there are still questions about how to best organize design challenges to promote learning of the discipline, including questions about the implications of the competitive nature of engineering design [2], how to promote productive collaboration [3], [4], and how to support students in evidence-based argumentation [5]–[8]. Both collaboration and decision making are complex and critical to the engineering design process used to solve these design challenges but require social and emotional work that can be difficult for elementary students to navigate [4]. Productive engagement in collaborative teams has been seen to be highly variable; for some teams, interpersonal conflicts move the design process forward, while for others they stall the process [9]. In our experience, we observed these interpersonal conflicts most frequently at decision points, centering decision making as an important and difficult practice of engineering.

This study is contextualized within a teaching experiment that incorporates two open-ended design challenges to provide students with engineering experiences. We included scaffolds for collaboration and decision making in the classroom: public engineering groupwork norms and a decision matrix to compare design solutions, respectively. We hypothesized these scaffolds would both reduce the tensions so often observed during decision making and socialize students into the practice of decision making in engineering. For this study, we analyzed student discourse while using the decision matrix in order to address the following research question: *what is the nature of students' disciplinary talk during scaffolded decision making?*

Theoretical Framework

Literature regarding the implementation of engineering design challenges in elementary school informed the design of the teaching experiment in this study; we considered recommendations from scholars about reducing the competitive nature of engineering design, promoting productive collaboration, and supporting students in evidence-based argumentation. These focal areas all concern how students learn the practices of engineering, which all rely heavily on language. As a community, engineers develop special vocabularies and distinct ways of thinking, doing, interacting, and using symbols and tools [10]. Part of learning engineering is being socialized into these modes of communication, the *discourse* practices of engineering.

Language practices act as resources for socializing social and cultural competence in particular communities or cultures [11]. Of particular concern for this study are resources cued to mark *affective stance* and *epistemic stance*. Affective stance can be seen through mood, attitude, feeling, disposition, and emotional intensity regarding some focus [11]–[14]; epistemic stance, through degrees of certainty of knowledge, degrees of commitment to truth of propositions, and sources of knowledge [11], [15]. The linguistic structures that index affective and epistemic stances are basic linguistic resources for constructing any and every social interaction [11], including acts of engineering like collaborative decision-making. This paper characterizes the nature of the collaborative decision-making talk of one group of student engineers.

Data Collection

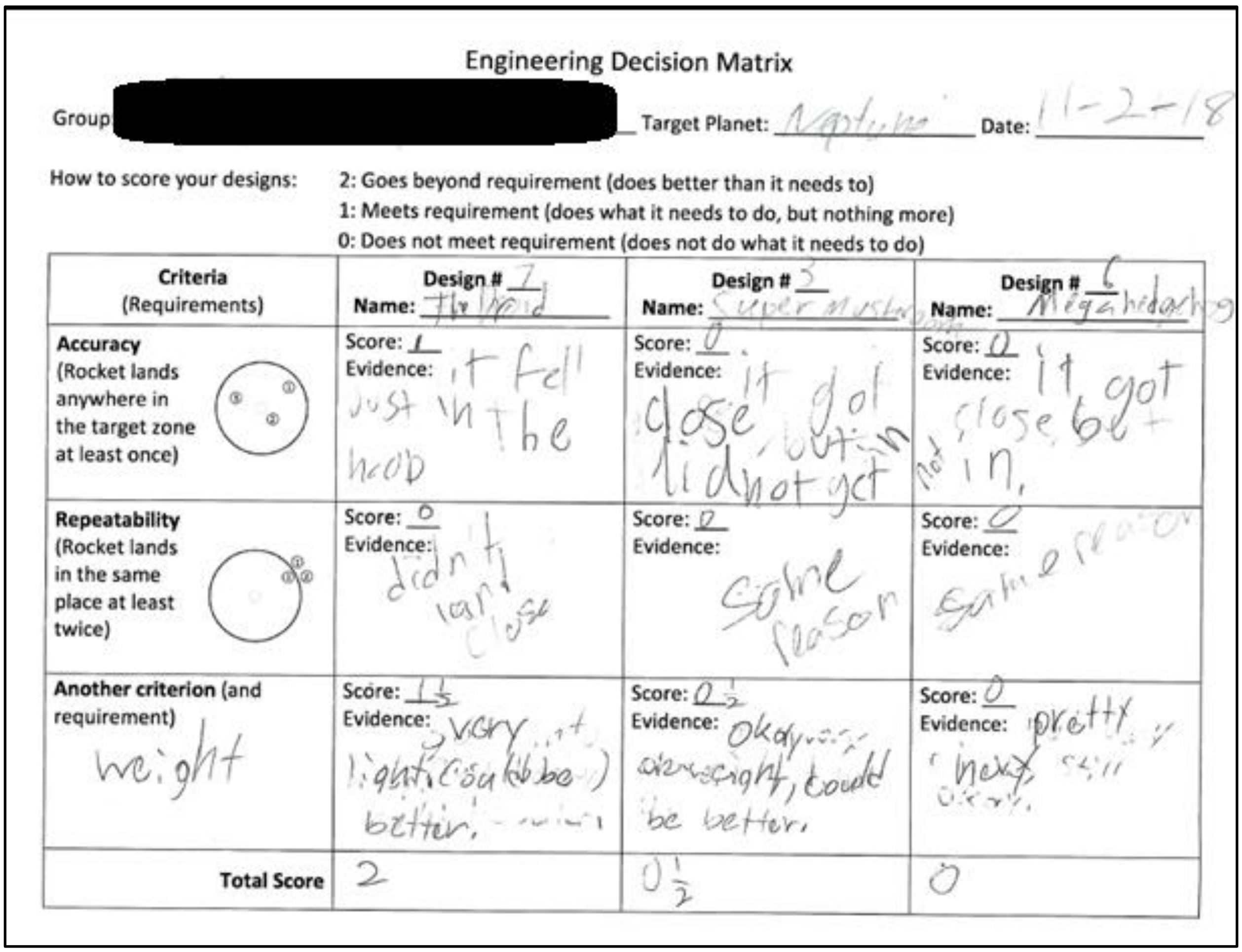
Participants and Curricular Context

This study took place within an engineering outreach program run by a private university in the northeastern United States. This program matches pairs of university students with local elementary classrooms to facilitate engineering for one hour per week. Typically, the university students develop and teach the curriculum. This study took place in a socioeconomically, racially, and linguistically diverse fourth-grade classroom. Of the 20 participating students, 11 were female, 9 were male, 11 were White, and 9 were People of Color. The curriculum was designed by two researchers to scaffold collaborative groupwork and decision making. The instruction was provided by an undergraduate Data Science major and the first author, a graduate student in engineering education. The scaffolds include a set of groupwork norms (Figure 1), adapted from Morris [16] and a decision matrix (Figure 2) developed by the authors.

Engineering Groupwork Norms

1. Say your own ideas
2. Listen to others; give everyone a chance to talk
3. Ask others for their ideas
4. Give reasons for your ideas
5. Discuss many different ideas

Figure 1. Groupwork norms.



Engineering Decision Matrix

Group: [redacted] Target Planet: Neptune Date: 11-2-18

How to score your designs:
2: Goes beyond requirement (does better than it needs to)
1: Meets requirement (does what it needs to do, but nothing more)
0: Does not meet requirement (does not do what it needs to do)

Criteria (Requirements)	Design # 1 Name: [illegible]	Design # 3 Name: [illegible]	Design # 6 Name: [illegible]
Accuracy (Rocket lands anywhere in the target zone at least once)	Score: 1 Evidence: it fell just in the hoop	Score: 0 Evidence: it got close but it did not get in	Score: 0 Evidence: it got close but not in.
Repeatability (Rocket lands in the same place at least twice)	Score: 0 Evidence: didn't land close	Score: 0 Evidence: same reason	Score: 0 Evidence: same reason
Another criterion (and requirement) weight	Score: 1½ Evidence: very light (could be better)	Score: 0½ Evidence: okay weight, could be better.	Score: 0 Evidence: pretty heavy [illegible]
Total Score	2	0½	0

Figure 2. Decision matrix completed by Bonnie, Elena, and Rebekah.

The groupwork norms were introduced on the first day of instruction; the instructors read them aloud, proposed groupwork scenarios to facilitate a whole class discussion about how the students could act to follow the norms, and provided time for students to practice the norms in their engineering design groups for the first project. For the rest of the semester, an anchor chart of the norms was displayed in the classroom. The researchers designed the decision matrix to scaffold design decisions among multiple prototypes based on problem criteria and test results. Students evaluated three of their prototypes by assigning them a score and stating evidence for that score. The scoring was guided by a rubric of scores from 0-2 based on how the design met the criteria. Two criteria, accuracy and precision, were prescribed and related to the goals of the design challenge; students chose a third criterion. Instructors modeled the use of this decision matrix on the third day of instruction, and students utilized the matrix in two multi-week design projects.

Data Sources

Data sources for this descriptive study include students' completed decision matrix, photos of their design constructions, and video records of whole-class and team discourse. The focal group of three white, female students, Bonnie, Elena, and Rebekah (all names are pseudonyms), was selected based on observations of their strong collaborative engineering work during the first engineering design challenge: building a craft material rocket to be launched a specified distance by a stomp launcher. Students were introduced to the challenge on the second class of the semester and spent most of the second and third class periods building and testing multiple rocket prototypes. On the fourth day of instruction, they began the class period by filling out the decision matrix to compare and evaluate three of their solutions to the design challenge before completing peer-to-peer feedback on a new design inspired by the decision matrix. The focal episode for this study is the early portion of the class period devoted to filling out the decision matrix.

Data Analysis

We transcribed the 13-minute focal episode using the Jefferson transcription system [17] to capture the verbal, paralinguistic, and nonverbal elements of the students' discourse. We then shared and discussed portions of the clip and transcript with our education research group. We used discourse analysis techniques to mark affective and epistemic stance and dissect the discourse during this session of scaffolded decision making. The first author went through the transcript line by line, highlighting episodes of significant displays of affective or epistemic stance. Affective stance markers included vocabulary; diminutives and augmentatives; quantifiers; verb voice; sentential adverbs; intonation; and affective intensity, marked by emphatic stress, loudness, syllable lengthening, intensifying adverbs, interjection, and repetition [11]. Epistemic stance markers included qualities of one's knowledge, degree of certainty, sentential adverbs, hedges, presuppositional structures, sentential mood, and source of knowledge [11].

Findings

Our analysis allowed us to characterize the linguistic resources (including the decision matrix) that the students used to complete four social acts during decision making: *design evaluation, disagreeing with a teammate, arguing for a novel idea, and sympathizing with a design.*

Design evaluation

In one pattern of design evaluation, students employed heightened affective intensity to recreate the story of how a design performed. Since most of this group's prototypes did not reach the target, descriptions of their performance tended to be negative, referencing the fact that they were not successful. Linguistic markers like syllable lengthening, intensifying adverbs, emphatic stress, repetition, and hedging language (Table 1) all served to index an affective stance that mitigated the severity of their evaluations.

Table 1. *Examples of linguistic markers used to index a heightened affective stance and mitigate the severity of design evaluations (underlined). Examples are not consecutive.*

Emphatic stress	Elena: It didn't it didn't get AS close (.) as it [could've Rebekah: [Noo it ↓<didn't> (.) It was a little ↓<off>
Syllable lengthening	Rebekah: For the super-mushroom accuracy it got clo:::se but not in it so it's zero. Same with mega-hedgehog.
Intensifying adverbs, repetition	Bonnie: I don't think it's really good. Elena: No none of them are really good at repeatability
Intensifying adverbs	Elena: Cuz it didn't make it but it got decently close. Elena: So it wouldn't be a complete zero. But it also wouldn't be a one.
Hedging language	Elena: ...it wasn't good enough to be a one, like it didn't make it all the way, but it also wasn't as like off course, or - like it wasn't close enough - it wasn't far enough away to be a zero, so we thought zero and a half, 'cause it was kind of stuck dead straight in the middle. It was good, but it wasn't as good as it could be.

We hypothesized that two salient features of the decision matrix would serve as linguistic resources: the recommendations for "how to score your designs" and the "criteria (requirements)" column of the matrix itself. Students in the focal group used the language from the decision matrix as a linguistic resource during design evaluation. For instance, Elena referenced the guidelines for assigning a score of 1 (underlined portion): "The droid [a rocket prototype] (.) did exactly what it needed to do but it could be improved so I that think we could give it one," though she added the intensifying adverb "exactly" and reframed the second clause to "could be improved" as opposed to the language on the decision matrix, which said that a "1: … does what it needs to do, but nothing more."

Disagreeing with a teammate

Linguistic resources used in the act of *disagreeing with a teammate* varied more from student to student; we did not observe generalized patterns. In one case of disagreement, the authority of the decision matrix was called upon as an epistemic resource to support one student's idea against another's (underlined).

1 Elena: How about zero and a half, because it got close?
2 Rebekah: That's not one of them.
3 Elena: Cuz like it's kind of like stuck in the middle like it doesn't really
4 Rebekah: Let's do zero question mark one

In this short excerpt, Rebekah firmly rebutted Elena's proposition, her reasoning being that "zero and a half" is "not one of them." As shown in Figure 2, the suggested scores on the decision matrix itself are either 0, 1, or 2; one-half is not an option if adhering to the guidelines presented by the tool. Elena defended her position (line 3), and Rebekah suggested, "let's do zero question mark one," seemingly attempting to give credit to their design in the same way that Elena is trying to while using the "approved" scores of 0, 1, or 2 from the decision matrix. In this way, Rebekah used the matrix as an epistemic resource to support her position while she disagreed with Elena.

Arguing for a novel idea

Putting forth and defending a novel idea was carried out in different ways by different students. In one case, Rebekah used syllable elongation and an intonation contour that indexes whining to petition for her idea (underlined), adopting a heightened affective stance.

5 Rebekah: If we flew them a short distance in the air, whichever one will land quicker is the one that's heaviest.
6 Bonnie: No, we know our evidence.
7 Rebekah: Awwwwww But just in ca::se

Conversely, another student, Elena, when arguing for her own novel ideas tended to play up the uncertainty of her epistemic stance through the use of hedging language (underlined).

8 Rebekah: That's not one of them.
9 Elena: Cuz like it's kind of like stuck in the middle like it doesn't really
10 Rebekah: Let's do zero question mark one

In line 9, Elena justified her idea to assign a half score, citing the fact that the performance of the rocket was "like stuck in the middle," so the score should reflect that. Her use of "like," "kind of," and "doesn't really" served to highlight her uncertainty, while still positing that a design was "stuck in the middle" and required some score that was not featured on the decision matrix.

Sympathizing with a design

Rebekah and Bonnie spent several turns sympathizing with one of their designs that scored 0 in every category (named "mega-hedgehog," Figure 2). This sympathy was indexed by a heightened affective stance adopted by the girls, marked by diminutive affix, repetition, and vocabulary choices (strategies underlined in the following excerpt).

11 Bonnie: I feel bad this was our best
12 Rebekah: Poor mega hedgehog
13 Bonnie: I feel bad for the mega hedgehog
14 Elena: It can always be improved
15 Rebekah: Poor meggy hedgehog

Rebekah expressed sympathy for the mega hedgehog prototype ("Poor mega hedgehog"), a sentiment echoed by Bonnie ("I feel bad for the mega hedgehog"). Rebekah took it another step further, using a diminutive suffix to alter the prototype name from "mega-hedgehog" to "meggy hedgehog," a move that accented the sympathy the girls felt for their prototype.

Discussion and Implications

In this study, we found students performing four social acts during evaluative decision making: design evaluation, disagreeing with a teammate, arguing for a novel idea, and sympathizing with a design. Overall, students showed a tendency to qualify the objectively "bad" performance of their prototypes, especially when evaluating their designs. This tendency, coupled with the act of sympathizing with their prototypes, show signs of the emotional investment these fourth-grade students are making in their design work.

Also observed was a coupling of the decision matrix as an epistemic resource with a stance of high epistemic certainty. For example, in both design evaluation and disagreeing with a teammate, different students adopted strong epistemic stances when they were relying on language or information from the decision matrix. This may indicate that these students took up the tool as an authority, be that from the instructor or otherwise.

That said, it is important to note that, in the approximately 13 minutes this group spent using the decision matrix tool, there were only two instances where the *evaluation guidelines* ("2: goes beyond requirements (does better than it needs to)," etc.) were explicitly referenced while trying to evaluate a design; both instances were initiated by the same student, Elena. This group more often referred to the *criteria* listed on the decision matrix ("accuracy," "repeatability") and used the tool to structure the flow of their work session.

Future work includes the application of these discourse analysis methods to more student groups in order to unpack the variety of ways the decision-making tool could be interpreted in the same classroom. Additionally, this analysis will inform the redesign of the instructional scaffolds; particularly how the tool could allow for more student agency in defining how designs are evaluated. These findings point to a student desire and capability to create their own criteria and evaluation guidelines that will be explored in future iterations of the tool.

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References

[1] N. A. of E. and N. R. C. (NAE and NRC), *Engineering in K-12 Education: Understanding the Status and Improving the Prospects*. Washington, DC: National Academies Press, 2009.

[2] P. M. Sadler, H. P. Coyle, and M. Schwartz, "Engineering Competitions in the Middle School Classroom: Key Elements in Developing Effective Design Challenges," *J. Learn. Sci.*, vol. 9, no. 3, pp. 299–327, 2000.

[3] K. L. Tonso, "Teams that Work: Campus Culture, Engineering identity, and Social Interactions," *J. Eng. Educ.*, vol. 95, no. 1, pp. 25–37, 2006.

[4] M. E. Jordan and R. R. McDaniel, "Managing Uncertainty During Collaborative Problem Solving in Elementary School Teams: The Role of Peer Influence in Robotics Engineering Activity," *J. Learn. Sci.*, vol. 23, no. 4, pp. 490–536, Oct. 2014.

[5] R. A. Engle and F. R. Conant, "Guiding Principles for Fostering Productive Disciplinary Engagement: Explaining an Emergent Argument in a Community of Learners Classroom," *Cogn. Instr.*, vol. 20:4, pp. 399–483, 2002.

[6] J. McFadden and G. Roehrig, *Engineering design in the elementary science classroom: supporting student discourse during an engineering design challenge*. Springer Netherlands, 2018.

[7] K. B. Wendell, C. Wright, and P. Paugh, "Reflective Decision-Making in Elementary Students' Engineering Design," *J. Eng. Educ.*, vol. 106, no. 3, pp. 356–397, 2017.

[8] A. Wilson-Lopez *et al.*, "Argumentation in K-12 Engineering Education: A Review of the Literature (Fundamental)," in *American Society for Engineering Education*, 2018.

[9] B. Barron, "When Smart Groups Fail," *J. Learn. Sci.*, vol. 12, no. 3, pp. 307–359, 2003.

[10] J. M. Kittleson and S. A. Southerland, "The Role of Discourse in Group Knowledge Construction: A Case Study of Engineering Students," *J. Res. Sci. Teach.*, vol. 41, no. 3, pp. 267–293, 2004.

[11] E. Ochs, "Linguistic Resources for Socializing Humanity," *Stud. Soc. Cult. Found. Lang. No. 17. Rethink. Linguist. Relativ.*, pp. 407–437, 1996.

[12] E. Ochs and B. Schiefflin, "Language acquisition and socialization: three developmental stories and their implications," in *Culture theory: essays on mind, self, and emotion*, R. Shweder and R. Levine, Eds. Cambridge University Press, 1984, pp. 276–320.

[13] W. Labov, "Meaning, form, and use in context: linguistic applications," in *Meaning, form, and use in context: linguistic applications*, D. Shiffrin, Ed. Washington, DC: Georgetown University Press, 1984, pp. 43–70.

[14] R. Levy, "Emotion, knowing and culture," in *Culture theory: essays on mind, self, and emotion*, R. Shweder and R. Levine, Eds. Cambridge University Press, 1984, pp. 214–237.

[15] W. Chafe and J. Nichols, Eds., “Evidentiality: the linguistic coding of epistemology,” in *Advances in Discourse Processes*, Norwood, NJ: Ablex, 1986.

[16] R. Morris, “A normative intervention to equalize participation in task-oriented groups.” Ph.D. dissertation, Stanford Univ., Palo Alto, CA, 1977.

[17] G. Jefferson, “Glossary of Transcript Symbols with an Introduction,” in *CONVERSATION ANALYSIS: STUDIES FROM THE FIRST GENERATION*, 2004, pp. 13–31.